Hazard Incident Management Plan

Capricorn BESS, QLD

Environmental Resources Management Australia Pty Ltd
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Environmental Resources Management Australia Pty Ltd

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Rev	Date	Remarks	Prepared By	Reviewed By
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Executive Summary

Background

Environmental Resource Management Australia Pty Ltd (ERM) is preparing the planning application on behalf of Enel Green Power Australia (EGPA) for the proposed Capricorn BESS (CB), a new 300 MW / 1,200 MWh Battery Energy Storage (BESS) facility in Bouldercombe QLD. The facility will be comprised of BESS units, electrical transformers and inverters, electrical cabling, telecommunications equipment, an electrical control room, connection to substation and perimeter fencing.

EGPA operates under a long-term ownership model, focusing on the development, ownership, and operation of renewable energy assets throughout their entire lifecycle, ensuring sustained investment and stability. EGPA has a growing portfolio in Australia, comprising wind, solar, and BESS, and is actively expanding its BESS projects to enhance grid stability. Globally, as part of Enel Green Power, EGPA manages a diverse range of renewable energy assets across Europe, the Americas, Africa, and Asia, reinforcing its commitment to supporting the transition to a low-carbon energy future.

A Hazard Incident Management Plan (HIMP) is to be developed to support the CB Development Application. It has been proposed to adopt the methodology for the HIMP from the NSW HIPAP 2 (Ref.) in the absence of QLD guidelines. Due to BESS facility being an emerging power systems facility there is little regulation that directly aligns with the development of these facilities within Queensland. FRNSW have developed a comprehensive Fire Safety Guideline *Technical Information – Large scale external lithium-ion battery energy storage systems – Fire safety study considerations* this document will be consulted to further the safety provisions of the facility. In addition, the Electrical Safety Office Code of Practice (Ref.) and The Best Practice Guide: Battery Storage Equipment 2018 (Ref.) will be also considered in the assessment.

ERM on behalf of EGPA has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the HIMP for the facility. This document represents the HIMP study for the BESS facility located Burnett Highway - Bouldercombe, QLD 4702.

Conclusions

A HIMP per the HIPAP No. 2 guidelines was prepared for the proposed BESS Facility located at Lot 2 on RP613051 off Burnett Highway Bouldercombe, QLD 4702. The analysis performed in the HIMP was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the designs and existing fire protection adequately managed the credible fire risks at the site.

Recommendations

Based on the analysis, the following recommendations have been made:

- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.

- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref.).
- A team of site personnel are to be trained in the use of the water cart and first-attack firefighting methods.
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- A site Emergency Response Plan per the requirements of HIPAP No. 1 shall be prepared and shall include measures to advise neighbouring premises in the event of an emergency with potential offsite impacts.
- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 and any applicable storage and handling standards.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
BMM	Battery Management Module
CBD	Central Business District
CB	Capricorn BESS
DA	Development Application
DGs	Dangerous Goods
EMS	Environmental Management Strategy
ERM	Environmental Resources Management Australia
FCAS	Frequency Control Ancillary Services
FER	Fire Engineering Report
FRNSW	Fire and Rescue New South Wales
HVAC	Heating, Ventilation and Air Conditioning
HIPAP	Hazardous Industry Planning Advisory Paper
ISO	International Organization for Standardization
LEL	Lower Explosive Limit
NSW	New South Wales
MVPS	Medium Voltage Power Station
PCU	Power Conditioning Unit
QLD	Queensland
QFES	Queensland Fire and Emergency Services
RFS	Rural Fire Service
SEP	Surface Emissive Power
SMSS	Storage Mode Sprinkler System
SMU	Battery Management System Unit

1.0 Introduction

1.1 Background

Environmental Resource Management Australia Pty Ltd (ERM) is preparing the planning application on behalf of Enel Green Power Australia (EGPA) for the proposed Capricorn BESS (CB), a new 300 MW / 1,200 MWh Battery Energy Storage (BESS) facility in Bouldercombe QLD. The facility will be comprised of BESS units, electrical transformers and inverters, electrical cabling, telecommunications equipment, an electrical control room, connection to substation and perimeter fencing.

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A Hazard Incident Management Plan (HIMP) is to be developed to support the CB Development Application. It has been proposed to adopt the methodology for the HIMP from the NSW HIPAP 2 (Ref. [1]) in the absence of QLD guidelines. Due to BESS facility being an emerging power systems facility there is little regulation that directly aligns with the development of these facilities within Queensland. FRNSW have developed a comprehensive Fire Safety Guideline *Technical Information – Large scale external lithium-ion battery energy storage systems – Fire safety study considerations* this document will be consulted to further the safety provisions of the facility. In addition, the Electrical Safety Office Code of Practice (Ref. [2]) and The Best Practice Guide: Battery Storage Equipment 2018 (Ref. [3]) will be also considered in the assessment.

ERM on behalf of EGPA has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the HIMP for the facility. This document represents the HIMP study for the BESS facility located Burnett Highway - Bouldercombe, QLD 4702.

1.2 Objectives

The objectives of the HIMP are to:

- Review the site operations and DG storages for the potential to initiate or become involved in a fire including flammable materials which may be present at the site.
- Identify heat radiation impacts from potential fire sources at the site and determine the potential impacts on the surrounding areas and fire protection system, and
- Review the proposed fire safety features and determine the adequacy of the fire safety systems based on the postulated fires.

1.3 Scope of Services

The scope of work is for the preparation of a HIMP for the facility to assess the potential hazards at the site to ensure the fire protection systems are commensurate with the identified hazards. This document follows the methodology recommended in HIPAP No.2 (Ref. [1]).

The HIMP focuses on the storage of commodities associated with the new development at the site in addition to the existing operations at the site as required by HIPAP No. 2. A review of the following components of the HIMP are within the scope of work:

- Determination of risk and consequences from fire or explosion scenarios throughout the facility.
- The preparation of a report on fire prevention, fire detection, fire alarm and fire suppression systems for the site.
- Firewater storage capacity for compliance with Australian Standards and Regulations.
- External fire hydrant configuration and locations.
- Recommendations based upon the study for implementation in the final design.

2.0 Methodology

2.1 Hazard Incident Management Plan Approach

The following methodology was used in the preparation of the HIMP for the facility. The methodology is to follow items required by HIPAP No. 2 (Ref. [1]).

- The fire hazards associated with the facility were identified to determine whether there were any fire or explosion hazards that may impact offsite or result in a potential to escalate. Where fire hazards with the potential to impact offsite or escalate were identified, these were carried forward for consequence assessment.
- The heat radiation impacts or overpressure impacts (consequences) from each of the postulated incidents from the proposed equipment were then estimated and potential impacts on surrounding areas assessed.
- Impacts of the fires from the proposed equipment were plotted on a layout plan of the proposed facility, to determine whether heat radiation impacts any critical areas (i.e. adjacent storage areas, fire services, safety systems, etc.) and whether such impact affected the ability of firefighters to respond to the postulated fire. The heat radiation impact from incidents at adjacent sites on the buildings and structures at the facility were then assessed against the maximum permissible levels in HIPAP No. 4 (Ref. [6]).
- The firefighting strategies were then assessed to determine whether these strategies require update in light of the location of the proposed equipment and storage areas.
- The response times for Queensland Fire & Emergency Service (QFES) in the immediate vicinity were assessed. In addition, further outlying QFES stations were included to provide a 'back-up plan' in the event that the closest fire brigades were unable to attend.
- A report was then developed for submission to the client and the regulatory authority.

In addition, the FRNSW Fire Safety Guideline *Technical Information – Large scale external lithium-ion battery energy storage systems – Fire safety study considerations*, (Ref. [7]) herein referred to as the 'FRNSW BESS Guideline', was reviewed as part of the preparation of the HIMP coupled with the Electrical Safety Office Code of Practice Managing electrical risks in the workplace 2021 (Ref. [2]).

2.2 Limitations and Assumptions

In this instance, the HIMP is developed based on applicable limitations and assumptions for the development which are listed as follows:

- The report is specifically limited to the project described in **Section 3.4** and the methodology and approach outlined in **Section 2.1**.
- The report is based on the information provided.
- The report does not provide guidance in respect of incidents that relate to sabotage or vandalism of fire safety systems.
- The assessment is limited to the objectives of the HIMP as provided in the guidelines issued as HIPAP No. 2 (Ref. [1]) and does not consider property damage such as building and contents damage caused by fire, potential increased insurance liability and loss of business continuity.

- Malicious acts or arson with respect to fire ignition and safety systems are limited in nature and are outside the scope of this report. Such acts can potentially overwhelm fire safety systems and therefore further strategies such as security, housekeeping and management procedures may better mitigate such risks.
- This report is prepared in good faith and with due care for information purposes only and should not be relied upon as providing any warranty or guarantee that ignition or a fire will not occur.

3.0 Site Description

3.1 Site Location

The development site is located on Lot 2 on RP613051 off Burnett Highway Bouldercombe, QLD 4702 within the Rockhampton Regional Council LGA. The site is located approximately 2.5 km north of Bouldercombe and 16 km form Rockhampton, QLD.

Figure 3-1 shows the regional location of the site. The Project layout has been provided in **Figure 3-3**. The BESS layout is provided in **Figure 3-4.**

Figure 3-1: Site Location (Source – Google Maps)

3.2 Adjacent Land Uses

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

- North – rural vacant land
- South – High voltage substation, rural vacant land and residential area
- East – Burnett Hwy and rural vacant land
- West – rural vacant land

3.3 Sensitive receptors

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

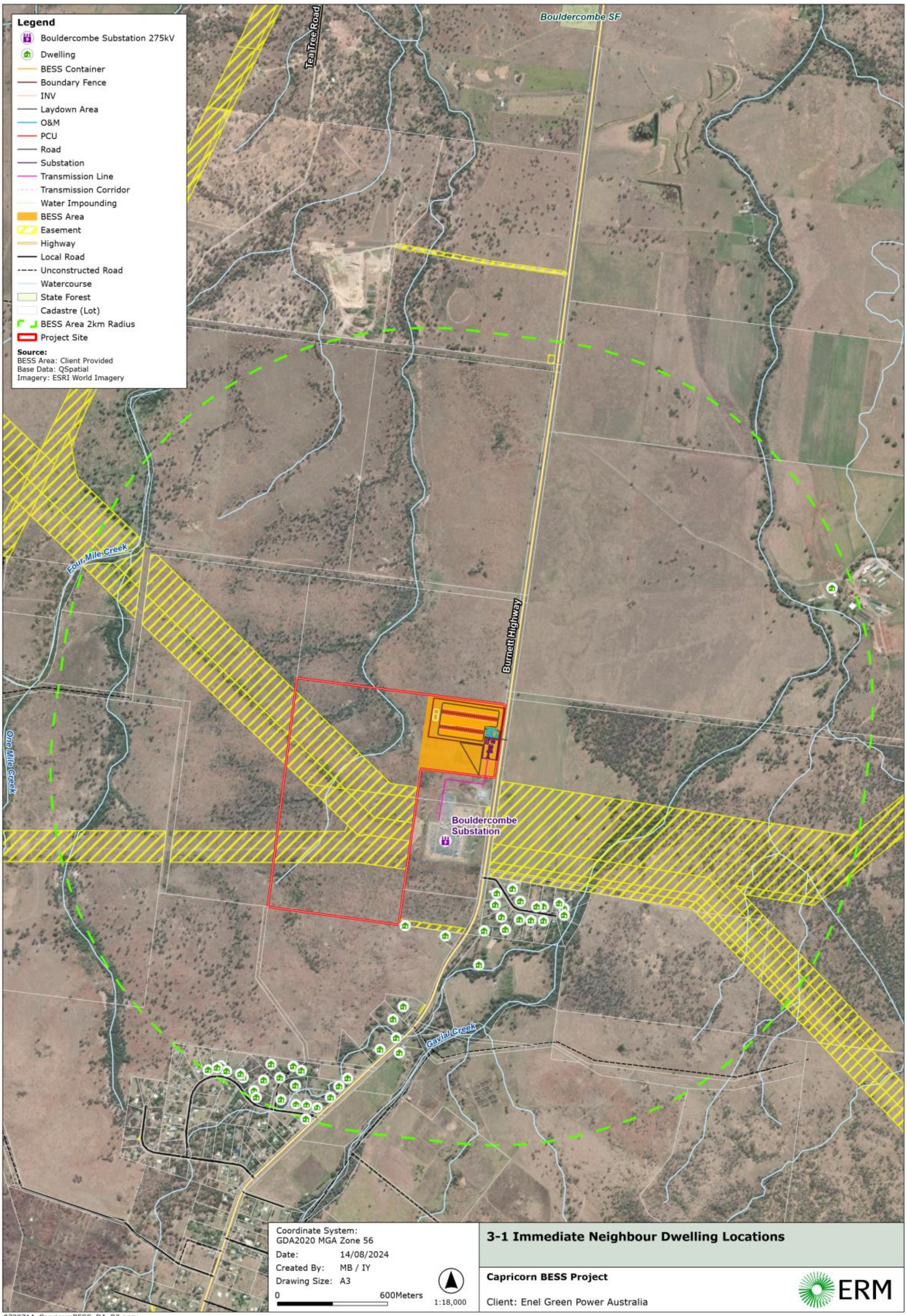

Figure 3-2: Distances to Sensitive Receptors

3.4 General Description

CB will store dispatchable energy generated from renewable sources for the QLD Grid. The facility will operate to provide electricity during peak energy consumption. The CB will be managed by personnel during standard working hours. The facility will consist of BESS modules, electrical transformers and inverters, electrical cabling, telecommunications equipment, an electrical control room, the connection to Bouldercombe substation, security lighting, perimeter security fencing and site access gates.

The stored electricity will be exported through an underground transmission line 275 kV connection to the Powerlink's Bouldercombe Substation located approximately 100 m south of the CB site.

The Project comprises the construction, operation and decommissioning of a BESS facility and associated infrastructure. The Project includes:

- BESS Infrastructure
  - BESS with a capacity of up to 300 MW / 1200 MWh.
  - 525 BESS containers (for this assessment and may differ to the final design)
  - BESS container capacity of 3 MWh.
- Electricity infrastructure:
  - 2 x 180 MVA Transformers.
  - 105 MVPS 4.4 MVA Transformers coupled with 105 Inverters.
  - Electrical cabling between BESS units and transformers.
  - Underground transmission line connection to substation.
  - Switching station.
- Onsite permanent supporting infrastructure:
  - Site access road and entry.
  - Internal access roads.
  - Operations and Maintenance (O&M) Facility including site offices, O&M buildings, amenities, equipment sheds, storage and parking areas, fire water tank and fire hydrants.
- Off-site supporting infrastructure:
- Existing public road and communications network; and
- Temporary supporting infrastructure:
  - Construction facilities such as offices, car park and amenities.
  - Fencing and landscaping works.
  - Delivery of project components, such as battery modules.
  - Installation of underground and overhead cabling.
  - Water sourcing.
  - Installing maintenance and environmental management processes and equipment.

- A minimum 10-meter defendable space surrounding the BESS facility. This space should allow unobstructed vehicle access to aid emergency services in the event of a nearby fire. Additionally, the 10 meter spacing should manage the defendable space and BESS areas as an Asset Protection Zone (APZ).

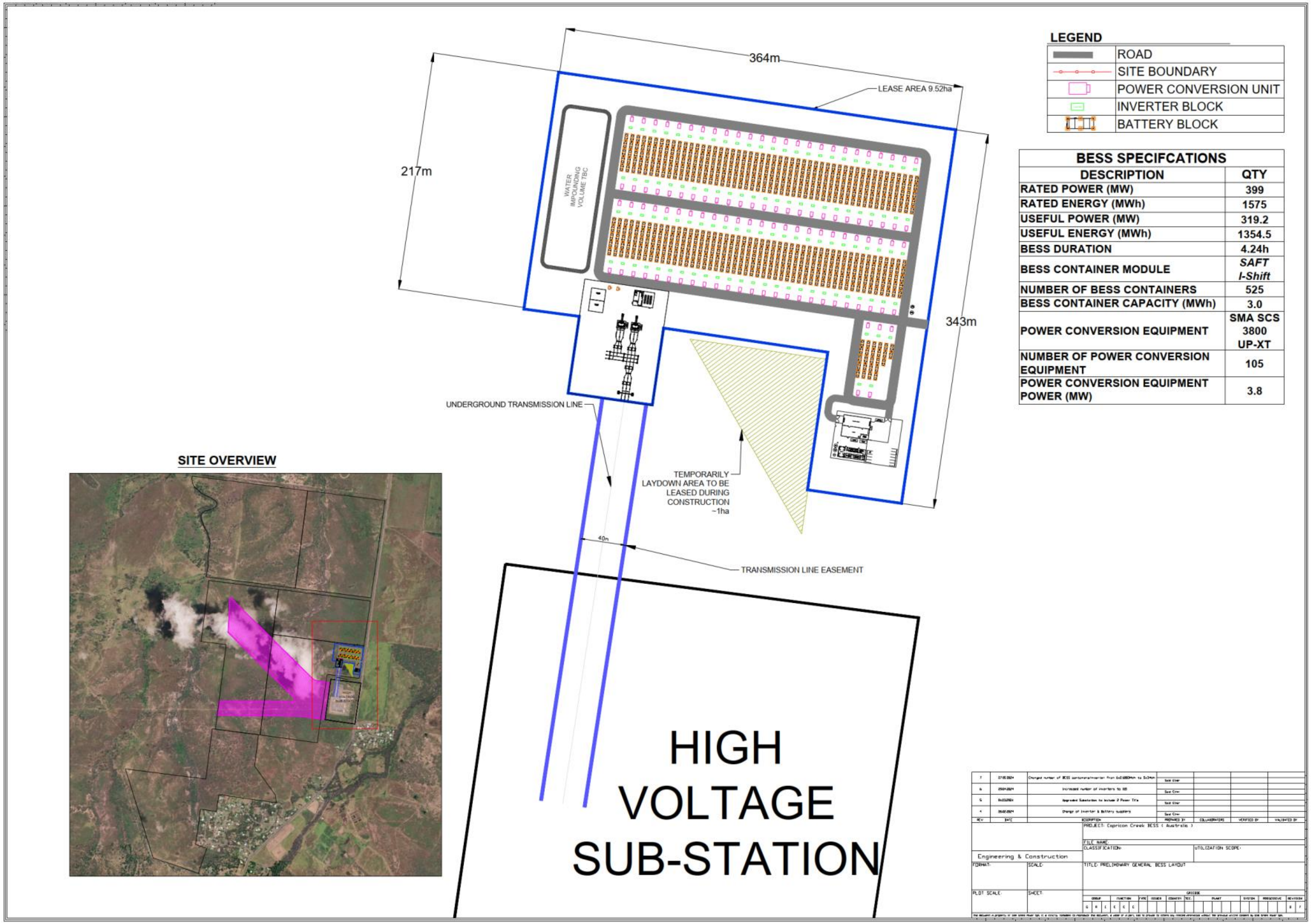

Figure 3-3: Project Layout

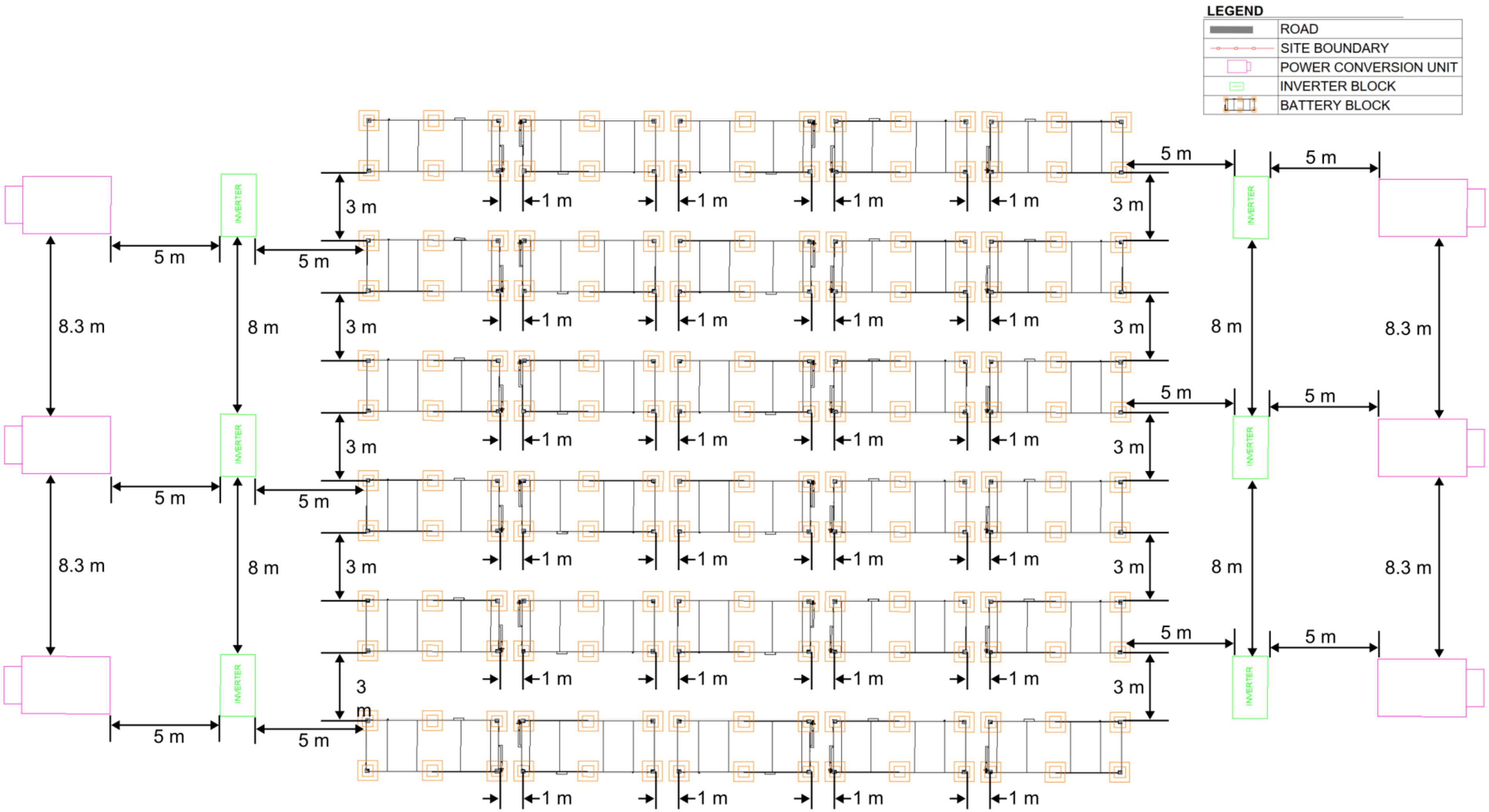

Figure 3-4: BESS Layout

3.5 Detailed Description

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

The electricity will be capable of storage in a 300 MW / 1200 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.

3.5.1 Battery Storage

The BESS will be located within the site compound, laydown and substation footprint area. 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. The SAFT Intensium Shift (I-Shift) BESS is shown in **Figure 3-5**. The OEM for the BESS has not yet been selected, therefore the SAFT I-Shift BESS shall provide a representative analysis of the system.

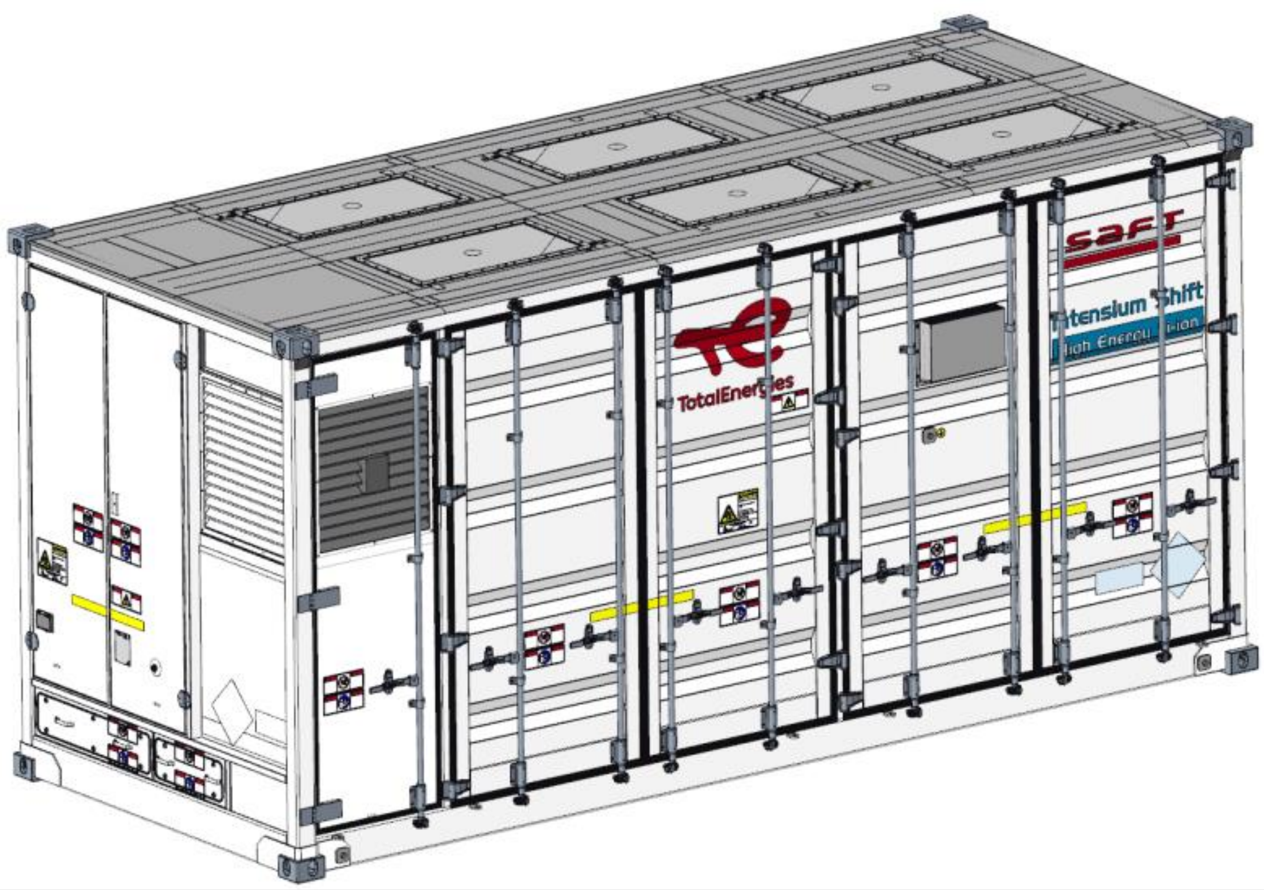

Figure 3-5: SAFT I-Shift BESS

The SAFT I-Shift BESS proposed for CB is housed in an ISO 20 ft container having a rating of IP64. The container is divided into 4 rooms:

- The battery room
- The control room

- The Battery Management Module (BMM) room
- The Heating, Ventilation and Air Conditioning (HVAC) room

The Battery Room houses Li-Ion battery modules arranged in 8 parallel strings, each consisting of 17 Lithium-Ion battery modules connected in series across 2 racks. These strings are organised into 9+8 parallel configurations. Each module, configured as 1P24S, is monitored by a Battery Management Module (BMM) located in the BMM room. The BMM tracks cell voltages and temperatures through a Battery Management System Unit (SMU) and ensures the stability of the batteries, preventing thermal runaway by isolating any cell that falls outside operating parameters. The BMM room also contains the fire suppression system.

