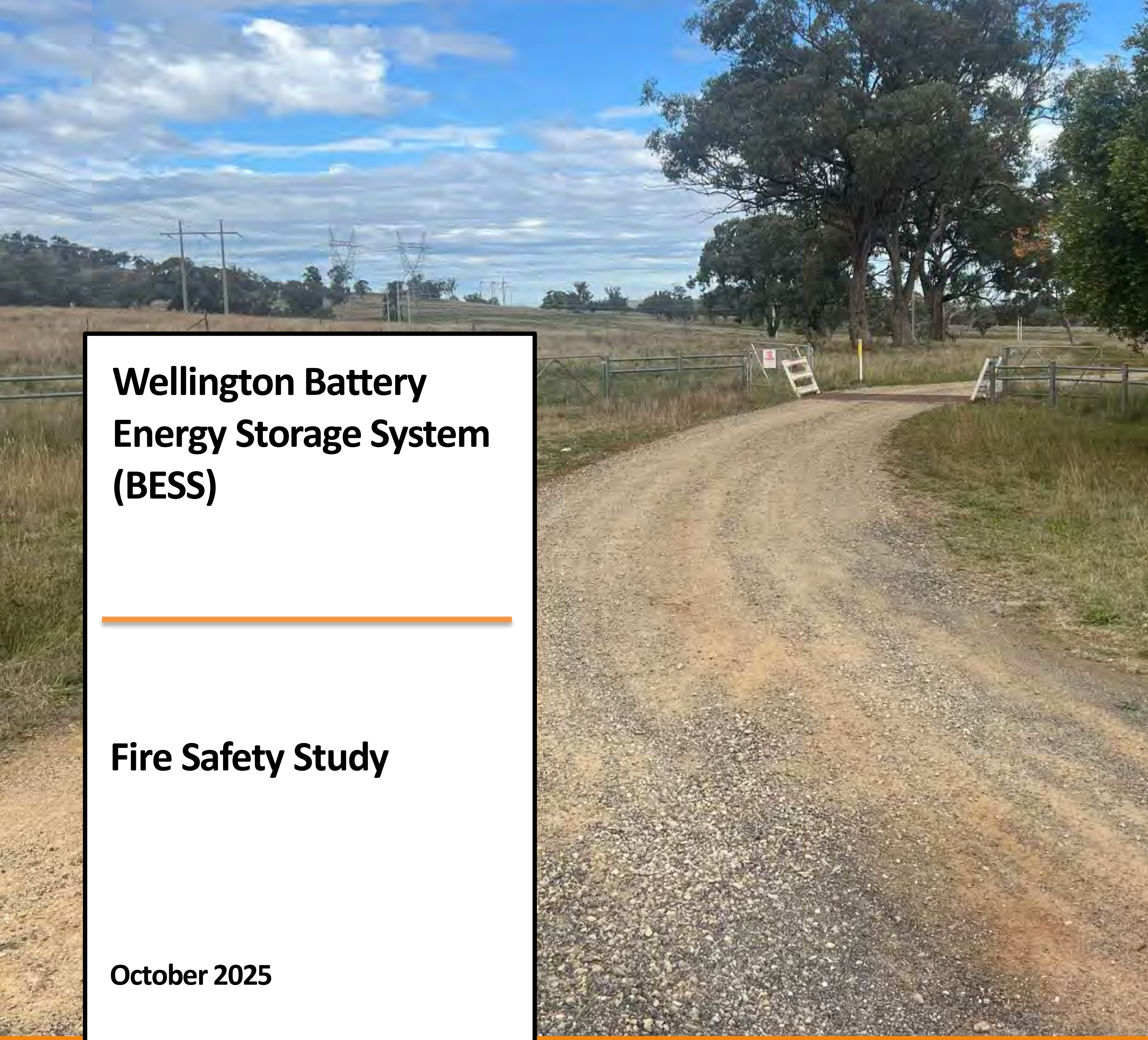

Wellington Battery Energy Storage System (BESS)

Fire Safety Study

October 2025

FIRE RISK
Consultants

Front cover – Main entrance to the Wellington BESS site

Document history

Revision	Date	Description	By	Review	Approved
V0.2 - DRAFT	15/7/2024	Initial draft following assessment of available information.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V1 - Final	12/2/2025	Updated following client feedback	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V1.1	27/3/2025	Updated following client feedback	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V2.2	21/8/2025	Updated following FRNSW feedback.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V2.3	02/10/2025	Updated following client and FRNSW feedback.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V2.4	09/10/2025	Updated to reflect changes to the report.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V2.5	20/10/2025	Updated to respond to FRNSW advice.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director
V3	23/10/2025	Final report following FRNSW approval.	M Potter & FRC Project Team	FRC Review Team	G Taylor Managing Director