Temperature and humidity within the container are regulated by a thermal power HVAC system, maintaining the environment at a consistent 20°C to 35°C. Each BESS unit comprises 3,400 lithium iron phosphate ($LiFePO_4$, or LFP) cells. Each cell weighs 5.4 kg, making the total weight of the I-Shift BESS 18,360 kg.

The SAFT I-Shift contains heat and smoke detectors and a gaseous suppression system. In the event of thermal runaway, flammable gases are generated which can be detected to initiate a safety response. The SAFT I-Shifts are fitted with flammable gas detection which identifies flammable gases at 25% of the Lower Explosive Limit (LEL) which will activate a visual and audible alarm as well as opening the off gassing valve to prevent over pressurisation and activation of the ventilation system to clear flammable gases. The units are fitted with blast panels in the event that the flammable gas protection systems fail to operate, and the flammable gas exceeds the LEL and is ignited. The presence of the explosion vent mitigates against escalation into an explosion as it relieves the pressure preventing the acceleration of the combustion through the vapour cloud and subsequent detonation.

3.5.2 Protection Measures

The BESS is fitted with a range of fire protection systems including:

- Gaseous fire protection system
- Thermal detection
- Smoke detection
- Audible & Visual alarms
- Fire system emergency start
- Emergency stop
- Water Fire Safety System
- Gass Fire Safety System
- Pressure relief valve
- 6 blast panels
- Thermally insulated rockwool top and sides

The arrangement of the fire protection systems are shown in **Figure 3-6**.

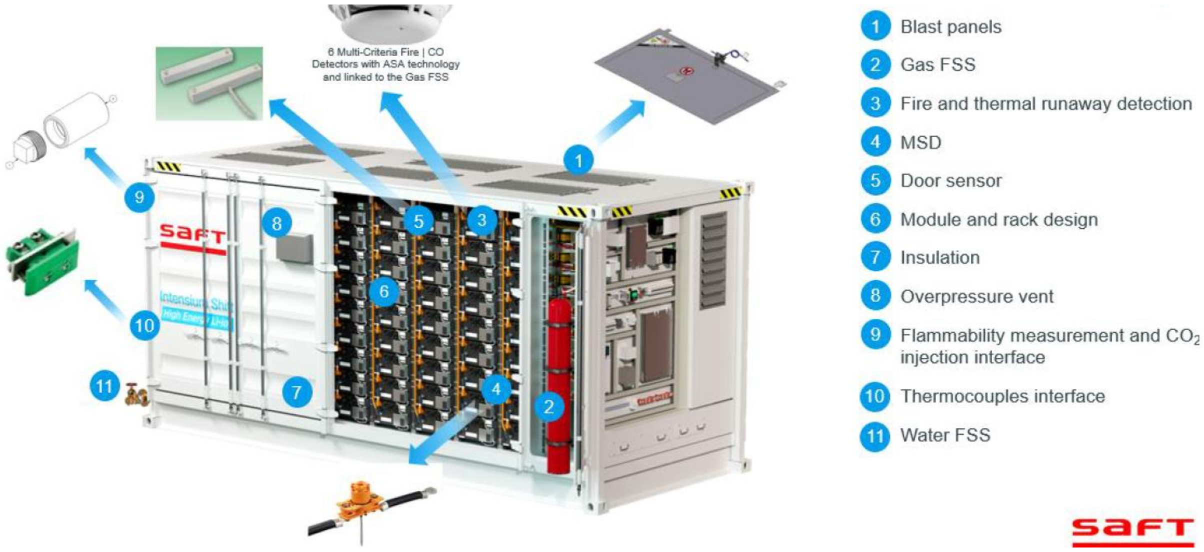

Figure 3-6: BESS Protection Systems

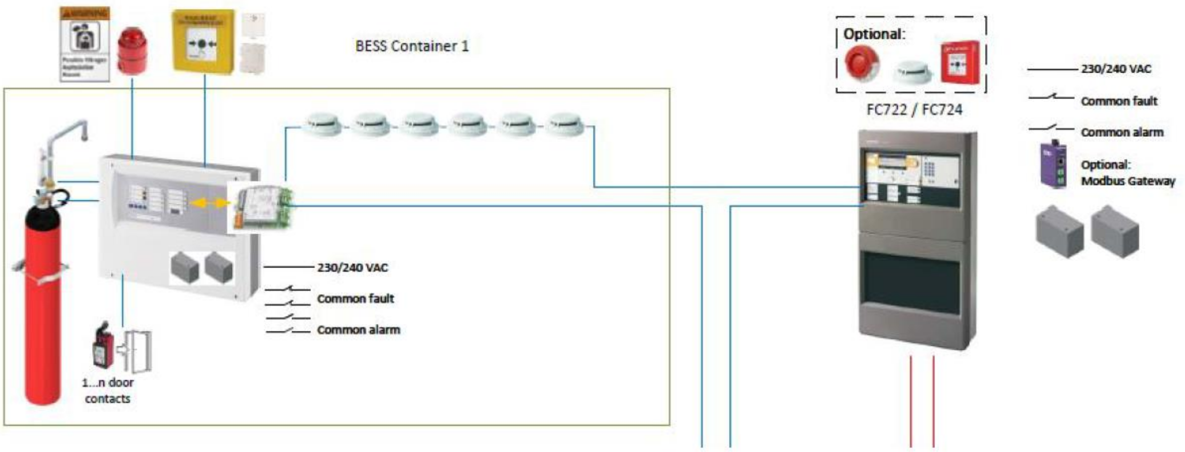

Figure 3-7: BESS Fire Protection Systems

3.6 Quantities of Dangerous Goods

The classes and quantities of DGs provided in **Table 3-1**.

Table 3-1: Maximum Quantities of Dangerous Goods Stored & Preliminary Risk Screening

Area	Class	Description	Quantity (L / tonne*)
BESS	9	Lithium Batteries	16,800 *
PCU Transformer	C2	Transformer oils	112,000 L
Substation Transformer	C2	Transformer oils	90,000
Control room generator	C1	Diesel	1,000

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential fire or explosion impact are assessed in the following sections of this document.

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°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. [8])

4.3 Hazard Identification

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

- Li-ion battery fault, thermal runaway and fire.
- Li-ion battery fire, toxic smoke plume
- Electrical equipment failure and fire.
- Transformer internal arcing, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Diesel release, ignition and pool fire.
- External fire impact.

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

4.4 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**.

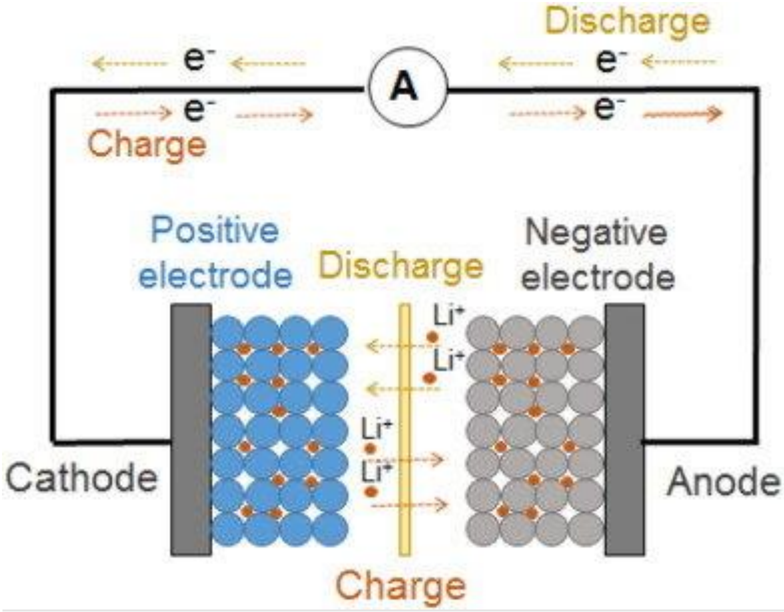

Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

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 by-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)
- Battery Management Systems (BMS) – constant monitoring of the voltage, temperature and state of charge of individual cells to aid in early detection of a fault condition. Upon detection of cell fault, the BMS disconnects and isolates the cell to prevent propagation of the incident, and alarms the site Emergency Management System (EMS).
- Emergency stop
- Fire proteciton emergency start
- Gaseous fire protection system
- Explosion prevention vent

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 incredibly low with the only exceptions being where batteries are manufactured poorly or due to manufacturing faults, or battery damage (i.e. battery cell is ruptured as this can short circuit the battery resulting in thermal runaway) or in the event of an ancillary system failure during commissioning (i.e. while protection systems are being tested).

The battery product that has been proposed for this project is the I-Shift SAFT BESS units. The battery chemistry of the I-Shift units is lithium-Ion phosphate ($LiFePO4$, or simply LFP), which are considered to be one of the safest battery chemistries within the industry. 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 oxidizes the electrolyte.

A UL9540A report was prepared for the I-Shift SAFT BESS which has been provided in **Appendix C**. It is noted that the testing involved 34 modules: A review of the report indicated that thermal-runaway in one cell would result in cell-to-cell propagation (i.e. between the cells within a single module). The maximum wall surface temperature (i.e. of a module) was measured at 30.3^{o}C which was below the BESS threshold limit of 35^{o}C. While cell-to-cell propagation was observed, module to module propagation did not occur. In addition, flaming of the cells was not observed and no explosion hazards were observed (i.e. no deflagration (flash fire), detonation (explosion), or accumulation (precursor to deflagration or detonation)). Therefore, it is considered that a thermal runaway even in the LFP batteries would not result in a BESS unit fire.

Additional testing for shock and damage to batteries (i.e. nail puncture test) has shown that LFP batteries when punctured through membranes 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. When exposed to external heat the thermal rise of typical lithium ion battery chemistries is 200-400 ^{o}C/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 1.5°C/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**.

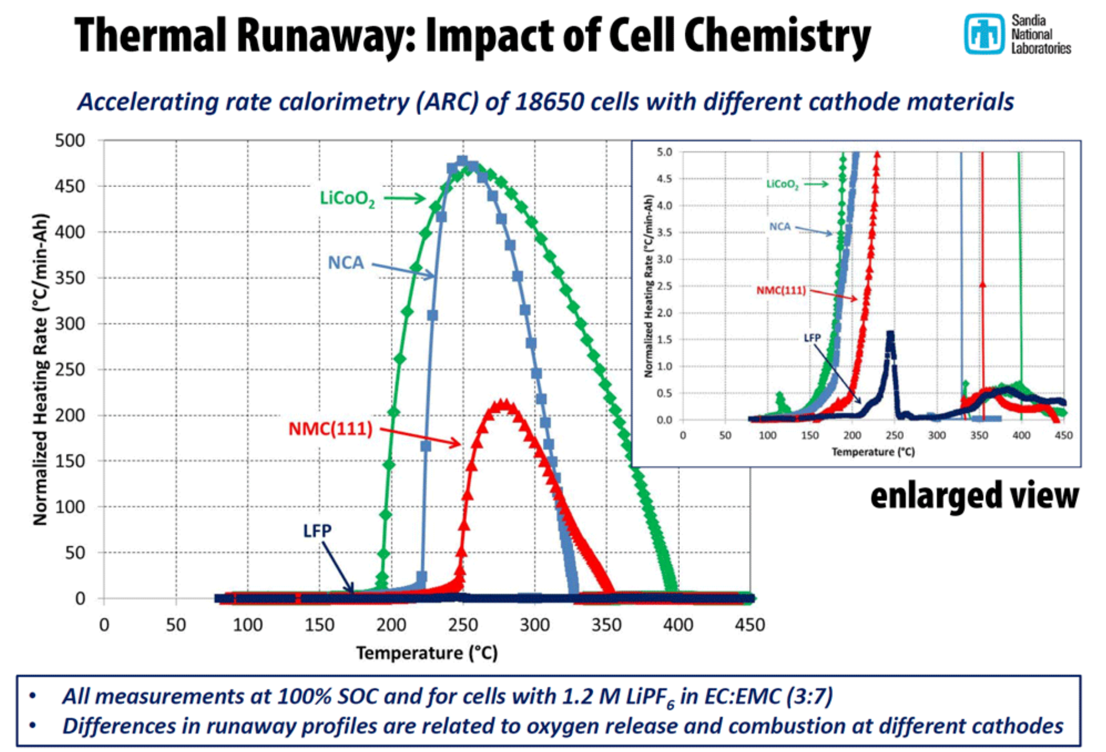

Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [9]).

Although the LFP technology does not typically cause fire, there can be circumstances where battery modules catch fire due to leaking coolant or electric faults. In those cases, fire will be constrained by the enclosure. In the event that LFP chemistries do ignite, the combustion by-products release carbon dioxide which reduces the oxygen concentration within a confined space reducing the combustion rate.

In conclusion, the LFP technology does not cause flaming fire during thermal runaway. Should fire be developed within one BESS enclosure it would not transfer to nearby enclosures due to the fire safety design features. 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.

Notwithstanding this, for conservatism it has been assumed that a flaming fire could occur from a BESS unit which may impact firefighting equipment or result in propagation of the incident to adjacent units. Therefore, this incident has been carried forward for further analysis for conservatism.

4.5 Li-ion Battery Fire and Toxic Gas Dispersion

As noted in **Section 4.4**, there is the potential for a BESS failure to occur resulting in a fire which may result in toxic by-products of combustion to form. As part of the BESS testing the off gases generated from the thermally running away battery cells were captured and tested. Provided in the **Table 4-2** is a summary of the gases that were detected.

Table 4-2: Gas Composition from Battery Cell Thermal Runaway

Gas Component	Gas volume in Percentage (%)
Carbon Monoxide	8.268
Carbon Dioxide	21.177
Hydrogen	53.408
Methane	6.962
Acetylene	0.311
Ethylene	6.101
Ethane	1.479
Propadiene (Allene)	0.001
Propylene	0.489
Propane	0.321
-	0.467
-	0.096
-	0.056
1-Heptene	0.005
Benzene	0.014
Toluene	0.002
Dimethyl Carbonate	0.645
Ethyl Methyl Carbonate	0.195
Diethyl Carbonate	0.003
Total	100

A review of the gases indicates they are predominantly flammable gases with the only gases of consideration for toxic impacts being carbon dioxide and carbon monoxide. These have been reviewed in further detail in the following subsections.

4.5.1 Carbon Dioxide

Carbon dioxide is a colourless, odourless, dense gas which 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 A-1**. This reaction proceeds when there is an excess of oxygen to the fuel being consumed and is known as complete combustion as it is the most efficient reaction pathway.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \qquad \textbf{Equation A-1}$$

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.

4.5.2 Carbon Monoxide

Carbon monoxide an odourless, colourless gas which 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 A-1**.

$$2C_3H_8(g) + 7O_2(g) \rightarrow 6CO(g) + 8H_2O(g) \qquad \textbf{Equation A-1}$$

As noted, in **Section 4.5.1** 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 which would result in a substantial downwind impact are not considered credible. Therefore, this incident has not been carried forward for further analysis.

4.6 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 impacts to firefighting equipment and incident propagation. Therefore, this incident has not been carried forward for further analysis.

4.7 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. To minimise the likelihood of such occurrence, transformers are fitted with a low oil pressure switch, oil temperature monitoring and switches, gas formation detectors and a pressure surge protection. These devices identify potential oil and pressure events within the transformer, isolating power and alarming operators.

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.

The transformer to be used on site will be insulated using natural ester based insulating oil. Natural esters have a flash point exceeds 300°C (Ref. [10]) and are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [8]). Therefore, ignition of the fluid is extremely difficult, and a fire occurring from a natural ester insulated transformer is not considered a credible scenario. Furthermore, transformers are ubiquitous units with a low potential for failure.

Notwithstanding this, due to the number of transformers on site, this incident has been carried forward for further analysis for conservatism.

4.8 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. [11]) 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 4.7**.

In order to protect against overheating and explosions, transformers have surge protection, which programs them to shut down upon detection of an energy spike. However, the surge protection can have a slight delay. In the event of a major lightning strike, significant oil deterioration or physical damage such as a fallen tree, the surge protection may be too slow to stop an electrical overload (Ref. [12]).

However, the transformers will be protected against lightning as per the requirements of AS 2067:2016 (Ref. [13]). Furthermore, the transformers will use natural esters as the insulating liquid instead of mineral oil. As previously discussed, natural esters have a flash point exceeding 300°C (Ref. [10]), and so are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [14]).

Therefore, there is the potential for an explosion to occur which may result in impacts to fire protection equipment; however, as noted, these units are ubiquitous and have a low potential for failure. Therefore, this incident has not been carried forward for further analysis.

4.9 Diesel Release, Ignition and Pool Fire

A self-bunded diesel fuel tank (1,000 L) is provided to supply a backup generator for the control room will be located at the site. The diesel tank will be designed in accordance with AS 1940:2017 (Ref. [15]), including fitting the tank with level alarms and overfill sensors. In the event the operator fails to respond alarm during tank filling, this may result in a release of diesel. However, the tank is integrally bunded and hence will be capable of containing the full volume of the liquid within the secondary tank, should deterioration of the internal tank or overfill occur.

A significant release of diesel may also occur if a vehicle were to impact the tanks as this may damage both the primary and secondary tanks. The risk of vehicle collision will be mitigated by the use of impact protection (e.g. bollards, armco barriers) which will prevent any wayward vehicles from contacting the tank; hence, catastrophic damage is unlikely to occur.

Furthermore, diesel is classified as a combustible liquid (flash point above 61°C), and as such does not readily form a vapour cloud at ambient temperature and is difficult to ignite. Therefore, a subsequent flash fire or explosion is not a possible scenario. Although combustible liquids are difficult to ignite in ambient conditions, there is potential for a pool fire to occur if the spill has prolonged exposure to ignition sources. The diesel tank will be located away from ignition sources.

Therefore, as the diesel tank will be designed with appropriate control measures to prevent a release and diesel does not readily ignite at ambient temperature, a diesel pool fire is not considered to be a credible scenario. Based on the protections and the size of the diesel tank, this incident has not been carried forward for further analysis.

4.10 External Fire Impact

There is the potential for an external fire event to impact the BESS facility such as bushfire. The development area is adjacent to medium potential bushfire intensity prone land. **Figure 4-3** shows the location of the bushfire prone land that is in proximity to the site. The distance between this vegetation and the site is an estimated 200 m and is classified as a potential impact buffer; hence, the potential for direct radiant heat impact from a bushfire on the site is considered negligible.

Notwithstanding this, with prevailing winds, embers can travel several kilometres which may result in ignition of vegetation at the BESS facility. The site operates a vegetation management plan to prevent the accumulation of combustible loads; hence, in such an event any escalation would be expected to be a grass fire. Grass fires can move quickly; however, they tend to be short lived as the combustible load is exhausted. Subsequently, sustained radiant heat impacts at the site would not be expected and would be unlikely to result in sufficient heat to impact the BESS or other infrastructure such that incident propagation occurs.

In addition, during operations, the site has an 80,000 L water tank. The tank is fitted with a 65 mm Storz fitting in addition to a QFES compatible suction connection adjacent to the internal access road. It is expected that this water supply can be used to combat a grass fire or provide cooling to critical infrastructure if necessary.

Based on the discussion above, the potential for incident escalation as a result of an external fire impact to occur is considered negligible; hence, this incident has not been carried forward for further analysis.

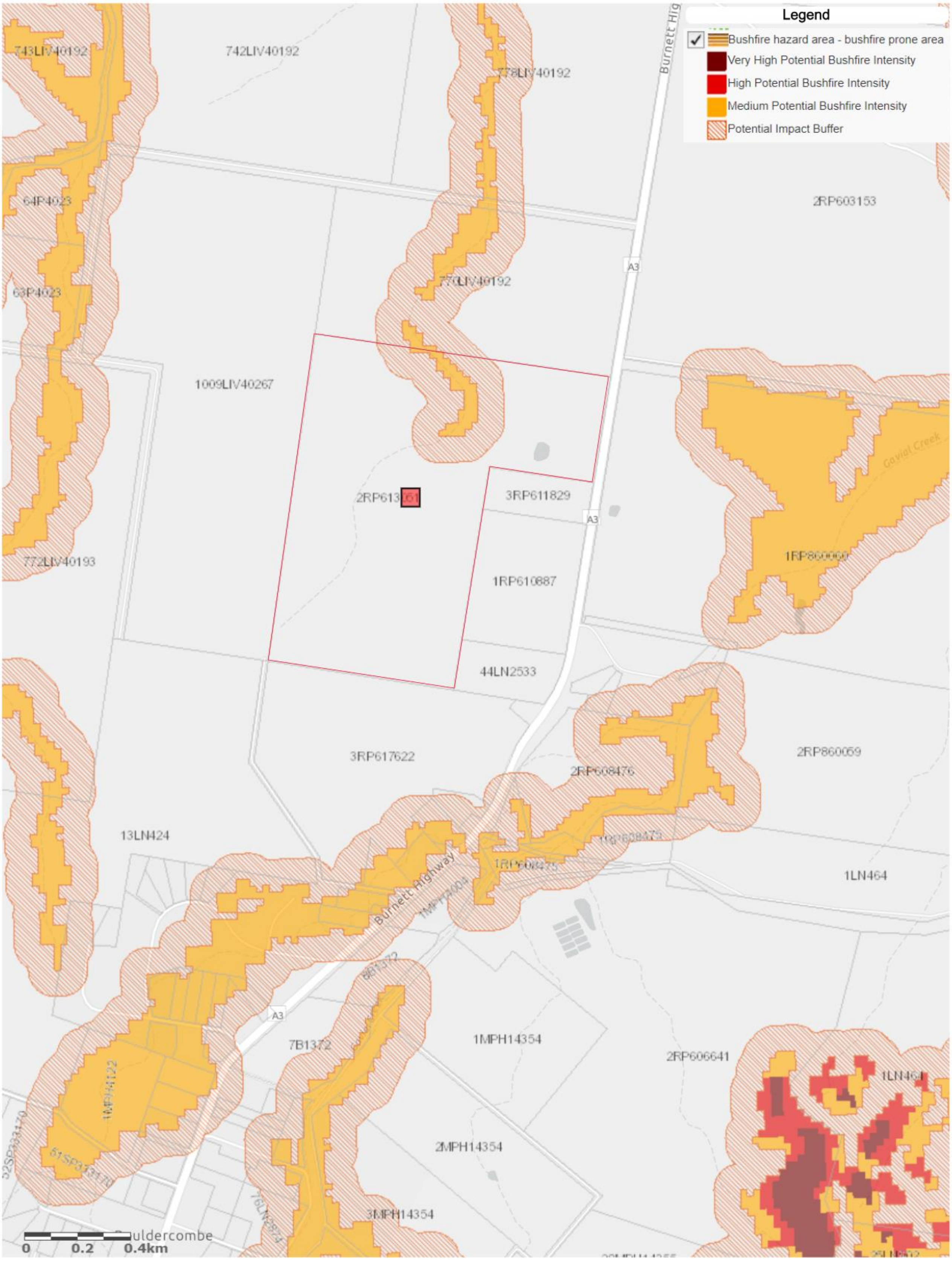

Figure 4-3: Bushfire Prone Land

5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were identified to have the potential to impact fire protection systems or to complicate firefighting interventions:

- Li-ion battery fault, thermal runaway and fire.
- Main transformer internal arcing, oil spill, ignition and bund fire.
- Power conversion unit transformers, oil release, ignition and fire.

Each incident has been assessed in the following sections. A detailed analysis of each scenario is outlined in **Appendix B**, along with the criteria used to assess each incident.

5.2 Li-Ion Battery Fault, Thermal Runaway and Fire

There is potential that a Li-Ion battery may fault resulting in thermal decomposition and fire which may spread throughout the whole fire unit if not isolated / protected. A detailed review of the test data for the BESS (Appendix C) was conducted in **Appendix B**. The testing conducted for the BESS indicated that the average cell venting temperature was 166°C and the average temperature at the onset of thermal runaway was 232°C with no flaming observed. This temperature value was adopted to determine the Surface Emissive Power (SEP) of the batteries undergoing thermal runaway. The calculation resulted in a SEP of 2.88 kW/m^2 which would be insufficient to result in incident propagation between BESS units.

The test data also identified that the maximum surface temperature of the BESS units under thermal runaway was 58.6°C which is consistent with a radiating surface with a low value. Based on the test data and the calculated SEP, it is considered that the potential for BESS propagation to occur is unlikely.

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

There is potential that arcing may occur within the transformers which may lead to generation of gases and pressure above the structural integrity of the oil reservoir which may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund. A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-1.** The radiant heat contours associated with a fire occurring within a transformer bund are shown in **Figure 5-1**.

Table 5-1: Radiant Heat from a Transformer Fire

Heat Radiation (KW/m^2)	Distance (m)
35	6
23	8
12.6	10
4.7	14
3.0	17

The 23 kW/m^2 contour has been used to assess the potential for propagation of the incident. As shown in **Figure 5-1**, the 23 kW/m^2 contour does not impact any other critical infrastructure and so incident propagation is not expected. There are no fixed fire protection systems in proximity to the transformer; hence, these are unimpacted by the 3 kW/m^2 contour.

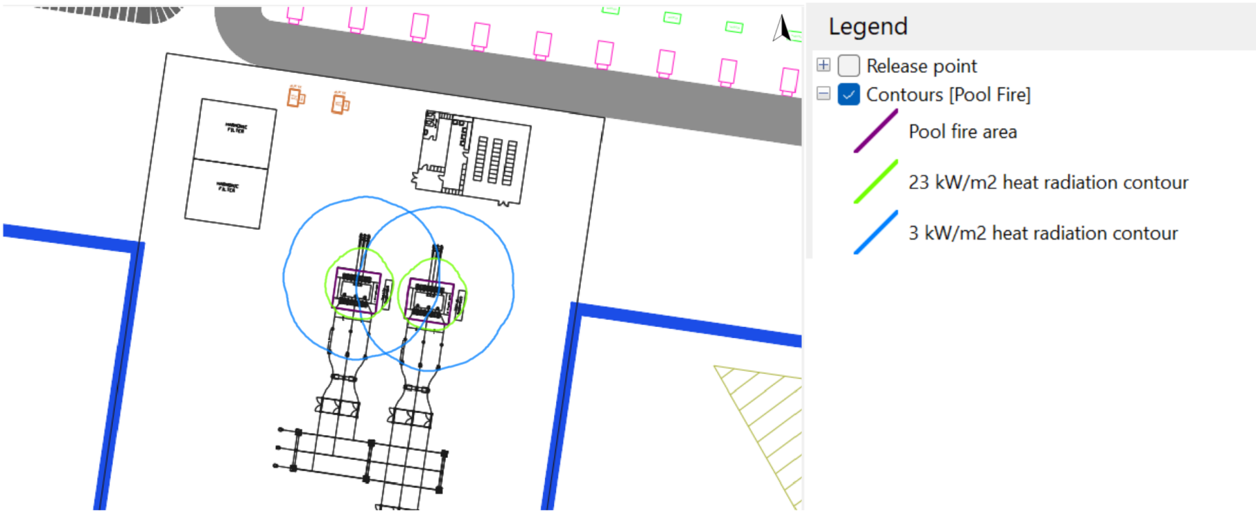

Figure 5-1: Transformer Fire Radiant Heat Contours

5.4 Power Conversion Unit Transformers, Oil Release, Ignition and Fire

There is potential that arcing may occur within the PCUs which may lead to generation of gases and pressure above the structural integrity of the oil reservoir which may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund. An extremely conservative detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-2.** The radiant heat contours associated with a fire occurring within the PCUs are shown in **Figure 5-1**.