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*Where the term **"Bushfire prevention and mitigation related activities"** (or words to that effect) are used, this is to be defined as the clearance of vegetation in accordance with the Victorian State Government guidelines, including clearing and maintenance of existing fire breaks and/or fire access for fire fighters under electricity pylons and properties that have been constructed to Australian Standard AS3959 and/or the National Construction Code.*

Contents

Executive summary

This Fire Safety Study (FSS) has been developed to support the assessment of fire risk associated with the Wellington Battery Energy Storage System (BESS) (the Project). This FSS has been prepared in accordance with NSW Planning's *Hazardous Industry Planning Advisory Paper 2: Fire Safety Study Guidelines (2011)*. This FSS forms part of the requirements under the State Significant Development consent and is intended to satisfy the conditions requiring FRNSW endorsement.

The Wellington South BESS project involves the deployment of a 300 MW BESS comprising modular Fluence BESS Cubes. These Cubes contain lithium iron phosphate (LFP) battery cells and are equipped with integrated fire detection, gas monitoring, and shutdown systems. Ancillary infrastructure on site includes transformers, inverters, a control room, and operations and maintenance (O&M) facilities. The site is accessed via Twelve Mile Road and sits adjacent to the Wellington Solar Farm. Fire management measures have been considered across all assets and site conditions.

Key fire hazards identified include thermal runaway events, toxic off-gassing, transformer oil fires, arc flash incidents, and potential bushfire exposure. The FSS includes a detailed assessment of each hazard, supported by testing data (e.g. UL9540A) and manufacturer specifications.

The fire safety strategy incorporates prevention, detection, containment, and emergency response measures. These include a battery management system (BMS), SCADA-linked fire alarms, gas detectors, emergency stop (E-stop) systems, and 24/7 remote monitoring. Firefighting water supply is provided by an AS2419 compliant system, with access for FRNSW vehicles and a hydrant/booster system. Firewater containment is designed to hold contaminated runoff during and after a firefighting event, ensuring environmental protection. Procedures for post-incident water disposal have been included in line with the FRNSW BESS Guideline.

The BESS enclosures are installed with a 3.5 m door-to-door separation (front-façade aisle) and 150 mm clearances at the back-to-back and side-to-side interfaces. Hand-based flame-tilt and radiant-heat analyses (Section 5.2.2) confirm that the 3.5 m aisle spacing maintains peak exposures below 20 kW/m² under adverse wind conditions (up to 11 m/s). The minimal 150 mm side and rear clearances are treated as shared-wall conditions with negligible radiative exchange between units. This configuration complies with manufacturer installation requirements and provides effective mitigation against unit-to-unit propagation, satisfying FRNSW performance expectations for separation and consequence management.

Separation distances for the BESS Units is based on the manufacturer specifications as a minimum and is exceeded in some situations. The separation from side to side and back to back is 150mm and door to door is 3.5 metres.

An Emergency Management Plan (EMP) has been recommended and will include site notification protocols, evacuation procedures, FRNSW information packs, and maps showing hazard zones. The site will have an Alarm Signalling Equipment (ASE) unit to automatically alert FRNSW in the event of fire detection. This, combined with defined exclusion zones, ensures that emergency responders can operate safely and effectively.

All recommendations in this Fire Safety Study have been accepted and incorporated into the project design and operation. A staged implementation plan ensures that fire systems, monitoring protocols, and water infrastructure are verified prior to commissioning. Ongoing review of fire risks and emergency plans will be conducted annually or following any significant system change or incident.

A summary of the document is provided in the tables below.

Table 1 - Scope and hazards identified

Section	Details
Scope	Installation, commissioning and operation of a 300 MW BESS and associated infrastructure, including inverters, transformers, control room and O&M building.
Key Hazards Identified	• Thermal runaway in BESS units • Oil fires in transformers • Electrical arc flash • Toxic off-gassing • Firewater contamination

Table 2 - Summary of recommendations made

Control Area	Recommended Actions	Status
Battery Management System (BMS)	Each BESS unit is equipped with an emergency stop button to initiate an immediate shutdown.	Accepted by Ampyr Energy and Fluence
Emergency Stop (E-Stop)	Establish a remote and local shutdown mechanism to isolate affected battery units in an emergency.	Accepted by Ampyr Energy and Fluence
System Shutdown	Establish a remote and local shutdown mechanism to isolate affected battery units in an emergency.	Accepted by Ampyr Energy and Fluence
Site Security & Monitoring	Install CCTV cameras to monitor potential hazards. Ensure 24/7 remote monitoring with an established alert and response system.	Accepted by Ampyr Energy and Fluence