Table 5-2: Radiant Heat from a PCU Fire

Heat Radiation (KW/m^2)	Distance (m)
35	4
23	5
12.6	6
4.7	8
3.0	9

The 23 kW/m^2 contour has been used to assess the potential for propagation of the incident. As shown in **Figure 5-1**, the 23 kW/m^2 contour does not impact any other critical infrastructure and so incident propagation is not expected. There are no fixed fire protection systems in proximity to the transformer; hence, these are unimpacted by the 3 kW/m^2 contour.

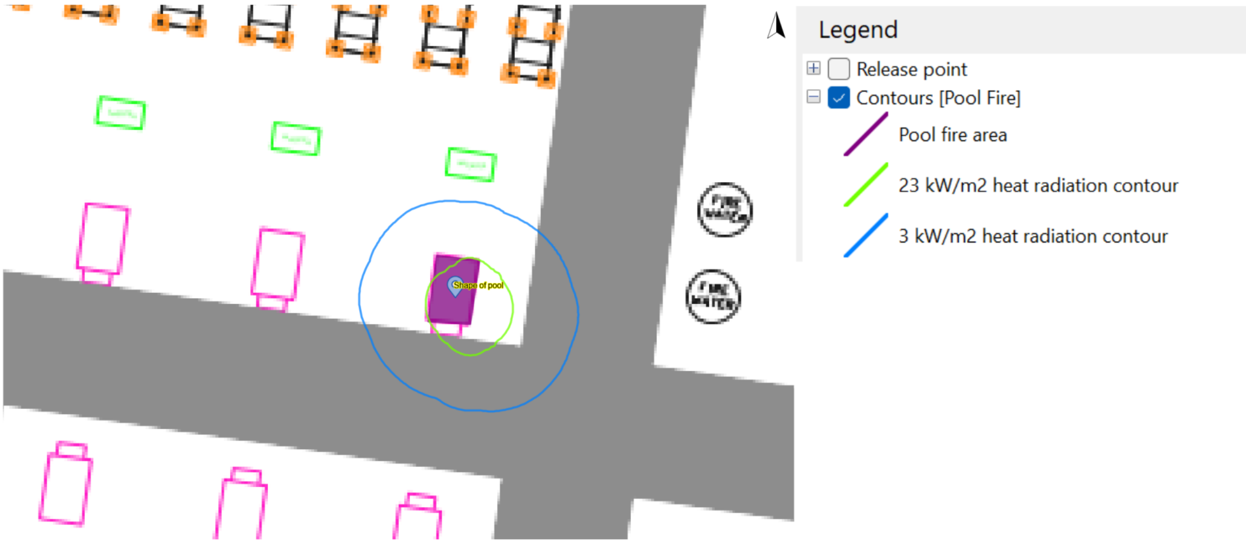

Figure 5-2: PCU Fire Radiant Heat Contours

6.0 Details of Prevention, Detection, Protection and Mitigation Measures

The fire safety systems at the site can be split into four main categories:

- **Fire Prevention** – systems, installed to prevent the conditions that may result in initiating fire.
- **Fire Detection** – systems installed to detect fire and raise alarm so that emergency response can be affected (both evacuation and firefighting)
- **Fire Protection** – systems installed to protect against the impacts of fire or explosion (e.g. fire walls)
- **Fire Mitigation** – systems installed to minimise the impacts of fire and to reduce the potential damage (e.g. fire water application)

Each category has been reviewed in the following sections, with respect to the existing systems incorporated into the design and those to be provided as part of the recommendations herein.

6.1 Fire Prevention

This section describes the fire prevention strategies and measures that will be undertaken at the site.

6.1.1 Control of Ignition Sources

The control of ignition sources reduces the likelihood of igniting a release of material. The site has a number of controls for ignition sources. These include controls for fixed potential ignition sources and controls for introduced ignition sources.

- A permit to work or clearance system will be used - hot work will be controlled as part of the permit to work system.
- Designated smoking areas within the site (i.e. external from building areas).

Table 6-1 presents the potential ignition sources and incidents for the facility which may lead to ignition and fire. The table also summarises the controls that will be used to reduce the likelihood of these potential sources of ignition and incidents resulting in a fire.

Table 6-1: Summary of Control of Ignition Sources

Ignition Source	Control
Smoking	No smoking policy for the site with smoking only permitted in designated areas.
Electrical	Fixed electrical equipment to be designed and installed to AS/NZS 3000:2018 (Ref. [14]).
Arson	The site will have a security fence and monitored security cameras.
Hot Work	A permit to work system and risk assessment prior to starting work will be provided for each job involving the introduction of ignition sources.

6.1.2 Separation of Incidents

The separation of incidents is used to minimise the impacts of a hazardous incident on the surrounding operations or the generation of potential “domino” effects. The storage locations of products have been designed based upon whether a product can be adequately protected by the fire protection system. The BESS tests indicated that propagation between modules did not occur from thermally running away battery cells. Therefore, propagation within the BESS is unlikely and therefore propagation between adjacent BESS units is not considered to be credible.

6.1.3 Housekeeping

The risk of fire can be significantly reduced by maintaining high standards of housekeeping. The site shall maintain a high housekeeping standard, ensuring all debris is cleaned up and removed from the areas. In addition, the site has vegetation management procedures to prevent accumulation of combustible vegetation in proximity to the site equipment and to minimise the potential for bushfire escalation.

6.1.4 Work Practices

The following work practices will be undertaken to reduce the likelihood of an incident. They include:

- DG identification
- Placarding & signage within the site
- Forms of chemical and DG information
- Availability of Safety Data Sheets
- Compliance with the Work Health and Safety Regulation 2011 (Ref. [17]).
- Safe work practices adhered to
- Personal Protective Equipment
- Emergency response plan and procedures
- Bushfire Management Plan
- Training of personnel

6.1.5 Emergency Response Plan

Emergency management is critical in controlling and responding to an emergency. Therefore, to ensure that an appropriate emergency response plan is developed, the following recommendation has been made:

- An emergency response plan shall be prepared in accordance with HIPAP No. 1 – Industry Emergency Planning Guidelines (Ref. [18]).

6.1.6 Site Security

Maintaining a secure site reduces the likelihood either of a fire being started maliciously by intruders or by accident. Access to the site will be restricted at all times and only authorised personnel will be permitted within the site.

6.2 Detection Procedures and Measures

This section discusses the detection and protection from fires for the hazardous incidents previously identified. These include detection of fire pre-conditions, detection of a fire suppression activated condition and prevention of propagation. This assessment includes identification of the detection and protection systems required.

6.2.1 Fire Detection and Alarming

The site will utilise I-Shift SAFT BESS Units or equivalent. The I-Shift BESS Safety Manual (**Appendix D**) indicates that the BESS units are equipped with smoke detectors and thermal detectors to detect the early signs of a fire. In the event that elevated temperatures or smoke is detected, an audible fire alarm and visual fire strobes fitted on the BESS unit will be activated. In addition, corresponding alarms will be sent to the EMS systems to alert site personnel to begin emergency procedures.

6.2.2 Gas Detection and Alarming

The I-Shift BESSs are fitted with flammable gas detection which will alarm and activate the ventilation system. Flammable gases are a by-product of thermal runaway in the battery chemistries; hence, detection of the flammable gases provides another point to isolate BESS failure.

6.3 Fire Protection

The required fire protection systems are summarised below. All drawings associated with the fire protection systems are provided in **Appendix D**.

The I-Shift BESS units selected are fitted with a ceiling mounted aerosol fire suppression system. In the event of detection of a fire within the BESS unit, the aerosol suppression system is triggered, releasing a gaseous suppressant BESS.

The site is provided with water tanks that can be access to provide water supply in the event of fires to other sources of fire (i.e. transformers, site buildings, etc.).

6.4 Fire Mitigation

6.4.1 Fire Water Supply

The site is equipped with an 80,000 L water tank. The water tank is to have a 65 mm Storz fitting and QFES compliant suction connection. Based on the low potential for fire and / or propagation of a BESS fire it is considered that the water supply would be adequate to deal with the potential fire hazards at the site (i.e. propagation of a fire from the BESS noting that a BESS fire should not be fought with water). The water may also be used to supply combat measures for transformer fires or other building fires.

6.4.2 Ventilation

In the event of thermal runaway, flammable gases are generated which if ignited could result in an explosion. The units are fitted with an extraction system that activates when a flammable gas is detected. The purpose of this system is to extract the gases to prevent accumulation to the explosive limits to minimise the potential for an explosion to occur.

6.4.3 Explosion Venting

In the event the extraction system is unable to remove sufficient gases to maintain a concentration below the Lower Explosive Limit (LEL) the potential for an explosion exists as the gases are contained within a confined area which is a necessary requirement for an explosion. The I-Shift BESSs are fitted with an explosion vent which is designed to open under pressure. In the event of ignition, the pressure will begin to rise within the unit as the combustion propagates through the flammable gas atmosphere. When the pressure reaches the activation point of the explosion vent, the vent opens relieving the pressure. With the pressure relieved, the combustion reaction slows prevent escalation to the point of detonation.

7.0 Local Brigade Access and Egress

7.1 Overview

In order to assess the likely fire brigade response times an indicative assessment of fire brigade intervention has been undertaken based on the methods defined in the Fire Brigade Intervention Model (FBIM, Ref. [19]). **Figure 7-1** illustrates the site layout with entry points to the site and fire services infrastructure.

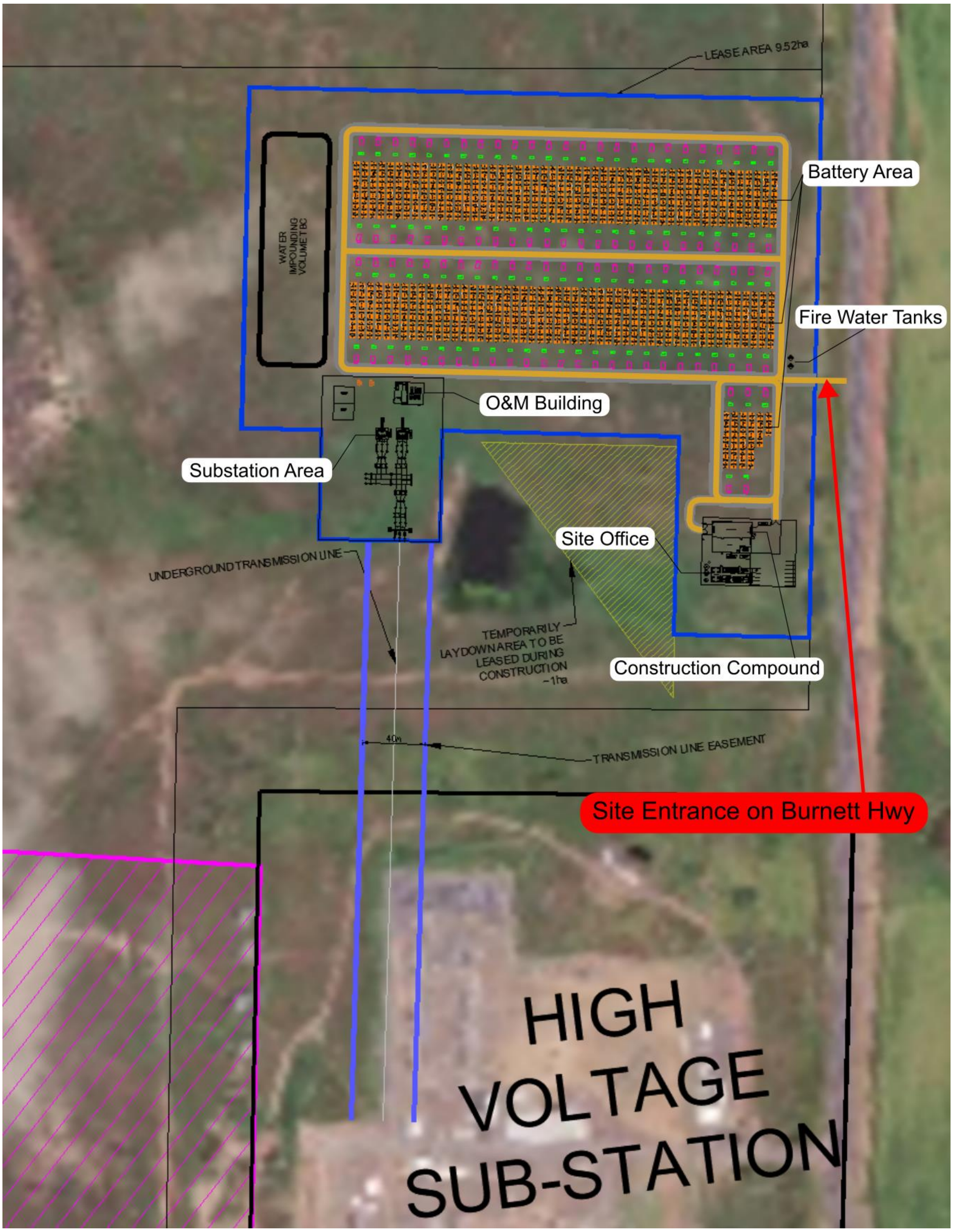

Figure 7-1: Fire Service Entry Point and Site Infrastructure

The closest fire stations to the site are described in **Table 7-1**. The expected routes from the stations to the site are illustrated in **Figure 7-2.**

Table 7-1: Station Locations

Station Name	Station Address	Distance (km)	Time (min)
Mount Morgan Fire Station	32 Morgan St, Mount Morgan, QLD	20	19
Gracemere Fire & Rescue Station	HF64+H5 Gracemere, QLD	14	11

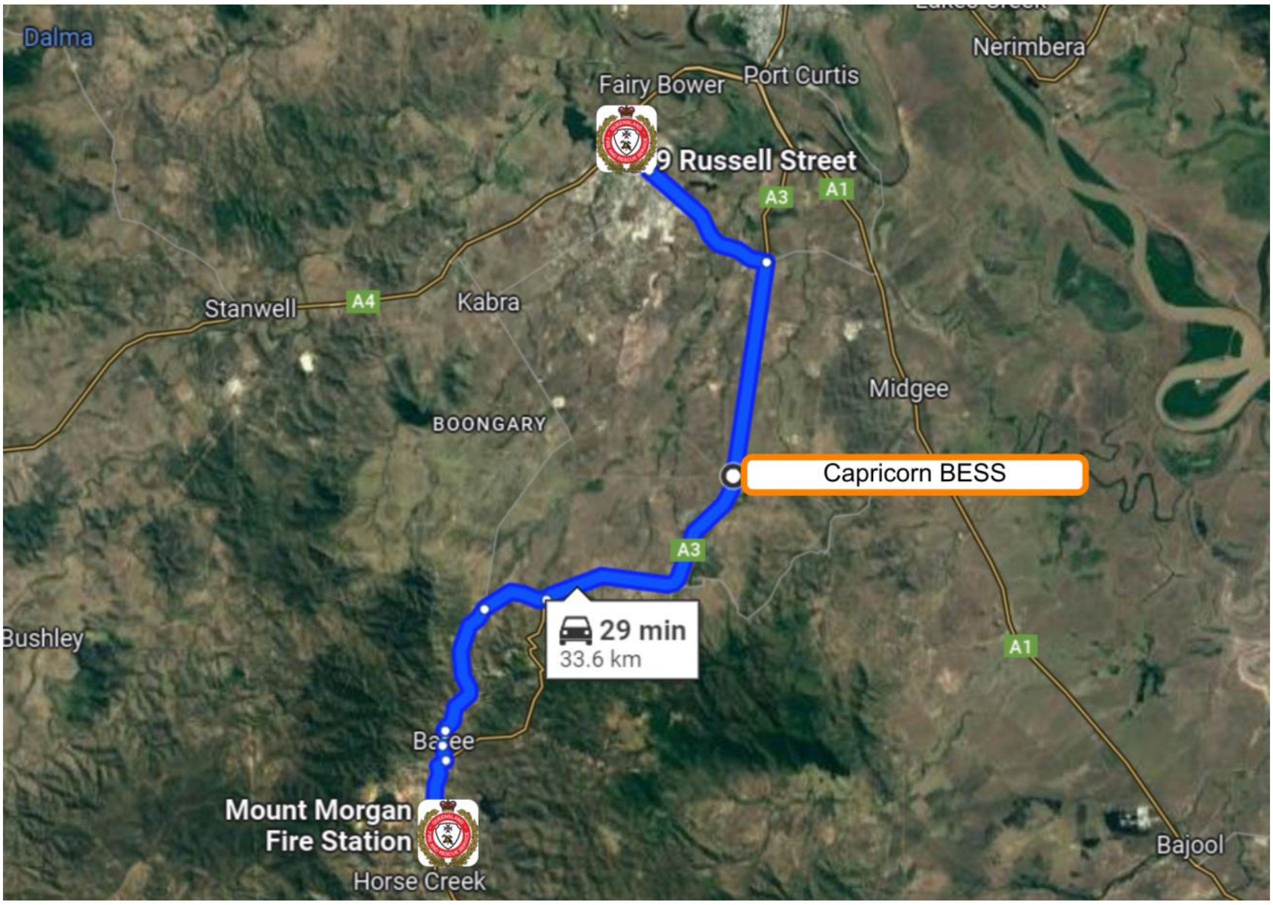

Figure 7-2: Location of Site with Respect to Closest Fire Stations

7.2 Response Time – Fire Brigade Intervention Model (FBIM)

Due to the nature of the Fire Brigade Intervention Model (FBIM, Ref. [19]), it is necessary to justify the results through the inclusion of assumptions. The accuracy of results weighs heavily upon the measure of which assumptions are made and the sources from which they are derived. The model produced details the time it will take for brigade personnel within the aforementioned location to receive notification of a fire, time to respond and dispatch resources, time for resources to reach the fire scene, time for the initial determination of the fire location, time to assess the fire, time for fire fighter travel to location of fire, and time for water setup such that suppression of the fire can commence. The following are details of the assumptions utilised in this FBIM:

7.2.1 Location of Fire

This FBIM will only be an indicative model of one fire scenario within the facility. For conservative purposes, the FBIM will consider a fire in the furthest incident from the point of entry.

7.2.2 Time between Ignition and Detection

- It is assumed that the initial brigade notification is via a direct contact by the site personnel.
- It was conservatively assumed that the time from ignition, detection and notification to fire brigade is 30 minutes, or 1,800 seconds, due to the remote nature of the site.

7.2.3 Time to Dispatch Resources

- The fire station is considered to be manned at the time of the fire.
- Based on QFES response times statistics from the 2022/2023 annual report (Ref. [20]), the average time for the fire brigade to respond to an emergency call (including call processing, turnout time and travel time) is 8.2 minutes as shown in **Figure 7-3**. The 90th percentile of response time of approximately 12.5 minutes. However, as this is for inner city areas and the site is rurally located, it was assumed that RFS would respond 30 minutes later (1,800 s).

Service area: Fire and Emergency Services

Performance measures	Notes	2022–23 SDS	Strategic plan	RoGS	2021–22 Actual	2022–23 Target/ Estimate	2022–23 Actual
Rate of accidental residential structure fires reported (per 100,000 households)	1, 2, 3	✓		✓	51.1	<60	48.0
Response times to structure fires including call taking time:	3, 4, 5	✓		✓			
• 50th percentile	6				8.3 minutes	<7.8 minutes	8.2 minutes
• 90th percentile	7				12.9 minutes	<14 minutes	12.5 minutes

Figure 7-3: QFES Response Time from 2022/2023 Annual Report

- As the site is located in a rural area, additional travel time should be taken into account. The travel time has been assumed to be 25 minutes (1,500 seconds).
- Therefore, with a brigade call out time of 1,820 seconds, response time of 1,800 seconds, and travel time of 1,500 seconds (25 minutes), the fire brigade can be expected to arrive on site 5,120 seconds after fire ignition (85 minutes).

7.2.4 Time for Initial Determination of Fire Location

- On arrival, the fire location may not be visible to the approaching brigade personnel, thus requiring information to be obtained from the site emergency box.
- Fire brigade personnel assemble at the office area.
- Fire brigade tactical fire plans will be provided.

7.2.5 Time to Assess the Fire

- Horizontal egress speeds have been based on fire brigade personnel dressed in turnout uniform in BA. An average travel speed of 1.4 m/s with a standard deviation of 0.6 m/s as shown in **Table 7-2**. As such, for the purposes of the calculations, a horizontal travel speed of 1.40 – (1.28x0.6) = 0.63 m/s is utilised.

Table 7-2: FBIM data for Horizontal Travel Speeds

Graph	Travel Conditions	Speed	
		Mean	SD*
Q1	Dressed in turnout uniform	2.3	1.4
Q2	Dressed in turnout uniform with equipment	1.9	1.3
Q3	Dressed in turnout uniform in BA with or without equipment	1.4	0.6
Q4	Dressed in full hazardous incident suit in BA	0.8	0.5

*Standard Deviation

Horizontal travel distances will include the following:

- Travel from the entrance to the main water tank is approximately 30 m. Assuming vehicles are travelling at 60 km/h, this results in a travel time of 2 s.
- From the water tank, the most northern west point of the site is approximately 464 m via internal access roads which would result in 28 s of travel time assuming a travel speed of 60 km/h within the site.
- It was assumed that RFS would only be required to travel approximately 100 m on foot. Coupled with an egress speed of 0.63 m/s results in a horizontal travel time of up to 63 seconds.
- Thus, the total horizontal travel time to respond to an incident in the farthest location would be expected to be in the realm of 93 s.

7.2.6 Time for Water Setup

- The first appliance would be expected to commence the initial attack on the fire.
- Time taken to connect and charge RFS tanker units to the water tanks and collect the water is based on Table X of the Fire Brigade Intervention Model Guidelines, which indicates an average time of 201.6 seconds, and a standard deviation of 115.6 seconds. Using a 90th percentile approach as documented in the FBIM (Ref. [19]), the standard deviation is multiplied by a constant *k*, in this case being equal to 1.28. Therefore, the time utilised in this FBIM is 201.6 + (1.28x115.6) = 350 s.

7.2.7 Search and Rescue

Search and Rescue of the site will consist of a perimeter search of the control building located adjacent to the BESS area. It was assumed this will provide firefighting personnel with an additional 500 m of travel.

At a speed of 0.63 m/s, this will take firefighting personnel approximately 315 seconds.

7.2.8 Summary

As summarised in **Table 7-3** the FBIM (Ref. [19]) indicates that the arrival times of the brigade from the nearest fire stations is approximately 96 minutes after fire ignition, and it is estimated that it takes another 9.7 minutes for the fire brigade to carry out activities including the determination of fire location and preparation of firefighting equipment. As such, the initial attack on the fire is expected to commence approximately 105.7 minutes after fire ignition (note rounding affects the basic addition of the reported figures).

Table 7-3: Summary of the Fire Brigade Intervention Model (FBIM)

Fire Station	Alarm Time	Travel Time	Time for Access & Assessment	Set-up Time	Time of Attack	Time for Search & Rescue
Gracemere Fire & Rescue Station	1,800 s	3,300 s	93 s	350 s	6,322 s (125 minutes)	315 s

8.0 Fire Water Supply & Contaminated Fire Water Retention

8.1 Detailed Fire Water System Assessment

Hydrants are not available at this site due to its rural location. Instead, fire water will be supplied by an 80,000 L water tank. AS 2419.1 places the minimum flow rate requirement for fire hydrants at 10 L/s. The site falls under the requirement of having two hydrants equating to a storage of 80,000 L for 60 minutes of firefighting operation.

The tank is located on the northern side of the site access road, next to the BESS area. This provides sufficient water to refuel a response tanker twenty times (each tanker having a capacity of 4,000 L) provided the tank is 100% full.

The site will not have fixed firefighting infrastructure other than the water supply from the tanks. The fire hazards have been assessed in **Section 5.0** which identified that there is a low potential for a fire to occur within the BESS units and that in the event of thermal runaway the radiant heat generated would be unable to result in incident propagation.

Based on this, the water demand required to combat fire incidents at the site is low and would be expected to be adequately managed by the provided water supply.

8.2 Contaminated Water/Fire Water Retention

Where materials are combusted in a fire, they may become toxic (i.e. formation of volatile organic compounds and aromatic hydrocarbons). Hence, when fire water is applied the materials may mix with the water resulting in a contaminated run off. To ensure environmental damage does not occur the facility is designed to contain a volume of liquid discharged from the site.

A risk assessment methodology is outlined by the NSW Department of Planning document "*Best Practice Guidelines for Potentially Contaminated Water Retention and Treatment Systems*" (Ref. [21]). This guide will be consulted to provide a conservative assessment of the site in the absence of an alternate guide provided by QLD regulation. Application of fire water to a BESS fire does not result in extinguishment as the fire will continue until the energy has been discharged from the battery. In addition, application of water can result in additional side reactions as the fire progresses which can form potentially toxic by-products. Therefore, the method for combatting a BESS fire is to prevent propagation to adjacent units / equipment.

Based on the test data, a flaming fire is not expected to occur; hence, the incident will likely be heated batteries which rupture resulting in the release of flammable gases which are handled by the ventilation system to prevent ignition. Therefore, it is expected the incident will mostly be contained within the BESS enclosure itself which will provide protection in the event that the incident occurs in the rain.

Vegetated areas around BESS are typically used for grazing of livestock; hence, the area will not be paved preventing any reasonable method for providing containment in the event that contamination does occur. However, given the protection systems incorporated into the BESS design, the likely outcome of thermal runaway not resulting in a flaming fire, the potential for contaminated water to be generated from this incident is considered low and that accommodating the unlikely formation of contaminated water would be disproportionately expensive to the risk of contamination.

Based on the above discussion, no recommendations have been made with respect to contaminated water retention.

9.0 Conclusion and Recommendations

9.1 Conclusions

A HIMP per the HIPAP No. 2 guidelines was prepared for the proposed BESS Facility located at Lot 2 on RP613051 off Burnett Highway Bouldercombe, QLD 4702. The analysis performed in the HIMP was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the designs and existing fire protection adequately managed the credible fire risks at the site.

9.2 Recommendations

Based on the analysis, the following recommendations have been made:

- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.
- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref. [1]).
- A team of site personnel are to be trained in the use of the water cart and first-attack firefighting methods.
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- A site Emergency Response Plan per the requirements of HIPAP No. 1 shall be prepared and shall include measures to advise neighbouring premises in the event of an emergency with potential offsite impacts.
- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 and any applicable storage and handling standards.

10.0 References

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Appendix A

Hazard Identification Table

Appendix A

A1. Hazard Identification Table

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
1	Battery Storage	• Battery fault / failure • 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 manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents 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 3000:2018 (Ref. [14]) • Ventilation • Explosion venting • Smoke & gas detection • Aerosol suppression system
2	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
3	Transformers	• Arcing within transformer, vaporisation of fluid and rupture of fluid reservoir	• Transformer fluid release spill, ignition and fire	• Natural ester used as dielectric fluid – Natural esters have a high flash point (>300ºC) such that ignition is very unlikely to occur. • Transformers are bunded • Electrical protection for transformer faults • Control of ignition sources – no smoking / open flames around the transformers

ID	Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
4	Main transformer	• Power surge to transformers (e.g. from lightning, fault, etc.)	• 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
5	Ancillary transformers	• Power surge to transformers (e.g. fault)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• Transformers are in containers which protect from lightning and cables are underground. • Control of ignition sources – no smoking / open flames around the transformers
6	Generator tank	• Release of diesel	• Ignition and pool fire	• Integrally bunded tank complying with AS 1940:2017 • Low volume of diesel stored (1,000 L) • Separated from other site areas. • Diesel is difficult to ignite as it's a combustible liquid.

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

The following incidents are assessed for consequence impacts.

- Li-ion battery fault, thermal runaway and fire.
- Main transformer internal arcing, oil spill, ignition and bund fire.
- Power conversion unit transformers, oil release, ignition and fire.

Each incident has been assessed in the sections below.

B2. Radiant Heat Physical Impacts

Appendix Table B-1 provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. [6]).

Appendix Table B-1: Heat Radiation and Associated Physical Impacts

Heat Radiation (kW/m^2)	Impact
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of a fatality for people exposed instantaneously
23	• Likely fatality for extended exposure and chance of a fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
12.6	• Significant chance of a fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
4.7	• Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)
3.0	• FRNSW criteria to access equipment

B3. Gexcon - Effects

The modelling was prepared using Effects where appropriate, which is proprietary software owned by Gexcon which has been developed based upon the TNO Coloured books and updated based upon CFD modelling tests and physical verification experiments. The software can model a range of incidents including pool fires, flash fires, explosions, jet fires, toxic dispersions, warehouse smoke plumes, etc.

B4. View Factor Radiant Heat Model

The modelling for the BESS units was carried out using a manual view factor calculation method outlined below.

B4.1 Radiant Heat Flux

The heat flux (Q) for the view factor model is given by **Equation B-1**.

$$Q = \tau E F \qquad \textbf{Equation B-1}$$

Where;

- Q = heat flux (kW/m^2) at the target
- F = geometric view factor
- τ = transmissivity
- E = SEP (kW/m^2)

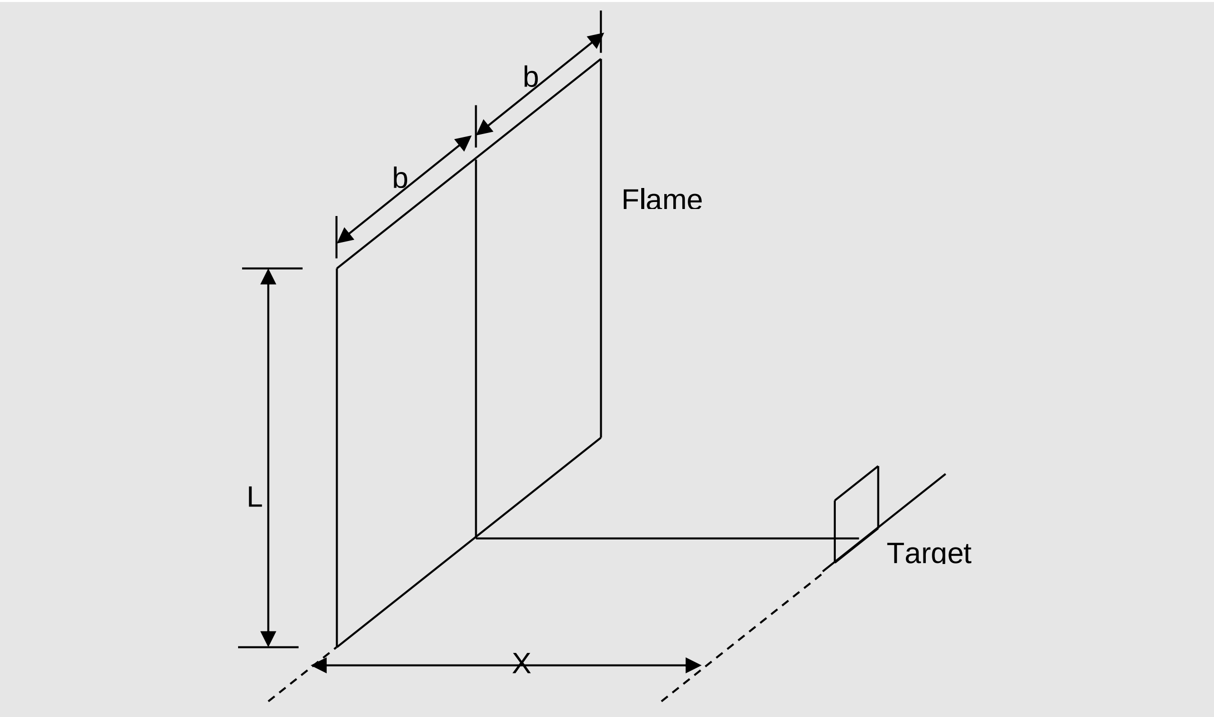
Each of the required inputs is determined in the sections following.

B4.2 View Factor

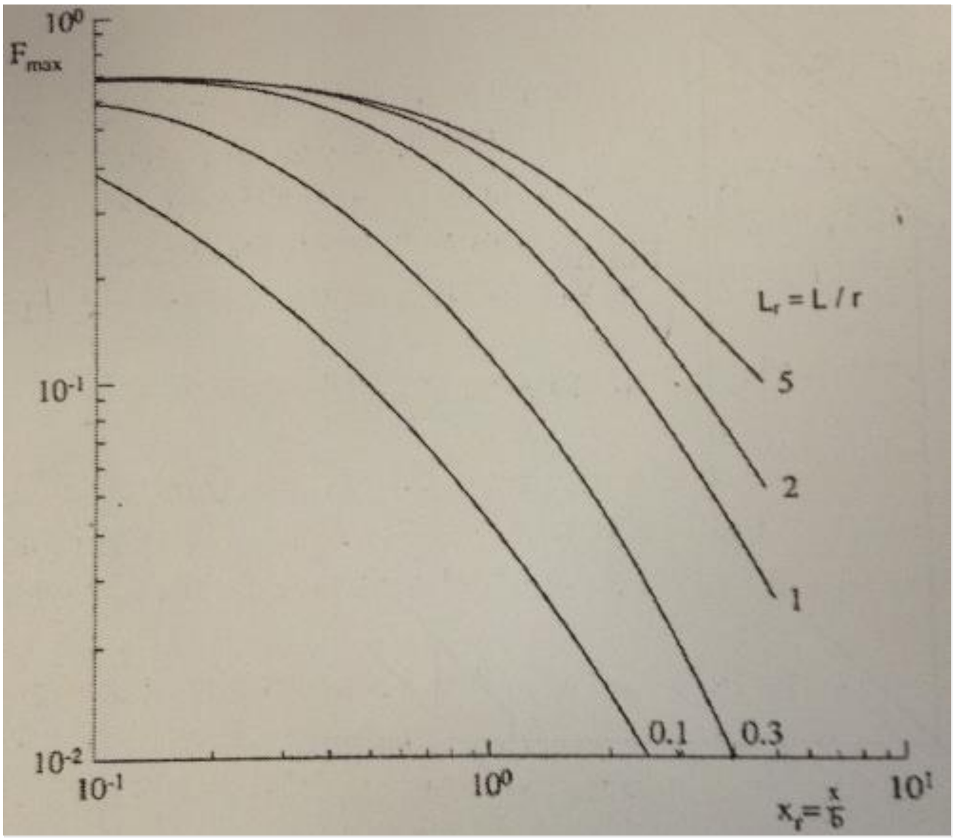
The view factor for a flat surface fire is estimated using the scenario shown in **Appendix Figure B-1** where the flame is the vertical surface of height L and length 2b with receiver located centrally and at a distance of X. Two dimensionless parameters are calculated, and the view factor read from **Appendix Figure B-2**. The dimensionless parameters are shown in **Equation B-2** and **Equation B-3**.

$$L_r = \frac{L}{b}$$ **Equation B-2**

$$X_r = \frac{x}{b}$$ **Equation B-3**



Appendix Figure B-1: Vertical Flame Geometry View Factor Geometry



Appendix Figure B-2: Vertical Flame Maximum View Factor (Ref. [22])

B4.3 Transmissivity

The transmissivity is estimated using **Equation B-4**.

$$\tau = 1.006 - 0.01171(\log_{10} X(H_2O) - 0.02368(\log_{10} X(H_2O))^2 - 0.03188(\log_{10} X(CO_2) + 0.001164(\log_{10} X(CO_2))^2 \quad \textbf{Equation B-4}$$

Where:

- $X(H_2O) = (R_H \times L \times S_{mm} \times 2.88651 \times 10^2)/T$
- $X(CO_2) = L \times 273/T$

And;

- R_H = percentage relative humidity
- L = distance to target (m)
- S_{mm} = saturated water vapour pressure in mm mercury at temperature (at 200°C S_{mm} = 11549)
- T = temperature (473 K assumed air is heated to 200°C)

B5. Li-Ion Battery Fault, Thermal Runaway and Fire

The BESS units selected are the I-Shift SAFT having 8 8+9 strings. Each module has dimensions of 0.525 m (W) x 0.876 m (D) x 0.250 m (H). They are arranged so that the cabinets open outwards; hence, the arrangement for the I-Shift BESS is conservatively (due to module between 8 and 9 stack heights to service the 17 module unit string) nine (8) x nine (2) x nine (9) yielding total dimensions of 4.2 m x 2.25 m.

To determine the radiant heat impacts from the BESS in the event of a fire it is necessary to assume the height of the flame. The rule of thumb for most flammable liquid fires is that the height is 2 times the width of the flame; however, a review of the Victorian Big Battery (VBB) fire indicates that it did not align with rule of thumb approach.

Based upon the VBB it has been assumed that the maximum height of the flame is 1 m above the height of the BESS unit. From the VBB it was apparent that only the flame through the roof was exposed as a radiant surface; hence, the assumed flame height of 1 m above the BESS container has been taken as the value of L for input into **Equation B-2**.

It is necessary to calculate the Surface Emissive Power (SEP) of the radiant surface to calculate the radiant heat at the target. The test data indicated the average temperature of the batteries at thermal runaway was 232ºC or 505.15 K. Therefore, for the purposes of modelling this temperature has been used.

The following equation can be used to estimate the SEP of the flame:

$$SEP = \varepsilon \sigma T^4$$ **Equation B-5**

Where:

- ε = flame emissivity (taken as 0.78 (Ref. [23]))
- σ = 5.67x10^{-11} kW/m^2.k^4
- T = Temperature (505.15 K)

Substituting into the above equation yields:

$$SEP = 0.78 \times 5.67 \times 10^{-11} \times 505.15^4 = 2.88 \frac{kW}{m^2}$$

B6. Main Transformer Internal Arcing, Oil Spill, Ignition and Bund Fire

Transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

The transformer is bunded and so in the event of a spill and ignition, the pool fire will have dimensions of the bund. The inputs for the model are provided in **Appendix Table B-2**.

Appendix Table B-2: Main Transformer Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200ºC. Natural ester oils typically have flash points exceeding 330ºC, thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target.

Input	Value	Justification
		The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	45,000 kg	Mass of oil in the transformers
Temperature of pool	20°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	14 m x 13 m	Scenarios to be modelled outlined above this table.
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a
Wind speed	2 m/s	Fire seat enclosed in building and unlikely to be impacted by wind at fire seat.
Wind direction	Any direction	Toward infrastructure
Ambient temperature	20°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	60%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-3.**

Appendix Table B-3: Heat Radiation Impacts from a Transformer Bund Fire

Heat Radiation (KW/m^2)	Distance (m)
35	6
23	8
12.6	10
4.7	14
3.0	17

B7. Power Conversion Unit Transformers, Oil Release, Ignition and Fire

The PCUs contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

It has been assumed that the transformer has bund dimensions of the PCU; hence, if a spill from the transformer was to occur it would fill the base of the bund resulting in a pool fire with the dimensions of the bund. The inputs for the model are provided in **Appendix Table B-4**.

Appendix Table B-4: PCU Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200°C. Natural ester oils typically have flash points exceeding 330°C, thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target. The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	1,065 kg	Mass of oil in the transformers
Temperature of pool	20°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	4 m x 2.6 m	Dimension of PCU enclosure
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a

Input	Value	Justification
Wind speed	2 m/s	Fire seat enclosed in building and unlikely to be impacted by wind at fire seat.
Wind direction	Any direction	Toward BESS units
Ambient temperature	20ºC	Conditions expected to be observed regularly. Also, negligible impact on results.
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	60%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-5**.

Appendix Table B-5: Heat Radiation Impacts from a PCU Fire

Heat Radiation (KW/m^2)	Distance (m)
35	4
23	5
12.6	6
4.7	8
3.0	9

Appendix C

Test Data

Appendix C

Test Report issued under the responsibility of:

TEST REPORT
ANSI/CAN/UL 9540A:2019
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Reference No. ....:	230400325SHA-001
Tested by (name + signature).........:	Chuanhui Xie — Chuanhui Xie
Approved by (name + signature) ....:	Robin Xu — Robin Xu
Total number of pages ....:	36
Date of issue ....:	2023-04-18
Testing Laboratory ....:	Intertek Testing Services Shanghai
Address ....:	Building No.86, 1198 Qinzhou Road (North), Shanghai 200233, China
Testing location/ procedure ....:	Witness testing
Testing location/ address ....:	No. 158, Changbangcun Road, Fengxian District, Shanghai
Applicant's name ....:	Qingdao Lishen New Energy Technology Co., Ltd.
Address ....:	No.6 Minshan Road, Huangdao, Qingdao, Shandong.
Test specification:	
Standard ....:	ANSI/CAN/UL 9540A:2019 (Fourth Edition) + UL CRD's
Test procedure ....:	Module level test (clause 8.1-8.4)
Non-standard test method…… ....:	N/A
Test Report Form No. ....:	ANSI/CAN/UL 9540A_Module
Test Report Form(s) Originator ......:	Intertek
Master TRF ....:	Dated 2022-01

Test item description.......................:	Lithium-ion battery module
Trade Mark.....................................:	Lishen
Manufacturer ....:	Qingdao Lishen New Energy Technology Co., Ltd.
Model/Type reference ....:	ESS-EM21.5B-LP71173207
Ratings ....:	76.8 V, 280 Ah

General disclaimer:

List of attachments:	
Attachment 1 – Photos	
Attachment 2 – Module conditioning (charge/discharge) profiles	
Attachment 3 – Module thermal runaway record	
Attachment 4 – Temperature and voltage profile during thermal runaway	
Attachment 5 – Chemical heat release rate measurement	
Attachment 6 – Gas generation measurement	
Attachment 7 – Smoke release rate measurement	
Attachment 8 – Equipment list	
Test video 220400325-1.mp4 and 220400325-2.mp4 are provided in addition to this test report.	
Summary of testing:	
Thermal runaway Propagation ....:	One cell thermal runaway due external heating, One cell thermal runaway due to thermal runaway propagation.
Peak chemical heat release rate HRR (kW)...........................:	1.62 kW
Peak smoke release rate SRR (m^2/s)....................................:	1.1314 m^2/s
Total smoke release TSR (m^2) ....:	307.19 m^2
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)...:	195.4 L
Module weight loss ....:	2.0 kg
Conclusion:	
Thermal runaway is contained by module design, but cell vent gas is flammable as determined by the cell level test. According to the standard, a unit level testing in accordance with UL 9540A need to be conducted on a unit employing this module.	
Possible test case verdicts:	
- test case does not apply to the test object................:	N/A
- test object was not evaluated for the requirement.....:	N/E
- test object does meet the requirement......................:	Pass (P)
- test object does not meet the requirement ....:	Fail (F)
Testing:	
Date of receipt of test items ....:	2023-04-02
Date(s) of test performaned..:	2023-04-03 to 2023-04-05

General remarks:
"(see Attachment #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.
The tests 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.
List of test equipment must be kept on file and available for review.
Additional test data and/or information is provided in the attachments to this report.
Throughout this report a ☐ comma / ☒ **point** is used as the decimal separator.
Determination of the test results includes consideration of measurement uncertainty from the test equipment and methods.

Product information:

Cell inforamtion

Manufacturer:	Qingdao Lishen New Energy Technology Co., Ltd.
Model name:	LP71173207-280Ah
Chemistry:	$LiFePO_4$
Physical configuration:	Prismatic
Dimension (W*L*H):	(173.8±0.5) mm * (71.45±0.5) mm * (207.15±1.0) mm
Weight:	5410±100 g
Nominal voltage:	3.2 V
Rated capacity:	280 Ah
If the cell compliance with UL 1973:	UL MH64445

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

Test result from cell level 9540A test report

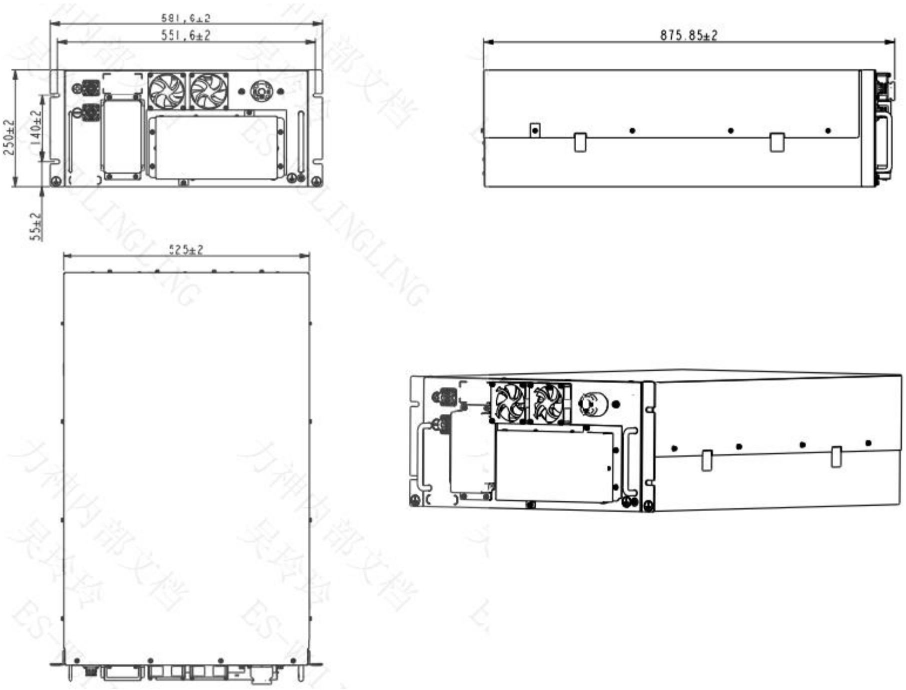
Cell level test report:	Report No. 4790485985 (UL)
Average cell venting temperature:	166 °C
Average cell thermal runaway onset temperature:	232 °C
Gas composition:	

Gas		Measured %
Carbon Monoxide	CO	8.268
Carbon Dioxide	CO2	21.177
Hydrogen	H2	53.408
Methane	CH4	6.962
Acetylene	C2H2	0.311
Ethylene	C2H4	6.101
Ethane	C2H6	1.479
Propadiene (Allene)	C3H4	0.001
Propylene	C3H6	0.489
Propane	C3H8	0.321
-	C4 (Total)	0.467
-	C5 (Total)	0.096
-	C6 (Total)	0.056
1-Heptene	C7H14	0.005
Benzene	C6H6	0.014
Toluene	C7H8	0.002
Dimethyl Carbonate	C3H6O3	0.645
Ethyl Methyl Carbonate	C4H8O3	0.195
Diethyl Carbonate	C5H10O3	0.003
Total	-	100

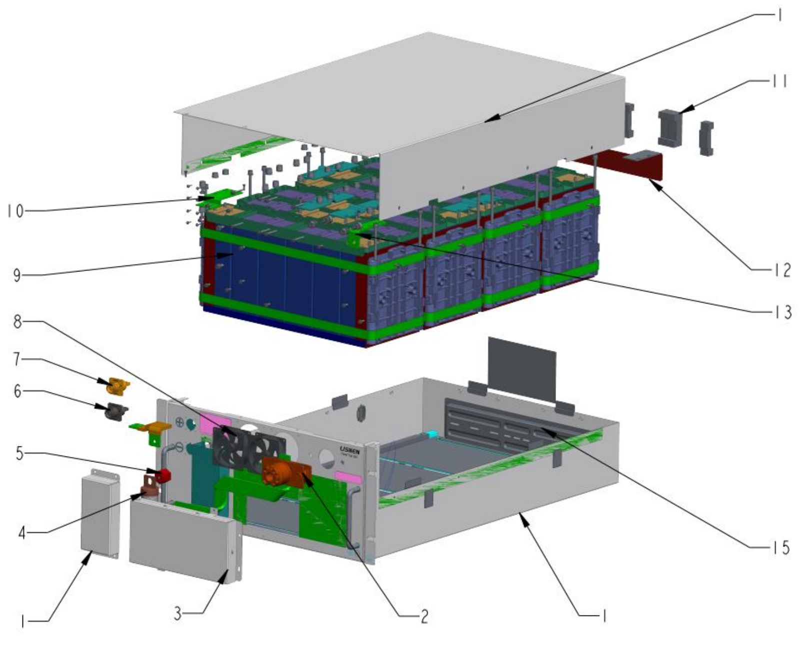
LFL at ambient temperature:	6.35%
LFL cell venting temperature:	5.35%
Burning velocity:	86.4 cm/s
P_{max}:	104.8 psig

Module information	
Manufacturer...:	Qingdao Lishen New Energy Technology Co., Ltd.
Address...:	No.6 Minshan Road, Huangdao, Qingdao, Shandong.
Model name ....:	ESS-EM21.5B-LP71173207
Physical configuration	
Enclosure material ....:	Metal
Dimension..:	875.85 mm*525mm*250mm (±2mm)
Weight..:	165±3 kg
Cells in series/parallel: ....:	24S1P
Total number of cells: ....:	24 cells
Cooling method...:	Electric fan
Separation between cells ....:	Aerogel used between cell blocks (each cell block has 2 cells in parallel), see module layout of the module contents Aerogel thickness: 2 mm
Electrical rating	
Rated capacity ....:	280 Ah
Rated energy ....:	21504 Wh
Nominal voltage ....:	76.8 V
Standard charge method	
Charge current...:	140 A
End of charge voltage..:	87.6 V (Cell end of charge voltage 3.65V)
Standard discharge method	
Discharge current ....:	140 A
End of discharge voltage ....:	60.0 V (Cell end of discharge voltage 2.50V)
If the module compliance with UL 1973 ....:	Certificate is ongoing.

Diagram of module with overall dimension

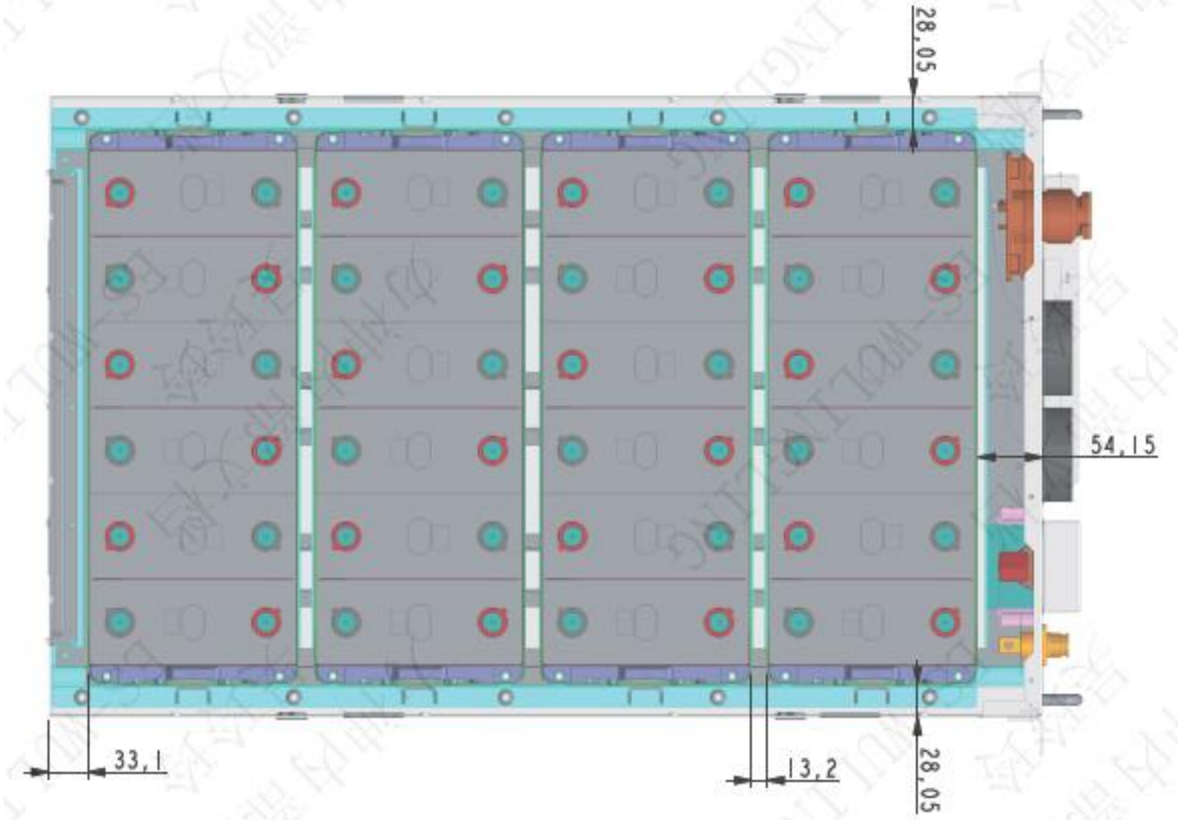


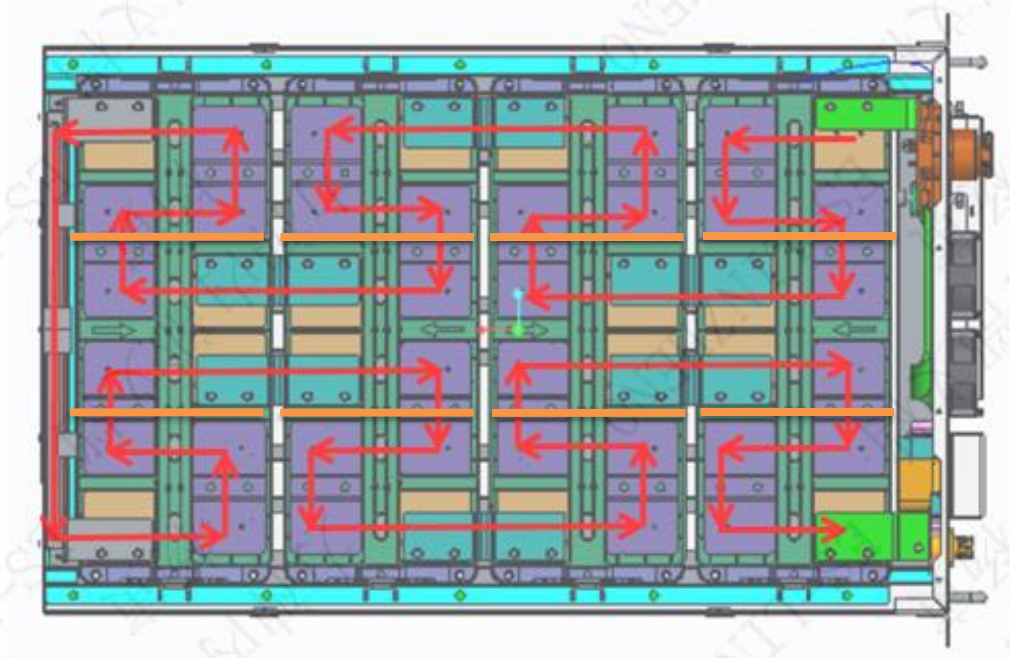
Contents (main components) of the module



Number	Name	Quantity	Unit
15	Wind shield	1	EA
14	Insulating sheet	1	EA
13	Negative busbar	1	EA
12	Bus bar	1	EA
11	Foam	4	EA
10	Front copper bar	1	EA
9	Cellblock	4	EA
8	Fan	2	EA
7	Positive pole	1	EA
6	Negative pole	1	EA
5	Electrical insulator	2	EA
4	Fuse	1	EA
3	BMU	1	EA
2	MSD	1	EA
1	Box	1	SET

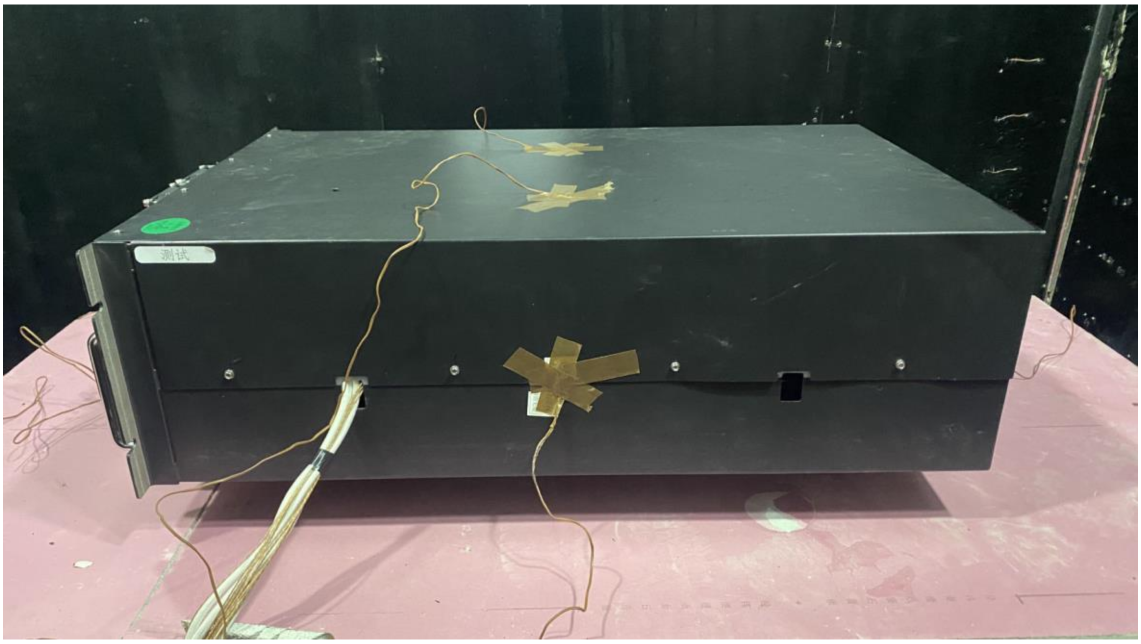
Layout of the module contents





Location of aerogel

Photo of the module



ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5	**Constrution – General**		
5.1	**Cell**		**--**
5.1.1	The cell info associated with the BESS includes:		Pass
	• cell chemistry (e.g. NMC, LFP);	LFP	Pass
	• the physical format of the cell;	Prismatic	Pass
	• the cell electrical rating in capacity and nominal voltage;	280Ah,3.2V	Pass
	• the overall dimensions of the cell, and weight.		Pass
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	UL MH64445	Pass
5.1.3	Further details are included in the cell level test report.		Pass
5.2	**Module**		**--**
5.2.1	The modules info associated with the BESS includes:		Pass
	• the generic enclosure material;	Metal	Pass
	• the general layout of the module contents;		Pass
	• the electrical configuration of the cells in the modules and the modules in the BESS.	24S1P	Pass
5.2.2	The modules associated with the BESS comply with UL 1973 or not.	Certificate is ongoing	Pass
5.2.3	Further details are included in the module level test report.	Refer to 8.3	Pass
5.3	**Battery energy storage system unit**		**--**
5.3.1	The BESS unit info includes:		N/A
	• the units comply with UL 9540 or not;		N/A
	• the manufacturer and model number;		N/A
	• electrical ratings;		N/A
	• energy capacity of all BESS.		N/A
5.3.2	For BESS units, which UL 9540 compliance cannot be determined, to include:		N/A
	• the number of modules in the BESS;		N/A
	• electrical configuration of the module;		N/A
	• physical layout of the modules in the BESS;		N/A
	• battery management system (BMS); and		N/A
	• other major components of the BESS;		N/A
	• the BESS enclosure overall dimensions and generic material;		N/A
	• battery system(s) may be tested as representative of the BESS;		N/A
	• battery system complies with UL 1973 or not.		N/A
5.3.3	Any fire detection and suppression systems that are an integral part of the BESS.		N/A
5.3.4	Further details included in the unit level and if applicable, installation level test reports.		N/A
5.4	**Flow Batteries**		**--**
5.4.1	For flow batteries, to include the following info:		N/A

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	• the chemistry;		N/A
	• a generic description of the electrolyte (s);		N/A
	• the overall dimensions of the individual stack;		N/A
	• the electrical rating in capacity and nominal voltage of the cell stack.		N/A
	And the Information of the complete flow battery system:		N/A
	• the manufacturer's name and model number of the system;		N/A
	• the electrical rating in volts and rated storage capacity in Ah or Wh;		N/A
	• the number of cells and stacks in the system;		N/A
	• the maximum volume of electrolyte(s) for the system.		N/A
5.4.2	The flow battery system complies with UL 1973 or not.		N/A
5.4.3	Further details included in the flow battery thermal runaway determination level test report.		N/A
6	**Performance – General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices, which may result in various kind of hazards.		Pass
6.2	At the conclusion of testing, samples discharged in accordance with the manufacturer' specifications.		Pass
	All samples disposed of in accordance with local regulations.		Pass
8	**Moudle Level**		
8.1	**Sample**		**--**
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a min. of 2 cycles, to verify that the module is functional.	See attachment 2	Pass
8.1.2	The module shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test.		Pass
8.1.3	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	BMS protections disabled during the testing	Pass
8.2	**Test method**		**--**
8.2.1	Ambient indoor laboratory conditions 25±5°C and 50±25% RH at the initiation of the test.	See attachment 3	Pass
8.2.2	The test conducted under a smoke collection hood sized appropriately to collect the gasses generated.		Pass
8.2.3	The weight of the module shall be recorded before and after testing is completed.	See attachment 3	Pass
8.2.4	The number of cells within the module that are forced into thermal runaway.	1	Pass
8.2.5	The methodology used for initiating thermal runaway for cells are used to initiate thermal runaway within the module.	See attachment 3	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
8.2.6	Occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway.	See attachment 4	Pass
8.2.7	The module shall be placed on top of a noncombustible horizontal surface.	Module orientation as intended for final installation	Pass
8.2.8	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry system.	See attachment 5	Pass
8.2.9	The chemical heat release rate shall be measured for the duration of the test.	See attachment 5	Pass
8.2.10	The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.		Pass
8.2.11	Chemical heat release rate is calculate at each of the flows as follows: $HRR_t = \left[E \times \varphi - (E_{CO} - E) \times \frac{1-\varphi}{2} \times \frac{X_{CO}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1 + \varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^{\circ}_{H_2O}) \times X^{\circ}_{O_2}$	See attachment 5	Pass
8.2.12	(Corrected by UL CRD-20200520) The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor	Three different kind of sensors were used. H_2 was not detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor. The value in attachment 6 was measured by electrochemistry sensor.	Pass
8.2.13	(Corrected by UL CRD-20200520) The hydrocarbon components of the vent gas composition may additionally be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or an equivalent gas analyzer, Velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.	See attachment 6	Pass
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter shall be measured using a white light source and photo detector for the duration of the test.	Light transmission is integerated into the testing system	Pass
8.2.15	Smoke release rate shall be calculated as follows: $SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_o}{I}\right)$	See attachment 7	Pass
8.3	**Module level test report**		--
8.3.1	The report on module level testing shall include the following:		Pass
	a) Module manufacturer name and model number (and whether UL 1973 compliant);	See module information.	Pass
	b) Number of cells in module;	24	Pass
	c) Module configuration with cells in series and parallel;	24S1P See module information	Pass
	d) Module construction features per 5.2;	See module information	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	e) Module voltage corresponding to the tested SOC	See Attachment 3	Pass
	f) Thermal runaway initiation method was used including number and locations of cells for initiating thermal runaway;	See Attachment 3	Pass
	g) Heat release rate versus time data;	See Attachment 5	Pass
	h) Flammable gas generation and composition data;	See Attachment 6	Pass
	i) Peak smoke release rate and total smoke release data.	See Attachment 7	Pass
	j) Observation(s) of flying debris or explosive discharge of gases;	See Attachment 4	Pass
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment 4	Pass
	l) Identification/location of cells(s) that exhibited thermal runaway within the module;	See Attachment 4	Pass
	m) Locations and visual estimations of flame extension and duration from the module shall be documented;	See Attachment 4	Pass
	n) Module weight loss based on measurements per 8.2.3;	2.0 kg	Pass
	o) Video of the test.	230400325-1.mp4 and 230400325-2.mp4 are provided	Pass

Attachment 1 Photos

Before test

During test
 Cell vent observed
 Thermal runaway observed

After test

Attachment 2 Module Conditioning (charge/discharge) profiles

The module was conditioned, prior to testing, through charge and discharge cycles for 2 cycles using a manufacturer specified methodology to verify that the module is functional.

As manufacturer specified, the module was charged with 140A current to module end charge voltage 87.6 V(cell end of charge voltage 3.65V), then keep the module stabilized for 30 minutes. After being stabilized, the module was discharged with 140A current to module end discharge voltage 60.0 V (cell end of discharge voltage 2.5V), then keep the module stabilized for 30 minutes.

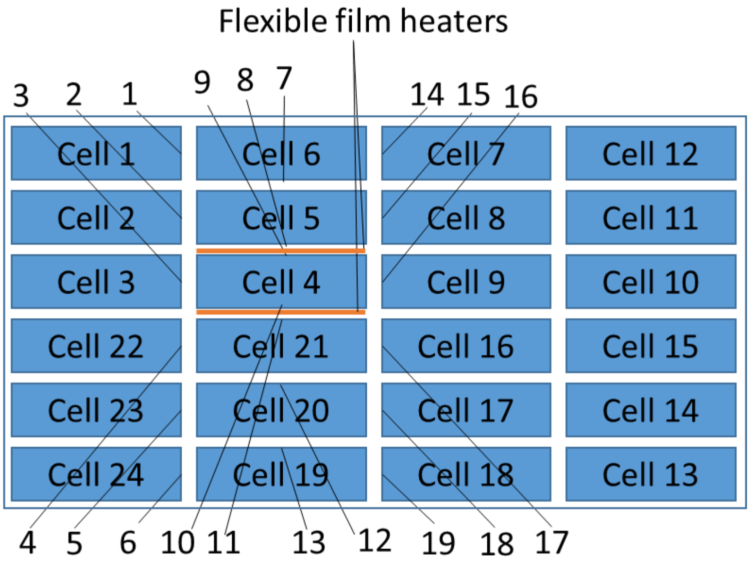
After repeat the cycle above twice and then module was fully charged with 140A current to module end charge voltage 87.6 V(cell end of charge voltage 3.65V), and before testing, the module was stabilized for about 7 hours. During conditioning the ambient temperature was maintained in 25 ±5°C and 50 ±25% RH.

Module charge and discharge voltage/current profiles

Attachment 3 Module thermal runaway record

External heating method was used to initiate thermal runaway in the module. 2 flexible film heaters, rated 220VAC/600W, sized 173*205mm, were pasted on big sides of cell 4.

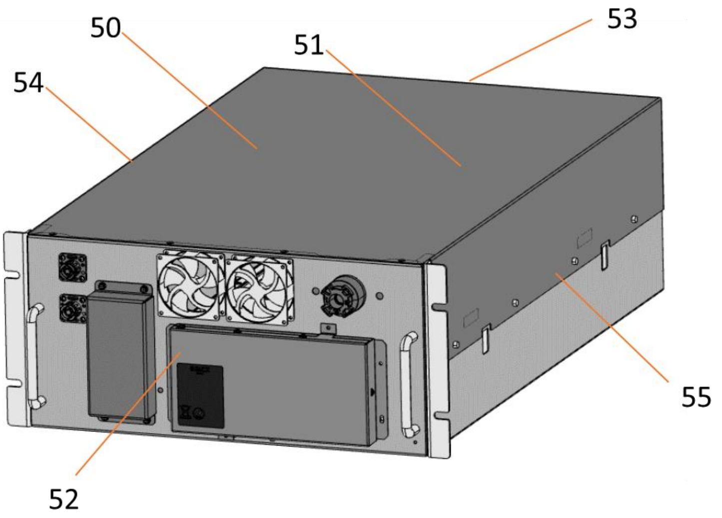
To monitor the cells temperature inside the module, 19 thermocouples, Type K, were used inside the module. See below figure and table for detail location of the film heaters and thermocouples.



Location of flexible film heaters and thermocouples inside the module

Thermocouple No.	Location
1-3	Narrow side of cell 1-cell 3, facing cell 6-cell 4
4-6	Narrow side of cell 22-cell 24, facing cell 21-cell 19
7	Big side of cell 6, facing cell 5
8	Big side of cell 5, facing cell 4
9	Big side of cell 4, facing cell 5, between heater and cell
10	Big side of cell 4, facing cell 21, between heater and cell
11-13	Big side of cell 21-cell 19, facing cell 4
14-16	Narrow side of cell 7-cell 9, facing cell 6-cell 4
17-19	Narrow side of cell 16-cell 18, facing cell 21-cell 19

Additional 6 thermocouples, Type K, were located on the surface of module. See below table for detailed location of thermocouple.



location of thermocouples on module enclosure

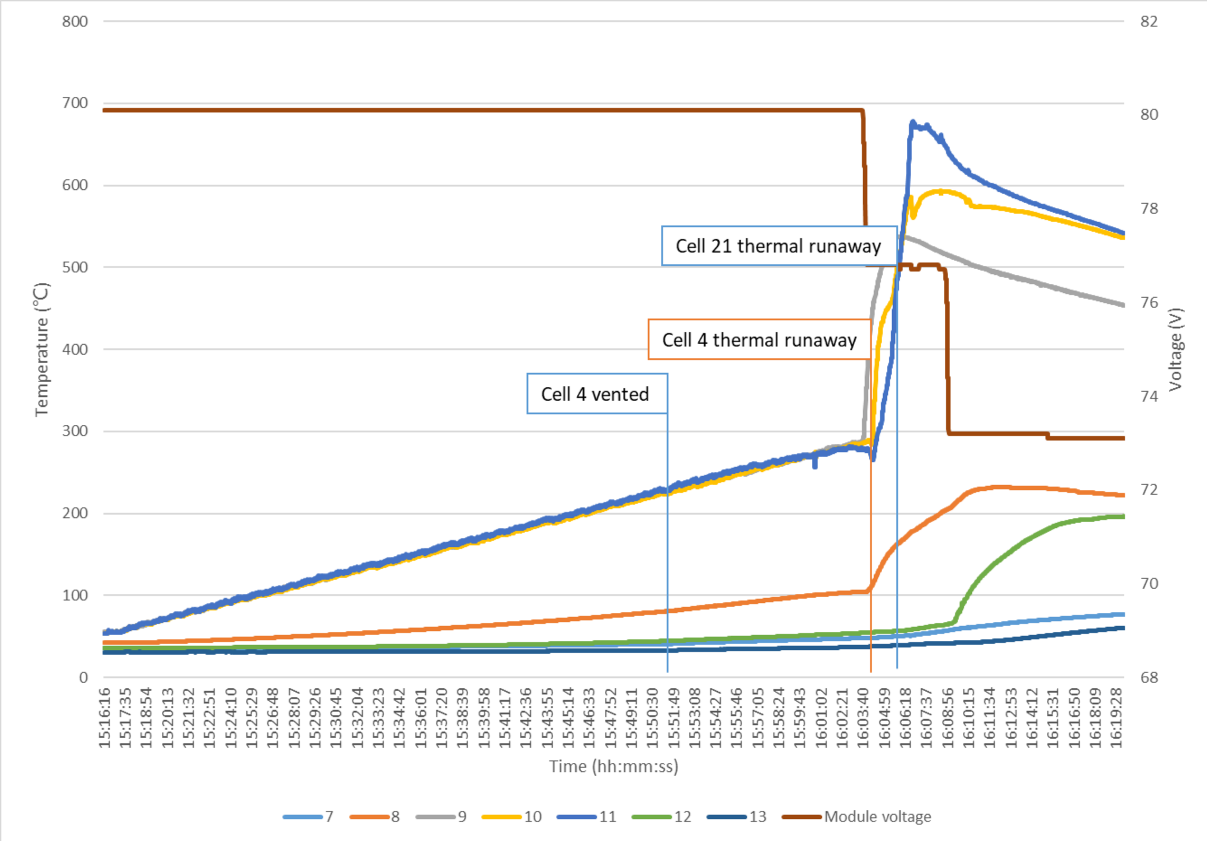
Thermocouple No.	Location
50	Enclosure top surface
51	Enclosure top surface
52	Centre of enclosure front surface
53	Centre of enclosure back surface
54	Centre of enclosure left surface
55	Centre of enclosure right surface

Cell 4 was heated as the target cell at a rate of 4°C-7°C per minute until thermal runaway was occurred. Below table summarizes the details:

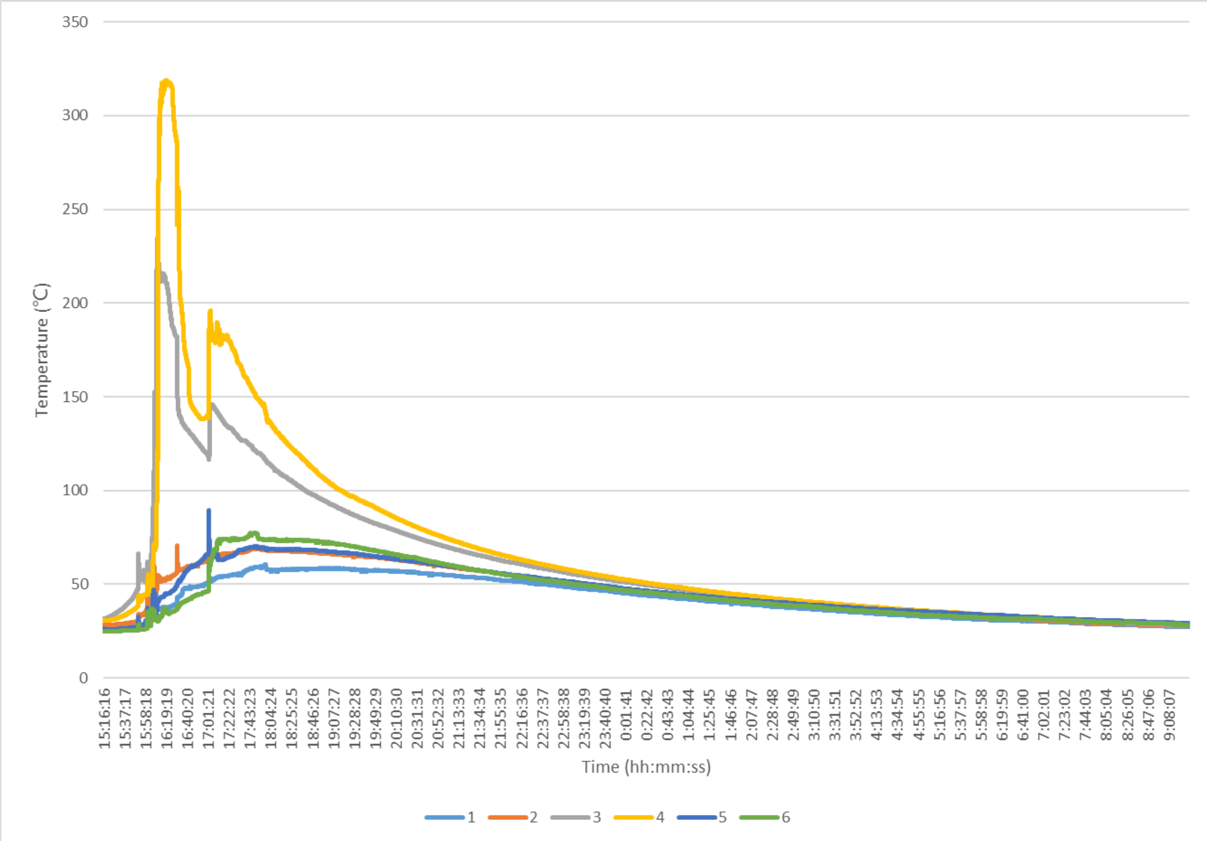
Ambient conditions at the initiation of the test:	21.6°C 52.9%RH			
Module voltage before test:	80.1 V			
Module voltage after test:	73.1 V			
Module weight before test	165.0 kg (with test auxiliary material)			
Time when test was initiated:	2023.04.04 15:00			
Observations during test:	1st vented	15:51	1st thermal runaway	16:03
	2nd vented	16:00	2nd thermal runaway	16:05
	3rd vented	16:30	3rd thermal runaway	Not observed
	4th vented	17:02		
	5th vented	Not observed		
	No flying debris or explosive discharge of gases. No sparks, electrical arcs, or other electrical events. No external flaming was observed			
Post-test evaluation:	Cell 4 went to thermal runaway due to external heating. Cell 21 vented and went to thermal runaway due to thermal runaway propagation. Cell 5, cell 20 vented and not went thermal runaway.			
Module weight after test	163.0 kg (with test auxiliary material)			
Module weight loss	2.0 kg			

Attachment 4 Temperature and voltage profile during test

Temperature describing cell to cell propagation and module voltage are show in below figure



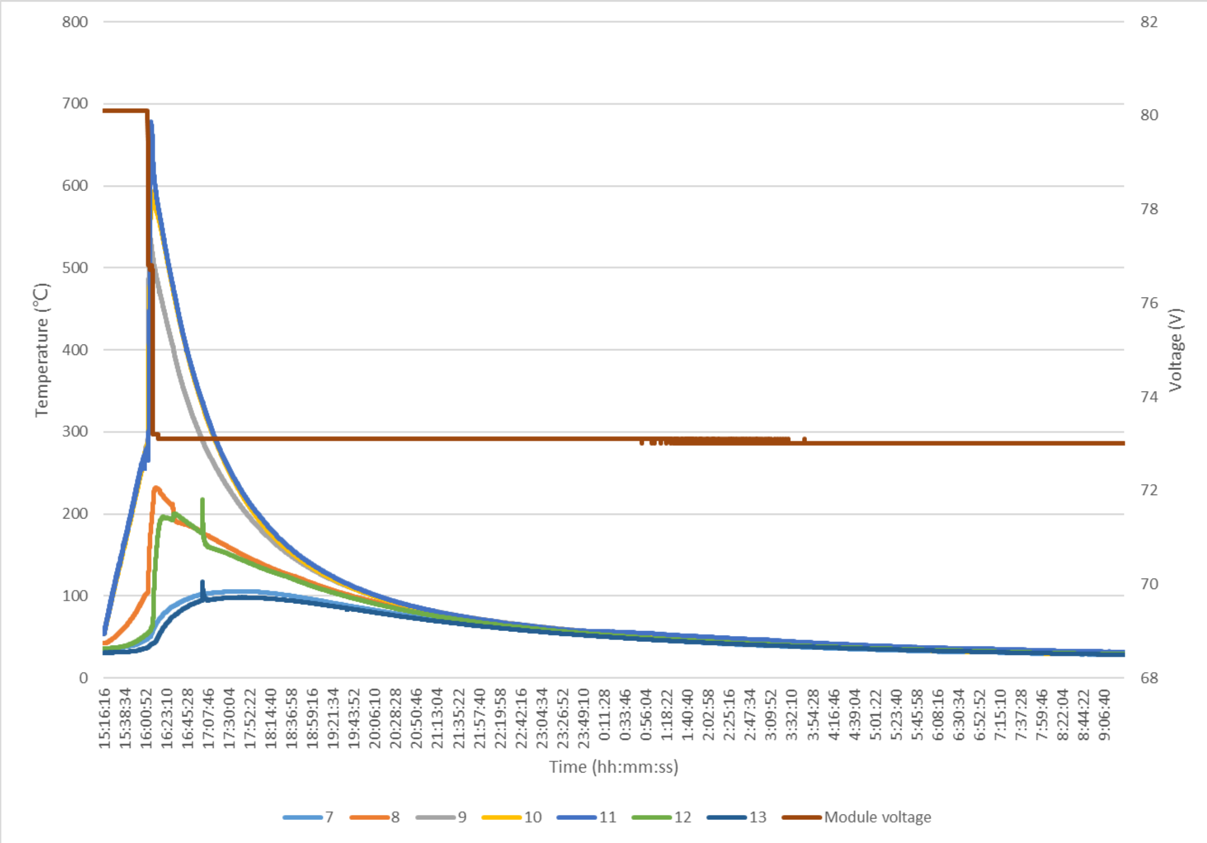
Measured temperature inside the module during the test is shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
1	Narrow side of cell 1, facing cell 6	60.6
2	Narrow side of cell 2, facing cell 5	70.8
3	Narrow side of cell 3, facing cell 4	234.8
4	Narrow side of cell 22, facing cell 21	319
5	Narrow side of cell 23, facing cell 20	89.7
6	Narrow side of cell 24, facing cell 19	77.5

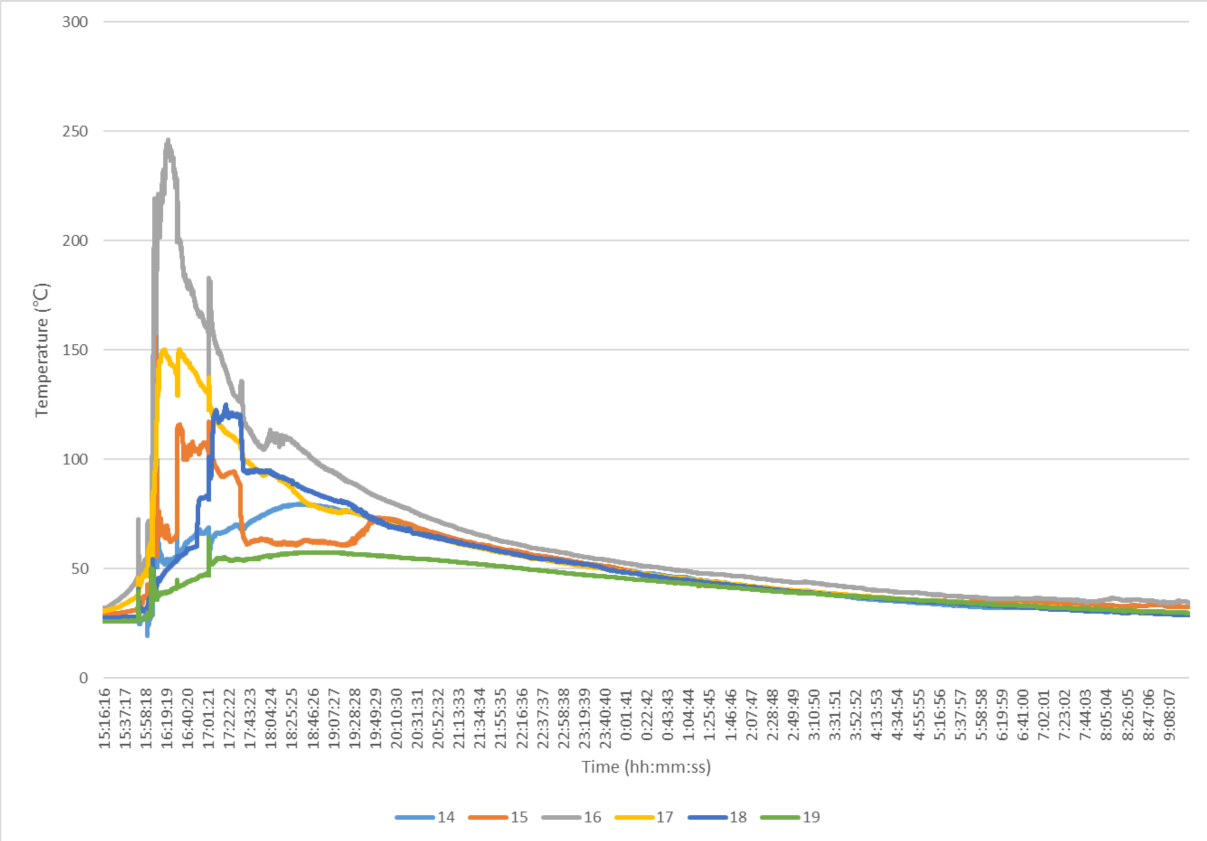
Measured temperature inside the module and module voltage during the test are shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
7	Big side of cell 6, facing cell 5	105.7
8	Big side of cell 5, facing cell 4	231.8
9	Big side of cell 4, facing cell 5, between heater and cell	537.7
10	Big side of cell 4, facing cell 21, between heater and cell	593.0
11	Big side of cell 21, facing cell 4	678.4
12	Big side of cell 20, facing cell 4	217.8
13	Big side of cell 19, facing cell 4	117.3

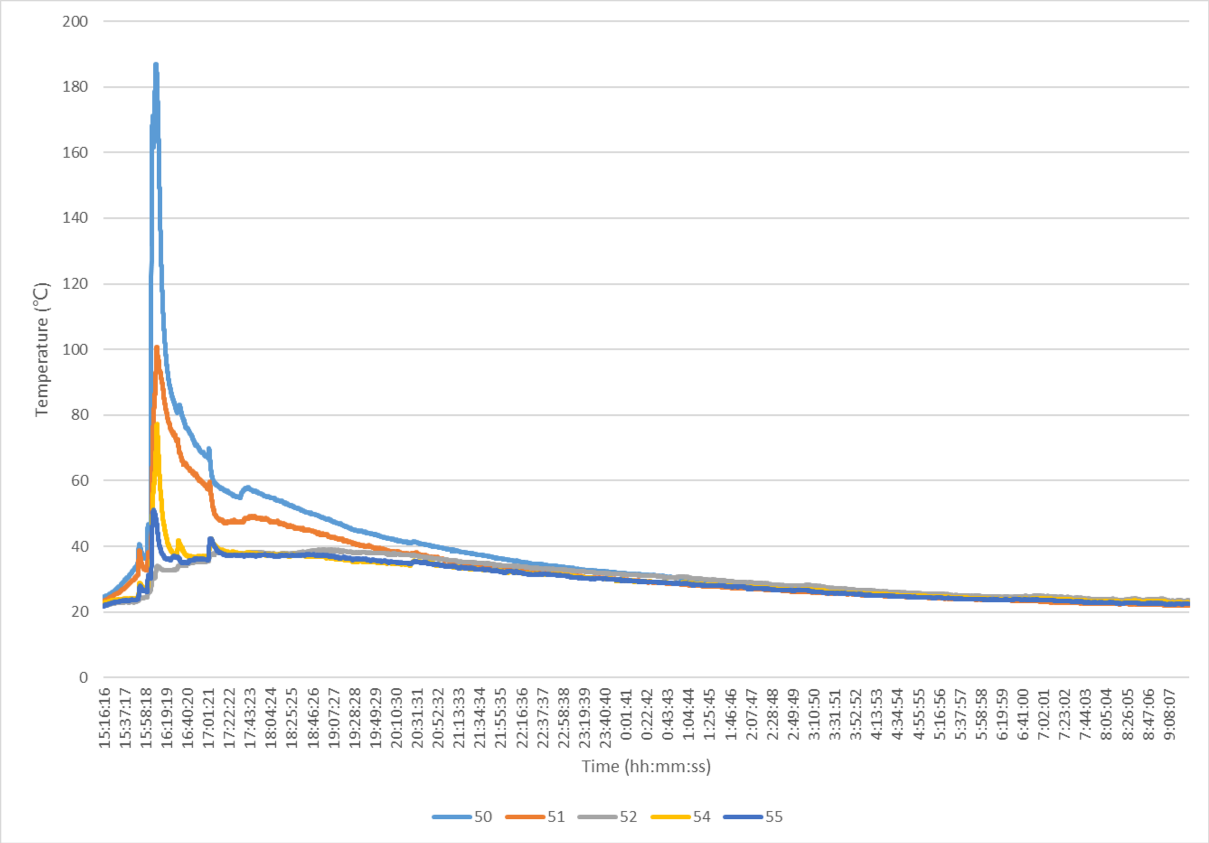
Measured temperature inside the module during the test is shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
14	Narrow side of cell 7, facing cell 6	157.7
15	Narrow side of cell 8, facing cell 5	159.9
16	Narrow side of cell 9, facing cell 4	246.0
17	Narrow side of cell 16, facing cell 21	150.4
18	Narrow side of cell 17, facing cell 20	125.0
19	Narrow side of cell 18, facing cell 19	64.1

The module enclosure temperature during the test is shown in below figure. Thermocouple No. 53 was abnormal during the test and hence not shown in below figure.



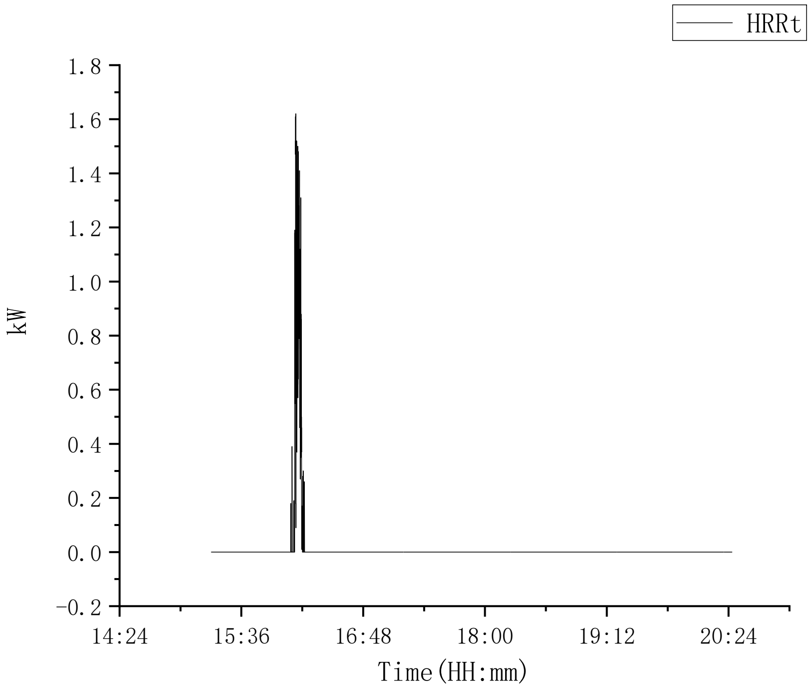
Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
50	Enclosure top surface	187
51	Enclosure top surface	100.6
52	Centre of enclosure front surface	39.1
53	Centre of enclosure back surface	--
54	Centre of enclosure left surface	77.2
55	Centre of enclosure right surface	187

Attachment 5 Chemical heat release rate measurement

The chemical heat release rate was measured by a measurement system consisting of a paramagnetic oxygen analyser, non-dispersive infrared carbon dioxide and carbon monoxide analyser, velocity probe, and a Type K thermocouple. The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.

Measured peak chemical heat release rate HRR=1.62 kW



HRR Curve

Attachment 6 Gas generation measurement

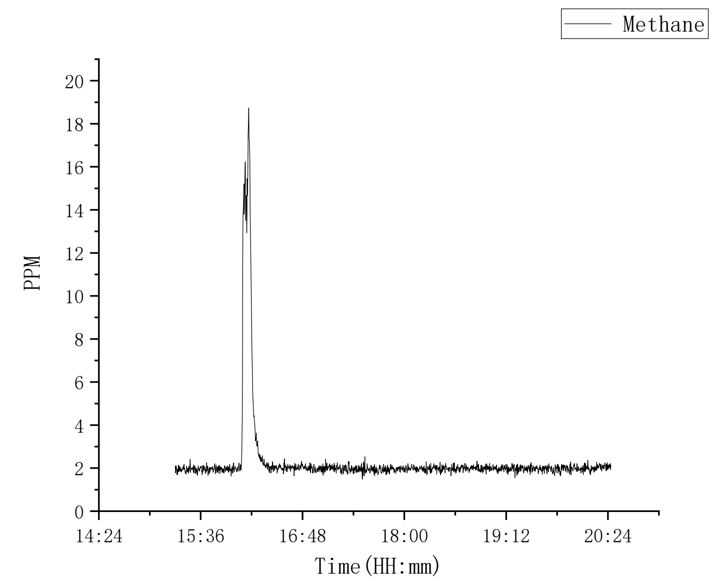
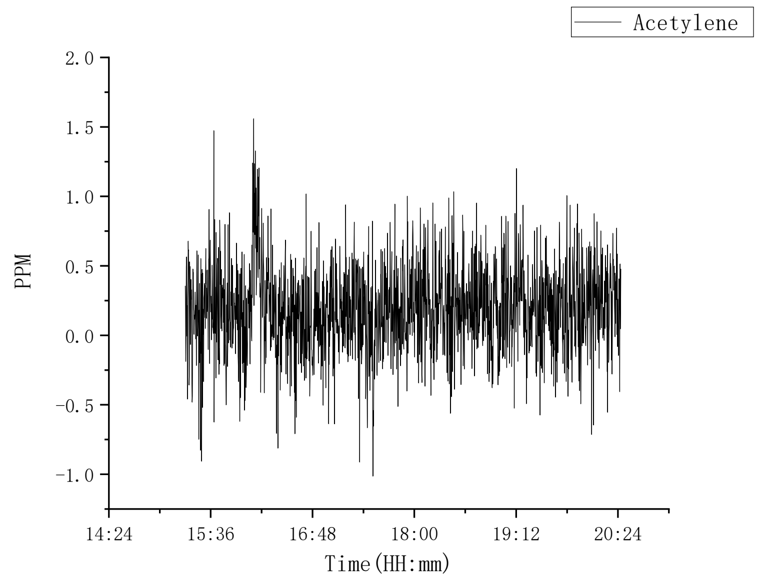
Vent gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 0.5 cm^{-1} and a path length of 3 m within the calorimeter's exhaust duct. And the composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

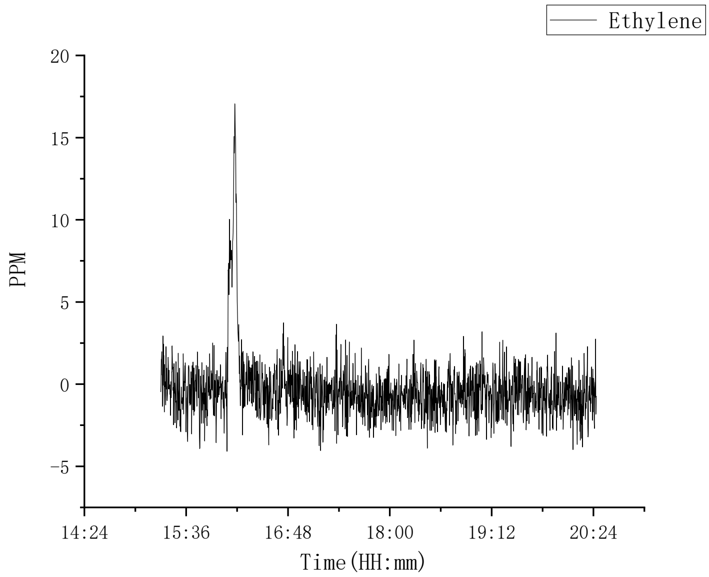
The hydrocarbon content of the vent gas was measured using flame ionization detection.
The hydrogen content was measured with a palladium-nickel thin-film solid state sensor, a heat conduction sensor and an electrochemistry sensor. The hydrogen was not detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor. Due to other gas content has the influence of cross sensitivity for hydrogen content, the hydrogen volume measured by electrochemical sensor is for reference only.

The gas composition and volume are shown in below table

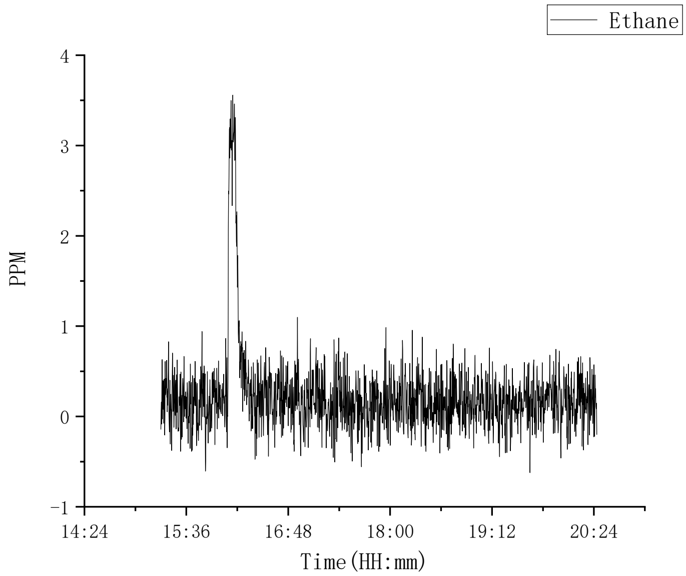
Gas type	Gas components		Volume (L)
Hydrocarbon species	Methane	CH_4	12.7
	Acetylene	C_2H_2	0.5
	Ethylene	C_2H_4	9.9
	Ethane	C_2H_6	3.2
	Propylene	C_3H_6	21.1
	Propane	C_3H_8	5.6
Hydrogen halide species	Hydrogen Fluoride	HF	11.2
Nitrogen containing species	Nitrogen Monoxide	NO	5.4
Other species	Carbon Monoxide	CO	12.3
	Carbon Dioxide	CO_2	47.0
	Hydrogen (Palladium nickel thin film solid state sensor)	H_2	0
	Hydrogen (TCD sensor)	H_2	0
	Hydrogen (Electrochemical sensor)	H_2	174.0
	Dimethyl carbonate	$C_5H_{10}O_3$	131.3
	Ethyl methyl carbonate	$C_4H_8O_3$	112.7
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)			195.4

Concentration of different gas components according to gas species classification was displayed as following graphs

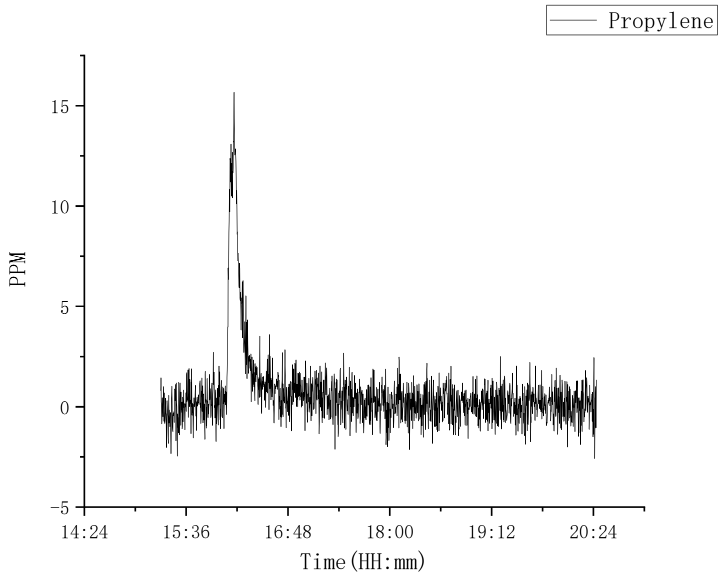
Hydrocarbon species
 Concentration of Methane (CH_4)
 Concentration of Acetylene (C_2H_2)



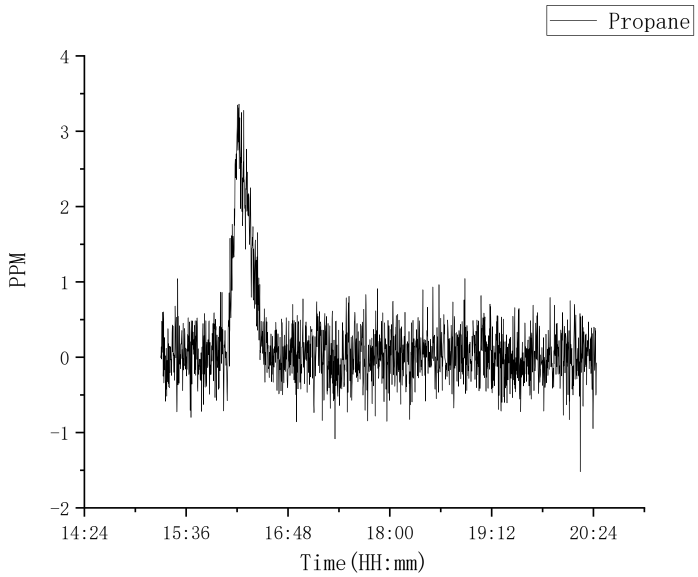
Concentration of Ethylene (C_2H_4)



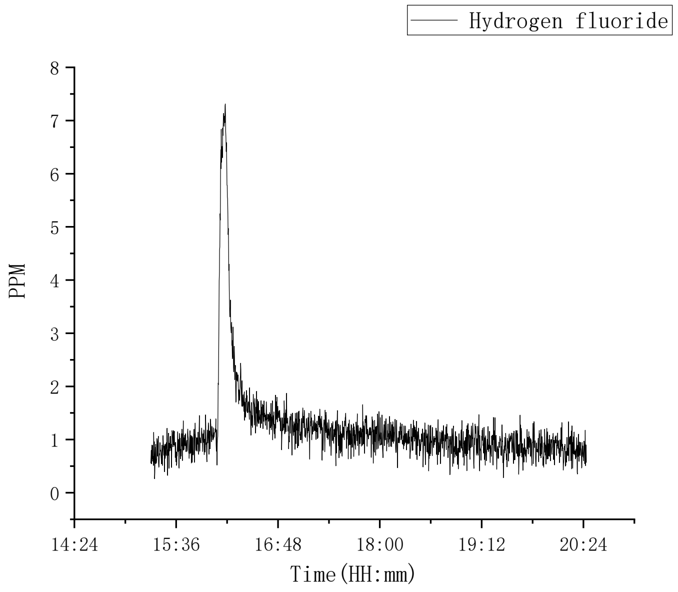
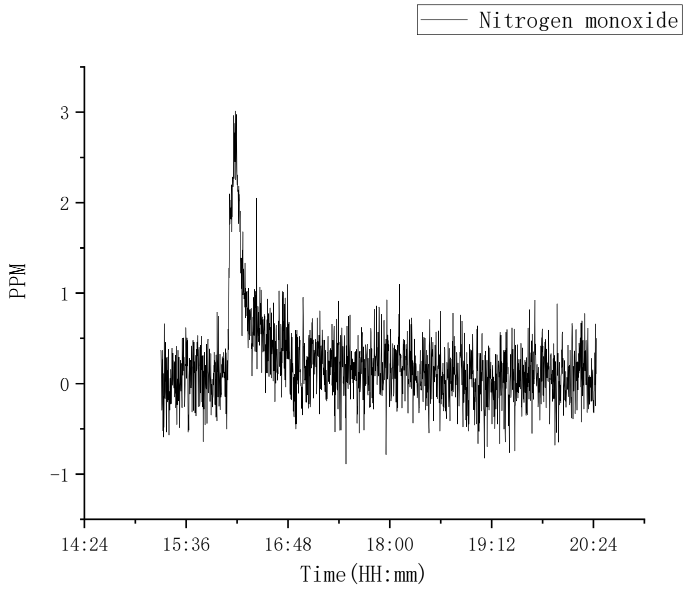
Concentration of Ethane (C_2H_6)



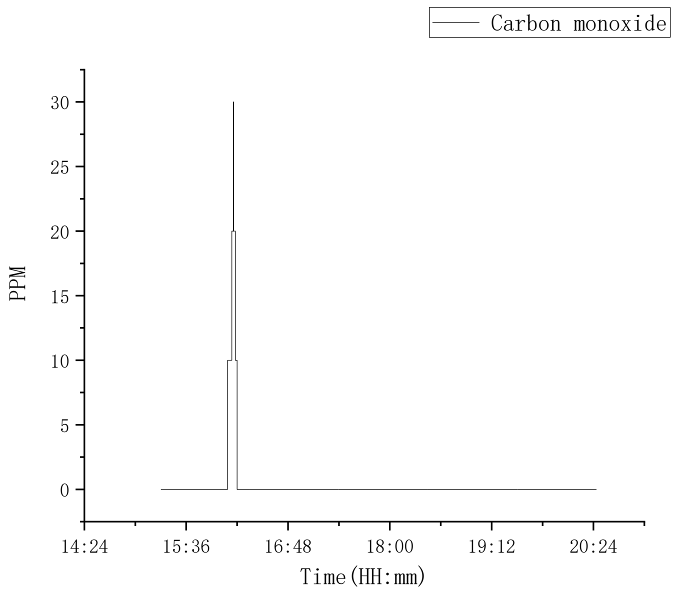
Concentration of Propylene (C_3H_6)



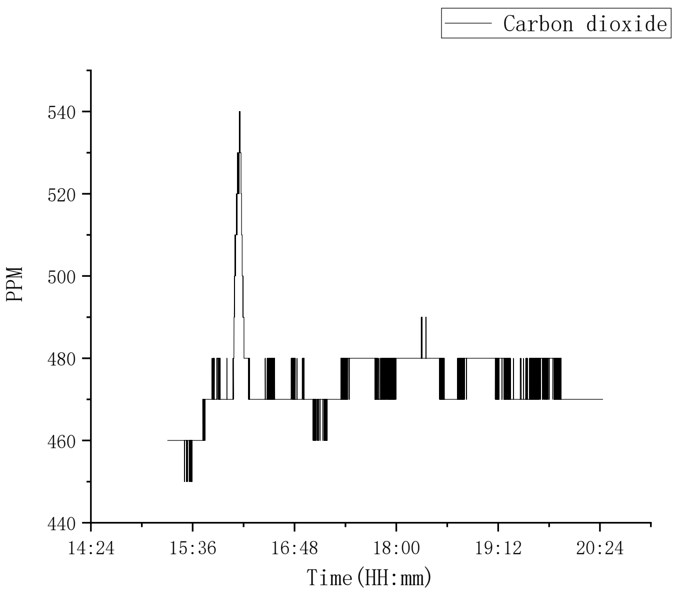
Concentration of Propane (C_3H_8)

Hydrogen halide species
 Concentration of Hydrogen Fluoride (HF)
Nitrogen containing species
 Concentration of Nitrogen Monoxide (NO)

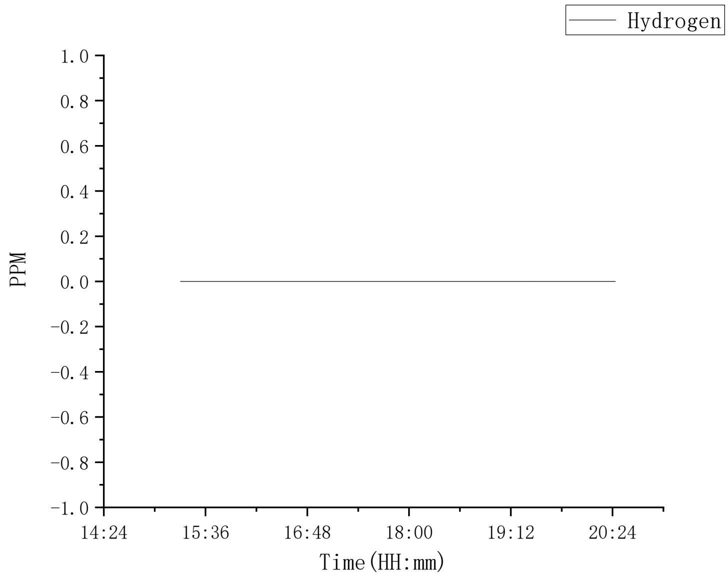
Other species



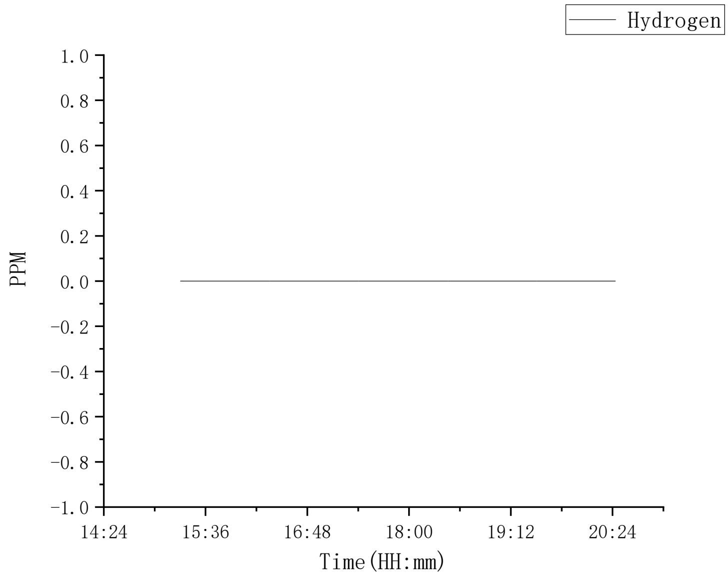
Concentration of Carbon Monoxide (CO)



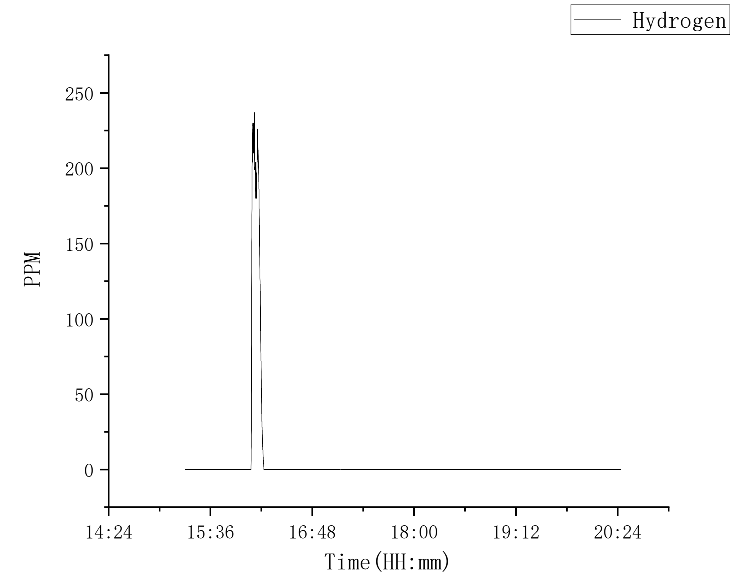
Concentration of Carbon Dioxide (CO_2)



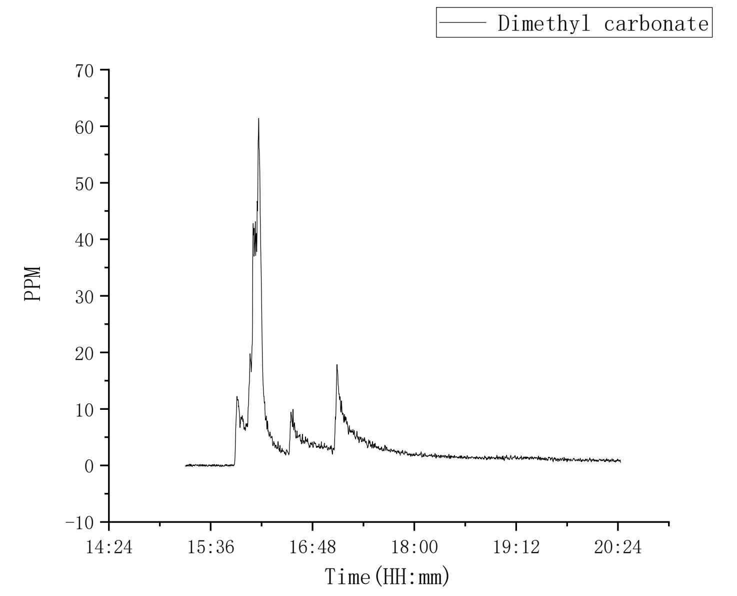
Concentration of Hydrogen (H_2) (Test by Palladium nickel thin film solid state sensor)



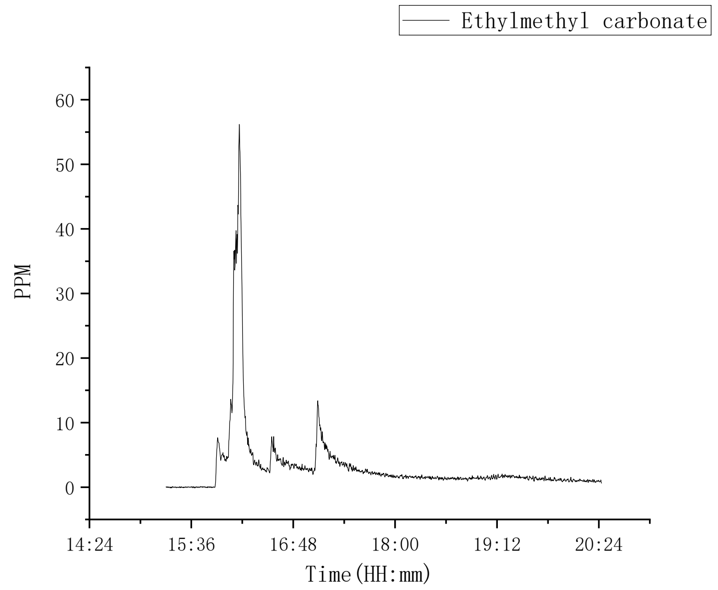
Concentration of Hydrogen (H_2) (Tested by TCD sensor)



Concentration of Hydrogen (H_2) (Tested by electrochemical sensor)

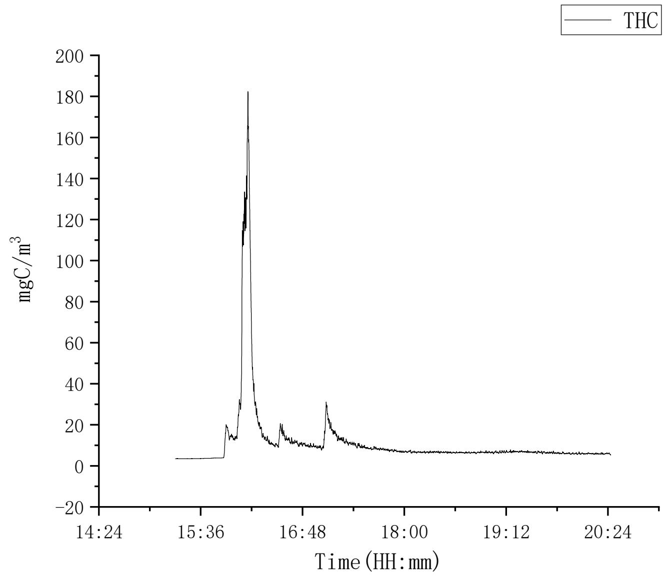


Concentration of Dimethyl carbonate ($C_5H_{10}O_3$)



Concentration of Ethyl methyl carbonate ($C_4H_8O_3$)

Total Hydrocarbons (measured by FID)



Concentration of total hydrocarbons (measured by FID)

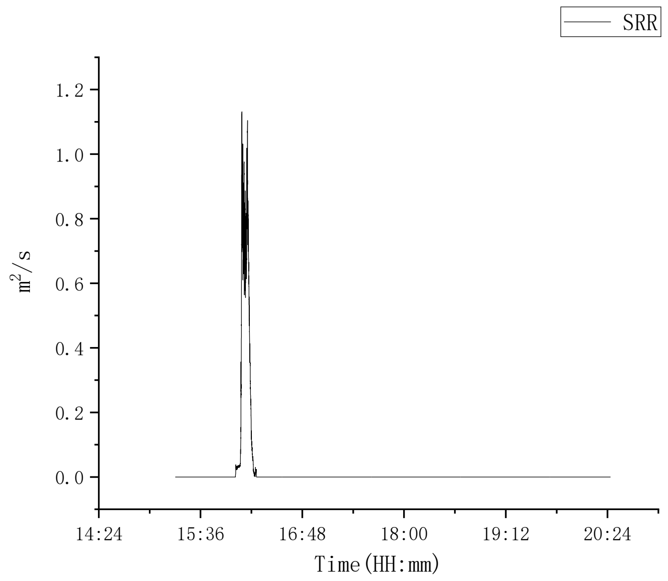
Attachment 7 Smoke release rate measurement

Smoke release rate shall be calculated as follows:

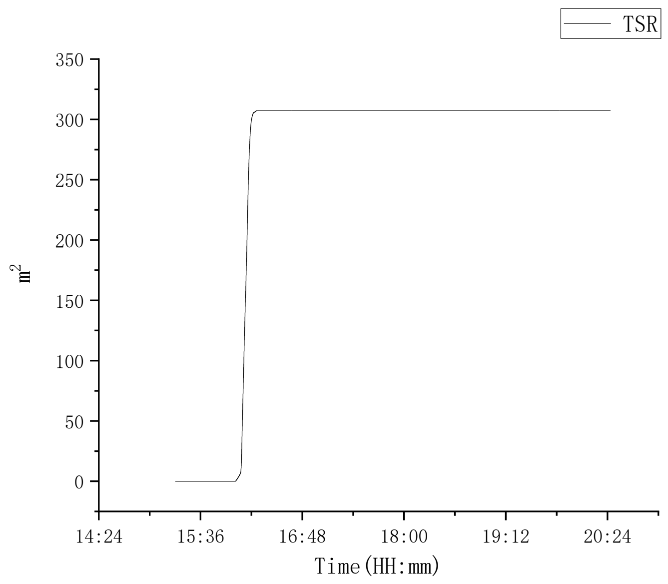
$$SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_o}{I}\right)$$

Where:
SRR = Smoke release rate (m^2/s)
V = Volumetric exhaust duct flow rate (m^3/s)
D = duct diameter (m)
Io = Light transmission signal of clear (pre-test) beam (V)
I = Light transmission signal during test (V)

Measured peak smoke release rate SRR: 1.1314 m^2/s
Measured total smoke release rate TSR: 307.19 m^2



SRR curve



TSR curve

Attachment 8 Equipment list

No.	Equipment		Model	Rating	Inventory No.	Last Cal. date
1	Ambient monitor		WSB-2-H1	0-40°C 10-90%RH	S-044	2023.01.03
2	Digital multi-meter		FLUKE101	0-600V	S-038	2022.02.23
3	Tape		1000mm 5000mm	0-1000mm 0-5000mm	S-040 S-042	2023.03.14 2023.03.14
4	Electronic scale		TCS-500	0-500kg	S-039	2023.02.23
5	Charge /discharge equipment		MRTS-DC-3869-250	800V, 600A	0221-055	2022.08.10
6	Heating control equipment		DTB4824	0-1000°C	S-046-2	2022.07.19
7	Data acquisition equipment		ADAM-4117 ADAM-4118 MT4W DTM	0-10V 0-1000°C 0-100V 0-1000°C	S-028-1 S-028-2 S-030-5~8 S-029	2022.08.09 2022.08.09 2022.08.09 2022.08.09
8	Oxygen consumption calorimeter measurement system	Paramagnetic oxygen analyzer	ABB AO2020	O2：0-21% CO2:0-10% CO:0-1%	S-062-5~7	2022.08.11
8	Oxygen consumption calorimeter measurement system	CO and CO2 sensor	ABB AO2020	O2：0-21% CO2:0-10% CO:0-1%	S-062-5~7	2022.08.11
8	Oxygen consumption calorimeter measurement system	Micro-differential pressure transmitter	DP101MD	-100~100Pa	S-024-4	2023.02.23
8	Oxygen consumption calorimeter measurement system	Thermopile	TT I 20-CAXL-I I 6U-10-SPW-M	0-1000°C	S-028-5~7	2023.02.26
8	Oxygen consumption calorimeter measurement system	Light filter	——	25%, 50%, 75%	S-024-6 S-024-7 S-024-8	2023.03.07
8	Oxygen consumption calorimeter measurement system	Gas mass flowmeter	Sevenstar D07-60G	0-8g/s	S-024-9	2023.03.29
9	Palladium-nickel thin-film solid state sensor		710B Model5000	1000ppm-100% 0-4%	S-023-5 S-023-2	2023.03.01
10	Hydrogen sensor (TCD)		ABB AO2020	0-4%	S-62~8	2023.03.01
11	Electrochemical hydrogen sensors		$H_2$40000 $H_2$1000	0-4% 0-0.1%	S-023-3~4	2023.03.01
12	Fourier-Transform Infrared Spectrometer		MG6000	0.01ppm-100%	S-019	2023.03.01
13	Flame Ionization Detector		ABB AO2020	0-30000ppm	S-062~10	2023.08.11

------------------------------------- End of test report --------------------------------------

Appendix D

SAFT Intensium Shift + Safety Manual and Certificates

Appendix D

saft	**Energy Storage Solution**		Page : 1 / 24
Nombre / *Number* : **0000140626**	Version : **A.9**	Etat / *State* : **Released**	Date : **June 28, 2023**
Titre / *Title*:	**Emergency_operational_guide_for_I-SHIFT**		

Projet *Project* :	**ALL**	**Produit** *Product* :	**I-SHIFT**
Sujet *Subject* :	The goal of these documents is to present the procedure to follow in case of emergency into the Battery Container System This procedure is applicable to the I-SHIFT generical product.		

	Nom *Name*	**Fonction** *Function*
Rédaction *Writing*	**VERMEULEN Pierre**	HSE Manager
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Classification		**Restricted**

Signature électronique
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Toutes les personnes citées ci-dessus ont signé numériquement le document via le logiciel WINDCHILL lorsque le statut « Officiel » est présent dans la case « Etat / State ». La date de cette signature est présente dans la case « Date »

All the person mentioned above have signed electronically the document with the WINDCHILL software when "Released" appears in the "Etat / State" box. The date of this signature appears in the "Date" box.

PLM Informations clés *Key Informations*	Type de Document *Document Family*	Entité *Entity*	Lieu *Location*	Marché *Market*	Domaine *Product Focus*	Application *Product Technics*	Technologie *Technology*	Activité *V-Cycle Activity*
	HSI	*Energy Storage Solution*	*Bordeaux*	*Grid*	*System-Battery*	*All the functions*	*Lithium*	*Verification / Validation*

Document Change Status			
Version Officielle *Released Version*	Date	Pages or §	Evolution / Change
A	March 2023	-	Creation / Initial Issue
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

This document IS
– Based generally on SAFT's experience and knowledge in Li-ion battery design and integration.
– A general recommendation of best practices regarding emergency interventions on IHE products.

This document IS NOT
– An exhaustive guideline to safety, regulatory compliance.
– A promise or representation by Saft in any fashion. It is the Customer's responsibility to follow all local codes and regulations.

TABLE DES MATIERES / *TABLE OF CONTENTS*

1. DOCUMENTS

1.1 ACRONYMS, SYMBOLS AND ABBREVIATIONS

BESS: Battery container
LEL: Low Explosivity Limit

2. ENERGY STOCKAGE SYSTEM DESCRIPTION

2.1 DESCRIPTION

Saft ESS (Energy Storage Systems) are based on Lithium-Ion battery technology. THE CELLS AND BATTERIES DO NOT CONTAIN METALLIC LITHIUM
The Saft I-Shift range of Lithium-Ion energy storage is a standard ISO container of 20 feet:

- 2896x2438x6058 (in mm).
- It has an IP54 protection index.
- It weighs about 30 T
- Container is fitted with 4 large battery access doors located on each side and 1 control room access doors located on the side and 1 electrical panel door located at the end.
- Connecting/disconnecting devices are located in the control room as well as the various battery management components called Battery Management System and a fire detection and protection system.
- Temperature and humidity of the entire container are controlled by a thermal power HVAC system installed inside the container (see orange part figure 1).

Each container is an assembly of modules under a voltage of 1500VDC depending on the type of battery.
Each battery module is composed by Li-ion cells connected in series and in parallel. The total number of Li-ion modules is 136, each one with 21.5kWh and +/- 165kg.

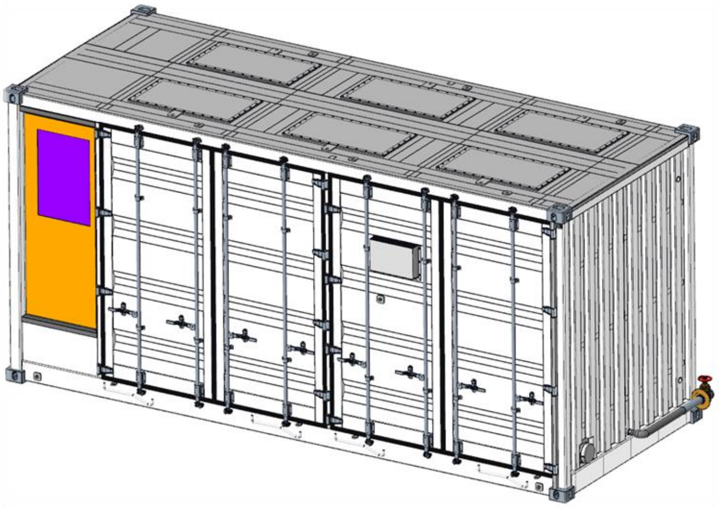


Figure 1 : I-Shift container

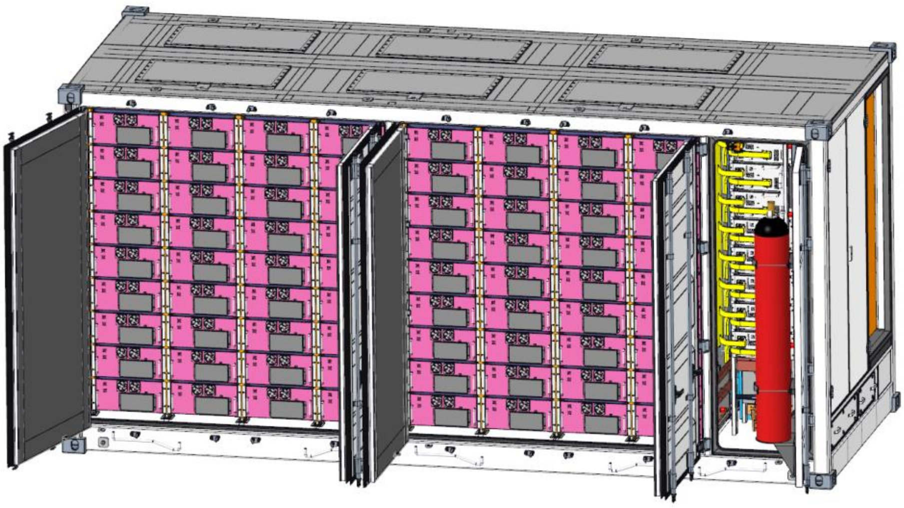


Figure 2 : I-Shift with doors open

2.2 SYNTHESIS OF THE SAFETY DEVICES/FUNCTIONS

The containers consist of a customised metallic maritime container envelope with thermal insulation

Each container has a fire safety system including:

- A global fire detection device based on smoke, temperature and CO sensors.
- An outdoor audible (horn) and visual alarm (Strobes) systems.
- 2 redundancy systems of remote alert.
- A primary fire suppression system (bottle of N2) design according to local regulation rules, connected to sensor base detection network.
- An external manual device for primary FSS gas release.

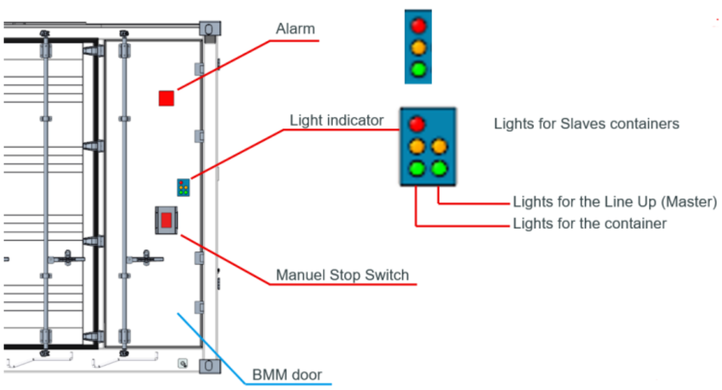


Figure 3 : External safety device

- A pressure relief vent located at the top of a side door to evacuate hot gases and gases during FSS discharge.

In addition, each container is equipped with:

- Blast panels located on the roof of the container (frangible panels)
- An internal water sprinkler network connected to a “dry pipe” with external connection for firehose (fixed or truck tank). This redundant FSS is called secondary FSS or Water FSS.
- A water drains release system to avoid flooding the I-Shift Container if the Water FSS is activated (to avoid potential H2 gas generation by electrolyze).
- A device for automatic disconnection of batteries/accumulators from the customer voltage network/application (inside the control room).
- 6 thermocouple sensors are installed inside the container (4 in the battery room and 2 in the control room)
- An electrical connection point to have data of this thermocouples is located above the water FSS plug.

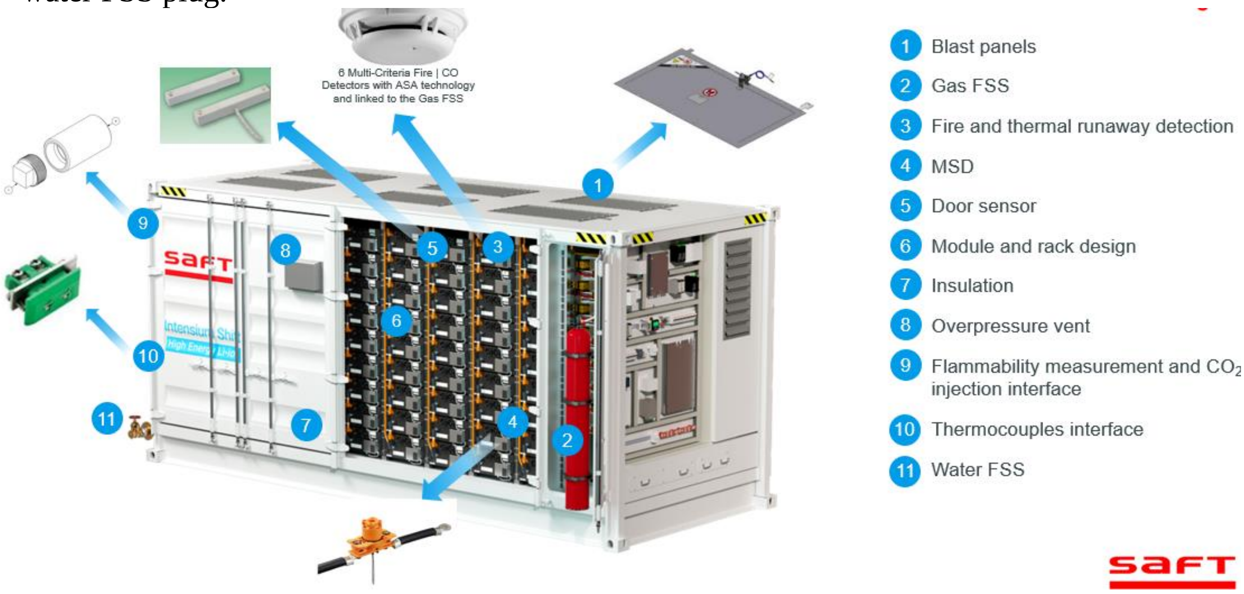


Figure 4: I-Shift container and Safety devices

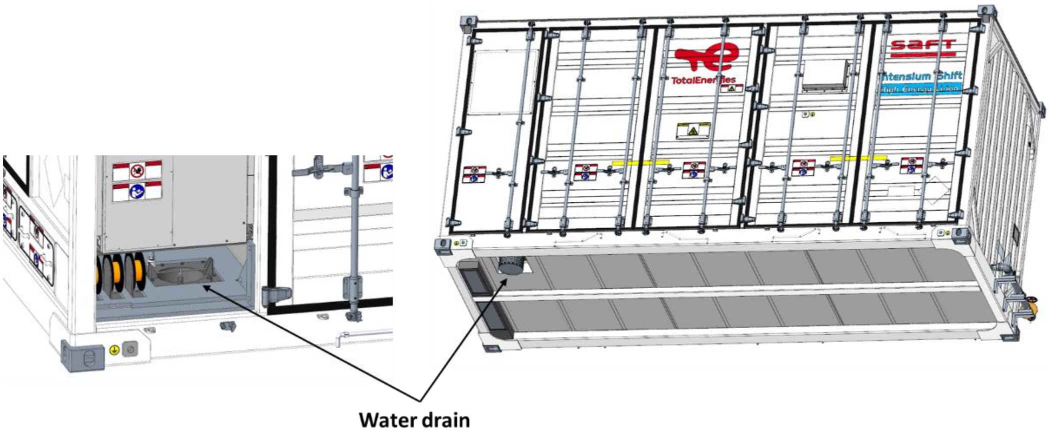


Figure 5 : Exhaust for water

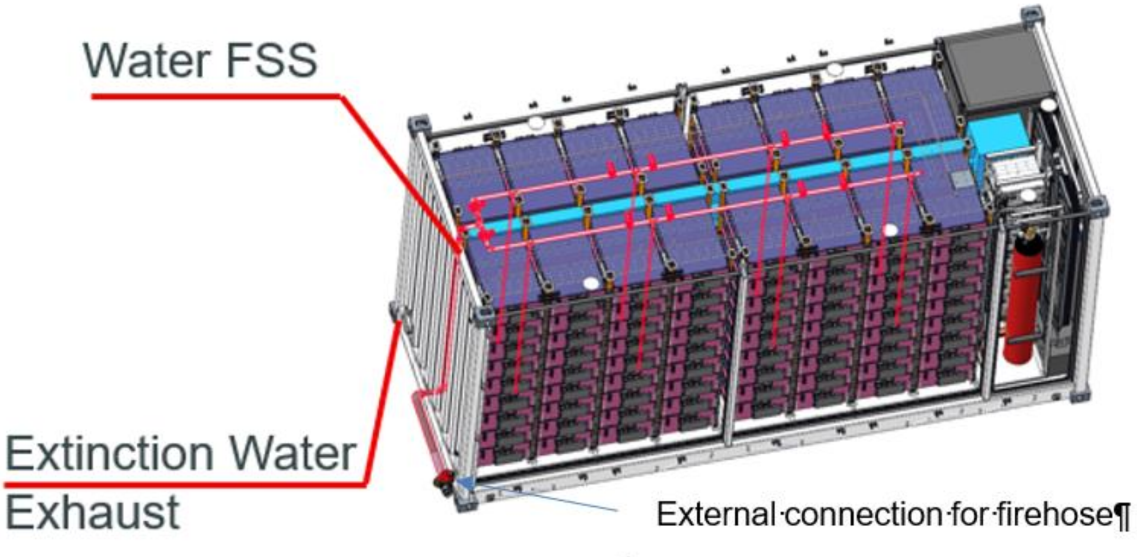


Figure 6 : Water FSS connection point and Exhaust

The external connection for firehose described below (eg DSP70mm²) is only for example. The external connection for firehose must be compliant with local firefighter tools thanks to customer feedbacks for water pipe connection.

The connection is grounded to the container to prevent electrical hazard.

External connection for firehose

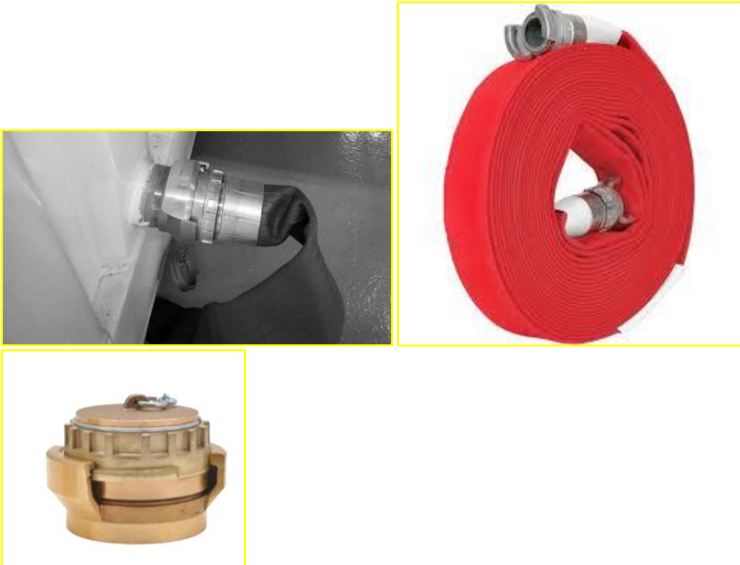


Figure 7: external connection for firehose and water hose

3. RISKS ASSOCIATED WITH THE LI-ION BATTERY SYSTEM

3.1 LI-ION BATTERY CONTAINER RISKS

Thermal	Electric	Toxic	Overpressure

Smoke

Release of toxic and corrosive gases when Thermal Runaway within the ESS.
Indicative composition:*
8.3 % Carbon monoxide CO
21,2% Carbon Dioxide CO_2
53,4% Hydrogen H_2
7% CH_4
6,1% C_2H_4
Traces of HF
…
*Composition is different in case of combustion

Fire

Fire of flammable gases during thermal runaway of a lithium-ion battery / fire components of the ESS (plastics, electronic components)

Contact with conductive part
Continuous current LV
Electric flash risk

Explosion
Release of flammable gases during thermal runaway of lithium-ion battery

3.1.1 Thermal Radiation

A single cell thermal runaway does not propagate to neighboring cells as demonstrated in testing per UL9540A standard and other internal Saft testing.

Accordingly, no thermal radiation is expected during an event.
For an unexpected scenario where flames are visible, do not approach the container and keep a 15m security distance.

3.1.2 Toxicity

A single cell thermal runaway does not propagate to neighboring cells as demonstrated in testing per UL9540A standard and other internal Saft testing. Therefore, no toxicity expected during an event.
For an unexpected scenario where big quantities of smoke are visible, do not approach the container and keep a 15m security distance.

3.1.3 Explosion

During a thermal runaway event, the emitted gas might create an explosive environment inside the BESS. To mitigate damages from potential explosion, blast panels were installed on the roof of the container.

These safety layers (blast panels) are effective only if the doors remain closed during an event.

Flying part can be created after the opening of the doors.

Accordingly, the doors must remain closed during an event.

4. GENERAL RECOMMENDATION FOR INTERVENTION

A single cell thermal runaway does not propagate to neighboring cells as demonstrated in testing per UL9540A standard and other internal Saft testing.

In this scenario, the absence of smoke and/or flames going out of the container (special attention should be given to the overpressure valve) for 6 hours means the system is stabilized.

For a scenario which was not anticipated by Saft such as external abuse of the container, flames and smoke can be visible. To stop the phenomenon as soon as possible, I-Shift container is equipped with an external connection for firehose.

This external connection for firehose is located on the end side of the container (see figure 7), it supplies the Water FSS distribution network with pressurized water.
The water supply source can be connected as soon as possible if safe access is guaranteed (no flames nor smoke coming out from the batterie container). The recommended water supply characteristic are:

- Pressure: **4 bars**
- Throughput: ~600liters (≈75 US gal) /minute
- Volume: ≈ 72m^3 (≈ 2542 ft^3)
- Running time: **2hours**

Fire restarts can occur after the water flow is interrupted; hence monitoring shall be performed for a minimum of 24H to confirm the absence of smoke or flames. A thermal camera can be used to confirm the presence/absence of fire and smoke. After this 24h, the system is considered stabilized.

This stabilized system is not synonymous with safe situation and the opening of the container doors is not allowed due to the potential presence of toxic and/or explosive gas if the frangible panels on the roof have not opened. These gases can be distributed in the entire dead volume of the container (about 19m^3).

<u>Opening the doors without respecting the adapted process can create injuries to the 1st responder's/firefighters due to backdraft</u>.
The light explosive gases (such as hydrogen) can accumulate at the top of the container.

Therefore, an explosivity measurement is mandatory. Doors can be opened **<u>only</u>** if LEL is < 20%. Otherwise, wait or discharge CO2 bottle inside the BESS to flush out the remaining explosive gas. The firefighters shall measure the explosive level of the internal gases with an explosive meter. The explosive gas measurement shall be performed through the injection interface. (See picture 9)

A way to reduce the explosivity level of the container is to use a CO_2 extinguisher with at least 50kg which its availability is under customer responsablity. The extinguisher nozzle must allow the introduction of CO2 gas into the container by the 48,26 mm diameter hole . A tool must be available on site to open this hole.

Figure 8: CO_2 extinguisher

The temperature can also be monitored using a multimeter connected to the six thermocouples.(See figure 9). The multimeter readings can be done from a safe distance (up to 35 m) using specific cables to connect the thermocouples interface to the multimeter. These cables shall be connected to the container at the same moment that the fire hose is connected to the water FSS distribution network.
Cables and multimeter shall be available on site.

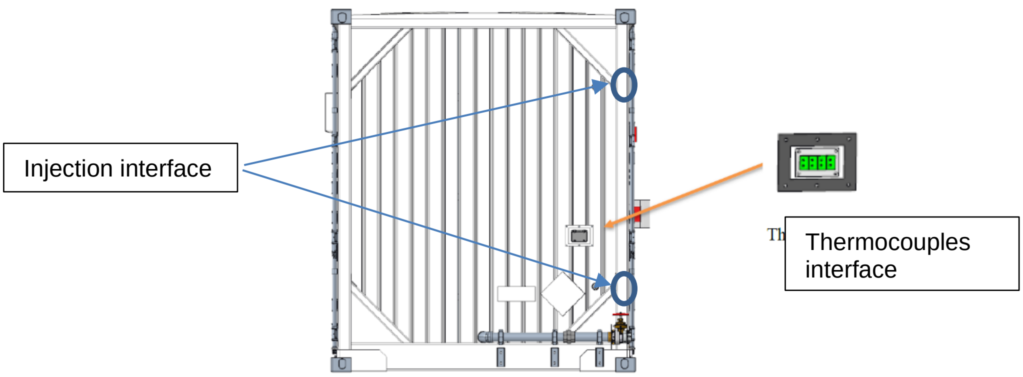


Figure 9 : Flammability measurement and CO_2 injection interface

Reminder: DO NOT OPEN THE DOORS UNTIL LEL IS UNDER 20% AND SAFT GIVE IS AGREMENT

5. THE APPROPRIATE OPERATIONAL RESPONSE TO EMERGENCY RESPONSE ON IHE CONTAINER

The FSS Fire alarm shall be constantly monitored 24 hours per day. This alarm is using reliable dry contact and the external fire control panel.

This alarm will notify the ESS Operator and the external Fire Control Panel located in the site control room may also be connected to other external fire alarm systems for direct fire alarm notification to local authorities.

During operations, after fire detection, an alarm is sent to the ESS Operator, and the 1st responders/firefighters shall be on site as soon as possible to have the most secure access.
The potentially failed ESS is identified thanks to the activated horn and with activated strobe.

When arriving on site, the first responder must monitor the presence of smoke and flames. If none are visible, they can safely connect the water FSS.

If flames or smoke are visible, the approach of the container and connection to the water FSS is let to the firefighter's judgement. Accordingly, the 1st responders/firefighter shall wear their PPE against thermal aggression and toxicity.

1st responders/firefighters shall follow the process and recommendations described within this document and addressed during training sessions. To secure the emergency response, a yearly training shall be deployed.

After intervention, the subsequent operations shall be carried out by authorized operator to work under-voltage, wearing the appropriate electrical PPE.

Saft provides a worldwide hotline service for emergency cases available 24/7:

Emergency Contact	
In case of SAFT ESS Safety Emergency	Contact SAFT +49 89 18 93 73 56 73 Available 24/7

Figure 10: Emergency contact

When you contact this number, hold the line until someone from Saft ESS respond.

Tell your interlocutor:

- Name of the site
- Location
- Type of product
- Name of the customer

Take stock of the situation:

- Reason for appeal
- Number of containers impacted
- Presence of smoke: yes/no
- Presence of flame: yes/no
- Presence of firefighters on site: yes/no

A) *Case 1 - No visible smoke and/or flames Visual & Sound Alarm outside the container*

General situation	EPI /PPE
No visible fumes or flames coming out from the container.	For first responder: No specific PPE need
Firefighting Engines needs	○ Fire Pump Truck ○ If no local fire water network is available, additional water tank/truck shall be required ○ Fire Brigade Group Leader (officer)
Access / Pathways	○ Don't park in front of openings ○ Park at least 15meters (49feet) from the concerned container

Immediate Actions

Action	Description
1	Smoke alarm activation (visual + sound alarm)
2	Primary Gas Fire Suppression System activation
3	Alarm transmission to the operator/duty technician
4	Operator/duty technician calls the Fire Brigade
5	Fire brigade arrives on scene
6	Local global power cut off if available (to be identified at site level when required)
7	Engines parking more than 15meters (49feet)
8	Identification of the faulty ESS (audible +visual flashlight)
9	Set up a 15meters (49feet) exclusion perimeter.
10	Trained fire brigade connects the firehose to the faulty container without opening the water.
11	The Fire brigade Group leader coordinates with the technician that arrives on site (explanation of risk, strategy)
12	+ other actions listed in the thoughtful actions below

Thoughtful Actions

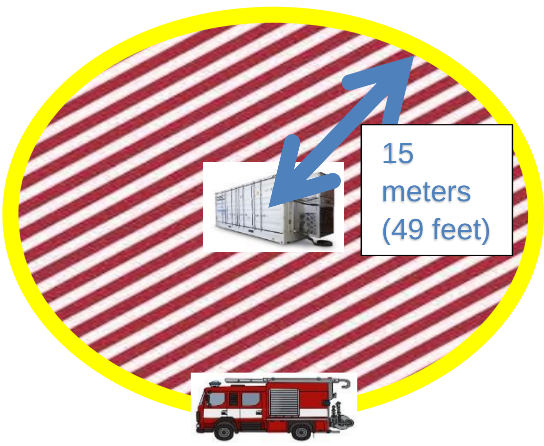
When arriving on site, the first responder must monitor the absence of smoke going out of the overpressure valve or anywhere else from the IHE container:

- Scenario 1: If there is no smoke for 6 hours: possible opening of the container.
  Decision shall be taken by trained staff to open the container and you must follow the procedure:
  - Measurement of internal explosivity:
    - If 20%<LEL-> container opening possible
    - If >20% LEL -> do not open, CO_2 bottle can be discharge in the container if necessary and repeat measure 30min later

If smoke or flames are observed during these 6 hours: proceed as for case number 2 of this guide.

What to remember	○ Do not open the container without explosive internal gas measurement (explosimeter) and without internal gas removal after using the CO2 site bottle if needed. ○ Do not come into contact with metal parts of the container other than the water FSS connection point ○ Do not come into contact with water (electrical hazard)
Major reminder	○ Electrical and toxic risk are always present ○ Batteries will always be energized (DC) ○ Do not stay next to the pressure relief vent located at the side door of the container.

SAFT recommends an exclusion zone of 15 meters (49 feet) around the container for persons not involved in the current event.



B) *Case 2 - Visible smoke and/or flames Visual & Sound Alarm outside the container*

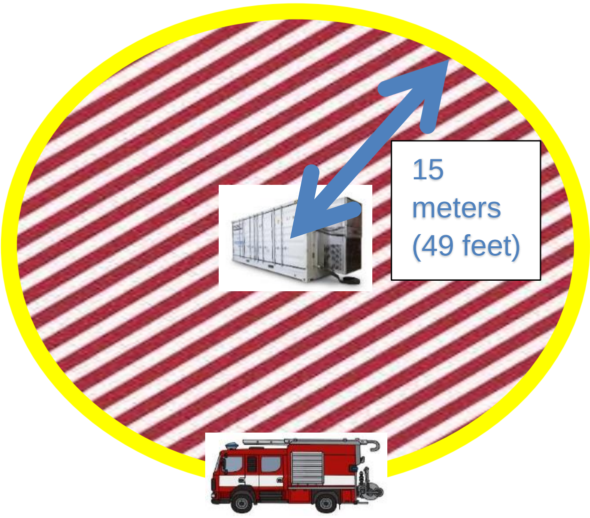
General situation	EPI /PPE
Visible smoke and/or flames coming out from the container	For first responder/firefighters: PPE is needed if flames or smoke are observed.
Firefighting Engines needs	○ FPT (Fire Pump Truck) ○ If no local fire water network is available, additional water tank/truck shall be required ○ Fire Brigade Group Leader
Access / Pathways	○ Don't park in front of openings Park at least 15meters (49feet) from the concerned container

Immediate Actions

Action n	Description
1	Smoke alarm activation (visual + sound alarm)
2	Primary Gas Fire Suppression System activation
3	Alarm transmission to the operator/duty technician
4	Operator/duty technician calls the Fire Brigade
5	Fire brigade arrives on scene
6	Local global power cut off if available (to be identified at site level when required)
7	Engines parking more than 15meters (49feet)
8	Identification of the ESS on alarm (Audible + visual flashlight)
9	Set up a 15meters (49feet) exclusion perimeter. Check toxicity (CO, HF, HCN) and adjust safe perimeter if needed
10	The approach of the container and connection to the water FSS is let to the firefighter's judgement
11	Decision for water opening after cross check with operator/duty technician
12	The Fire brigade Group leader coordinates with the operator/duty technician that arrives on site (explanation of risk, strategy)
13	+ other actions listed in the thoughtful actions below

Thoughtful Actions	
- If flames or 15 minutes of smoke are visible: - Start the water sprinkling, 4 bar supply pressure max and leave the internal sprinkling of the container in operation for 2 hours after the end of the smoke release and or flame. After 2 hours of sprinkling: - Control the absence of smoke going out of the overpressure valve and anywhere else. - When situation is under control (no smoke or flames visible for 24 hours) & after recommendation or decision by SAFT expert: - Measurement of internal explosivity: - If 20%<LEL-> container opening possible - If >20% LEL -> do not open, CO2 bottle can be discharge in the container if necessary and repeat measure 30min later - If there is smoke visible: Continue internal sprinkling and keep monitoring the absence of smokes.	
What to remember	- Do not open the container without explosive internal gas measurement (explosimeter) and without internal gas removal after using the CO2 site bottle if needed. - Do not come into contact with metal parts of the container other than the water FSS connection point - Do not come into contact with water (electrical hazard)
Major reminder	- Electrical and toxic risk are always present - Batteries will always be energized (DC) Do not stay next to the pressure relief vent located at the side door of the container

SAFT recommends an exclusion zone of 15 meters (49 feet) around the container for persons not involved in the current event.



C/ Case 3 - External fire close to the ESS: ESS under fire or customer site fire alarm triggered.

General strategy	EPI /PPE
Call Fire brigade Strong heat radiation and/or flames near the container due to external fire or due to other IHE burning. Check the safe access to the ESS If the safe access is not possible, the firefighters can use a binocular to see remotely the external ESS overpressure valve.	For first responder: Fire PPE is needed if flames are observed For firefighter: Full ***fire PPE set*** is required for the intervention
Firefighting Engines needs	○ FPT (Fire Pump Truck) ○ If no local fire water network is available, Additional water tank/truck will be required ○ Fire Brigade Group Leader
Access / Pathways	○ Don't park in front of openings ○ Park at least 15meters (197feet) from the concerned container

Immediate Actions

Action n	Description
1	External Fire detection
2	Alert Transmission to the operator duty technician
3	Operator/duty technician calls the fire brigade
4	Fire brigade arrives on scene
5	Local global power cut off if available (to be identified at site level when required)
6	Engines parking more than 15meters (49feet) Set up a 15meters (49 feet) exclusion perimeter. Check toxicity (CO, HF, HCN) and adjust safe perimeter is needed
7	Identification of the closest ESS to external heat radiation
8	The fire brigade Group Leader deploys a water curtain between the exposed ESS and the external fire.
9	The fire brigade Group Leader connects the fire line to all ESS without opening the water
10	The Fire brigade Group leader coordinates with the operator/duty technician that arrives on site (explanation of risk, strategy)
11	+ other actions listed in the thoughtful actions below

Thoughtful Actions

When arriving on site, the first responder must monitor the absence of smoke going out of the overpressure valve or anywhere else from all nearby IHE container:

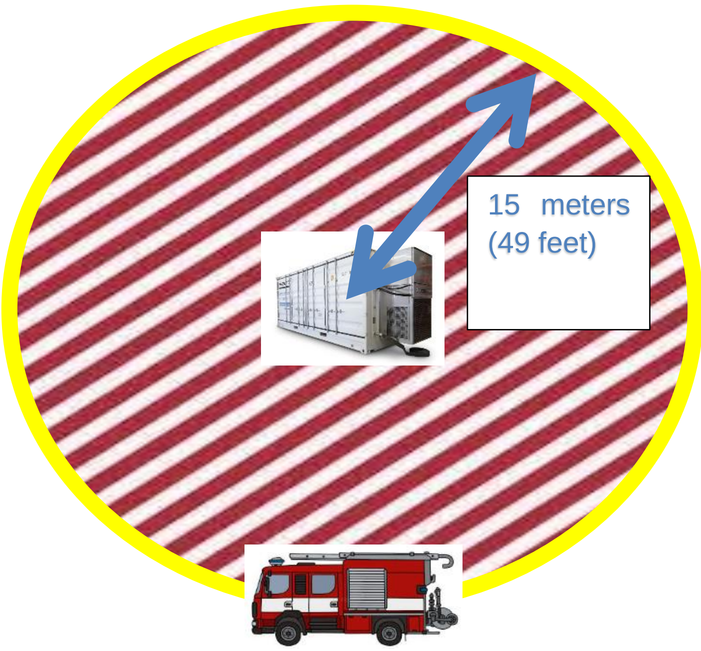
Water curtain can be used to avoid propagation from the external fire to the closet battery container.

Connect the water FSS if possible.
If there is no smoke for 6 hours: refer to case 1 of this guide.

If smoke or flames are observed during these 6 hours: proceed as for case number 2 of this guide.
.

What to remember	○ Do not open the container without an explosive internal gas measurement (explosimeter) ○ Do not come into contact with metal part of the container without appropriate PPE (electric hazard) ○ Do not come into contact with water (electrical hazard)
Major reminder	○ Electrical and toxic risk are always present ○ Batteries will always be energized (DC) ○ Do not stay next to the pressure relief vent located at the side door of the container.

SAFT recommends an exclusion zone of 15 meters (49 feet) around the container for persons not involved in the current event.



D/ Case 4 - Incident during the transport, storage or installation phases

General strategy	EPI / PPE
In the event of an accident during road transport of the container Situation for which the integrity of the container is involved (container on the blank, structure of the container deformed, etc.). Incident during the storage phase (smoke, fire, questioning of integrity).	For first responder: Fire PPE is needed if flames are observed For firefight: Full ***fire PPE set*** is required for the intervention
Firefighting Engines needs	○ FPT (Fire Pump Truck) ○ If no local fire water network is available, Additional water tank/truck will be required ○ Hazmat response truck ○ Fire Brigade Group Leader
Access / Pathways	○ Don't park in front of openings ○ Park at least 15meters (49feet) from the concerned container

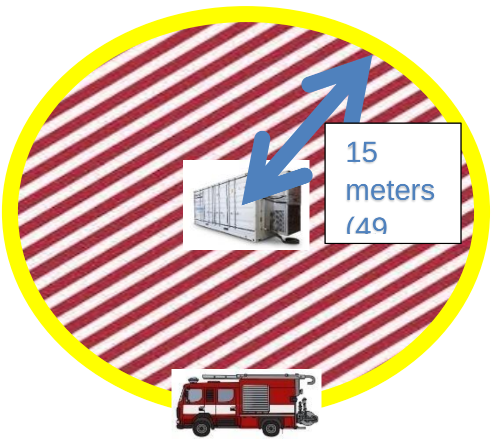
Immediate and thoughtful Actions

Action #	Option A: no smoke or apparent fire	Option B: smoke or apparent fire
1	Avoid the accident. Safety of the surroundings and markings	Avoid the accident. Safety of the surroundings and markings
2	When arriving on site, the first responder must monitor the absence of smoke going out of the overpressure valve or anywhere else from the IHE container	Connect a DN70 fire supply hose to the external connection and monitor the internal temperature frequently.

3	• Scenario 1: If there is no smoke for 6 hours: possible opening of the container. Decision shall be taken by trained staff to open the IHE container and you must follow the procedure:
	  ○ Discharge CO2 bottle in the container.
	  ○ Measurement of internal explosivity:
	    ▪ If 20% LEL-> container opening possible
	    ▪ If >20% LEL -> do not open and repeat measure 30min later
	• Scenario 2: If there are continuous visible smokes since the fire alarm is triggered (15 minutes straight): Do not open the container, trigger water
		Trigger the water spray, at a pressure of 4 bar, at least 1 bar, and let the internal spraying of the container run for 2 hours.

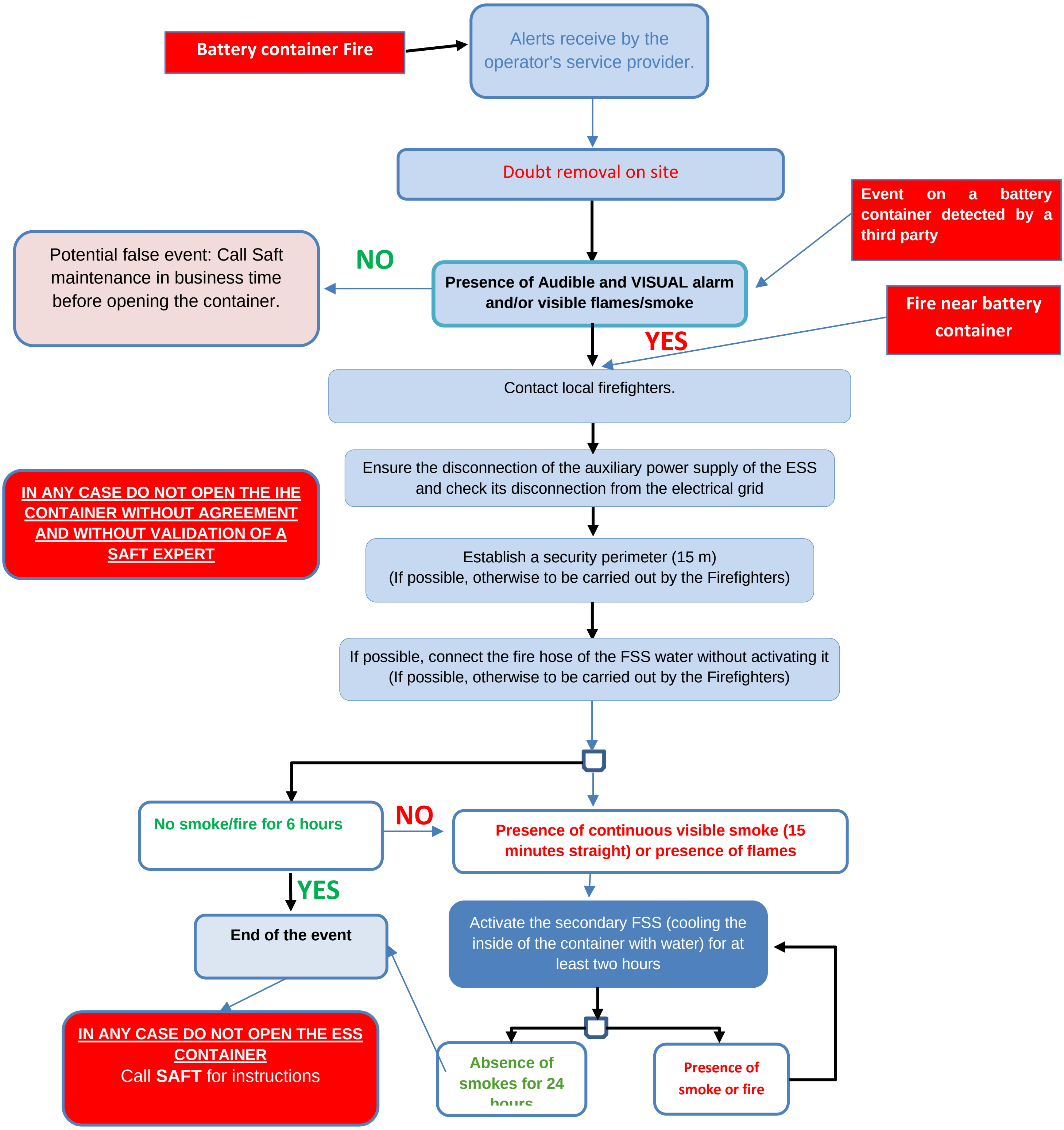
	sprinkling, 4 bar supply pressure and leave the internal sprinkling of the container in operation for 2 hours.	
4	After 2 hours of sprinkling: o Control the absence of smoke going out of the overpressure valve and anywhere else. When situation is under control (no smokes visible for 24 hours) & after recommendation or decision by SAFT expert: Discharge CO2 bottle in the container. • Measurement of internal explosivity: ○ If 20% LEL-> container opening possible ○ If >20% LEL -> do not open and repeat measure 30min later. • If there is smoke visible: Continue internal sprinkling and keep monitoring the absence of smokes.	After 2 hours of sprinkling: o Control the absence of smoke going out of the overpressure valve and anywhere else. When situation is under control (no smokes visible for 24 hours) & after recommendation or decision by SAFT expert: Discharge CO2 bottle in the container. • Measurement of internal explosivity: ○ If 20% LEL-> container opening possible ○ If >20% LEL -> do not open and repeat measure 30min later. If there is smoke visible: Continue internal sprinkling and keep monitoring the absence of smokes.
What to remember	○ Do not open the container without internal gas removal after using the CO2 site bottle and without an explosive internal gas measurement (explosimeter) ○ Do not come into contact with metal part of the container without appropriate PPE (electric hazard) ○ Do not come into contact with water (electrical hazard)	
Major reminder	○ Electrical and toxic risk are always present ○ Batteries will always be energized (DC) ○ Do not stay next to the pressure relief vent located at the side door of the container.	

SAFT recommends an exclusion zone of 15 meters (49 feet) around the container for persons not involved in the current event.



TotalEnergies

6. STANDARD FLOWCHART OF INTERVENTION



TotalEnergies

FIN DU DOCUMENT

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