Control Area	Recommended Actions	Status
Bushfire Prevention	Implement regular vegetation management and weed removal programs. Establish and maintain firebreaks to prevent fire spread.	Accepted by Ampyr Energy and Fluence
Training & Inductions	Conduct regular fire safety training for staff and contractors. Provide site-specific fire safety inductions for visitors and workers.	Accepted by Ampyr Energy and Fluence
Fire Agency Engagement	Facilitate annual site tours for Fire and Rescue NSW (FRNSW) and NSW Rural Fire Service to ensure responders are familiar with the site layout. Develop emergency response plans in coordination with fire agencies.	Accepted by Ampyr Energy and Fluence
Emergency Info Container	Install an Emergency Information Container at the main entrance with site plans, hazard maps, and emergency contact details that complies with the NSW Guideline.	Accepted by Ampyr Energy and Fluence
Occupant Warning System (OWS)	Ensure the site has an audible and visual alarm system activated in case of smoke, fire, or toxic gas detection that alerts people within the Switch Room, Control Room and the BESS area.	Accepted by Ampyr Energy and Fluence
Firefighting Water Supply	An AS2419.1 fire hydrant system will be installed within the site.	Accepted by Ampyr Energy and Fluence
Firewater Containment	Implement firewater retention systems (minimum 251,000 litres) to prevent contaminated runoff. Establish procedures for safe disposal of firewater following testing that are included within the Emergency Response Plan.	Accepted by Ampyr Energy and Fluence
Detection & Suppression	Equip BESS units with gas and smoke detection systems linked to automated alerts. Install smoke detection systems in the switch and control rooms.	Accepted by Ampyr Energy and Fluence

Control Area	Recommended Actions	Status
Emergency Planning	Develop an Emergency Response Plan aligned with AS 3745-2010. Provide fire agencies with: • Evacuation plans • Tactical fire checklists • Hazardous chemical manifests • Site and firefighting water access maps	Accepted by Ampyr Energy and Fluence
First Aid Fire Protection	Ensure fire extinguishers are available throughout the site. Train personnel in basic firefighting and evacuation procedures.	Accepted by Ampyr Energy and Fluence
FRNSW Access	Ensure access roads meet fire brigade standards for emergency vehicle entry.	Accepted by Ampyr Energy and Fluence
Separation Distances	Separation distances in accordance with manufacturers recommendations.	Accepted by Ampyr Energy and Fluence
Alarm Signalling Equipment (ASE)	An Alarm Signalling Equipment (ASE) device will be installed on site and the fire detection equipment to ensure early notification of FRNSW.	Accepted by Ampyr Energy and Fluence

Following a review of the Fire Safety Study by FRNSW, they have advised that the study has been prepared to the satisfaction of FRNSW (Appendix H).

1 Abbreviations and acronyms

Term	Definition
BESS	Battery Energy Storage System
EMS	Energy Management System
FSS	Fire Safety Study
FRNSW	Fire and Rescue New South Wales
HIPAP2	Hazardous Industry Planning Advisory Paper No. 2
SOC	State of Charge (of battery cells)
SCADA	Supervisory Control and Data Acquisition
UL9540A	Test method for evaluating thermal runaway fire propagation in BESS
ASE	Alarm Signalling Equipment used to notify FRNSW of fire events
APZ	Asset Protection Zone surrounding critical infrastructure
HVAC	Heating, Ventilation and Air Conditioning system
LFP	Lithium Iron Phosphate battery chemistry
PPE	Personal Protective Equipment used during emergency response

2 Introduction

This Fire Safety Study (FSS) has been developed to support the assessment of fire risk associated with the Wellington Battery Energy Storage System (BESS) (the Project). This FSS has been prepared in accordance with NSW Planning's *Hazardous Industry Planning Advisory Paper 2: Fire Safety Study Guidelines (2011)*.

In addition, this FSS is also informed by the following:

- Preliminary Hazard Analysis – Wellington South Battery Energy Storage System – prepared by EMM Consulting Pty Ltd September 2022
- Wellington South Battery Energy Storage System – Instrument of Consent (SSD 27014706)
- Fire and Rescue NSW (FRNSW) advice on the proposed Wellington South Battery Energy Storage System (D22/102300)
- FRNSW Technical Information – Large-scale external lithium-ion battery energy storage systems – Fire safety study considerations

The project is to the northeast of Wellington and to the south of the Wellington Solar Farm. The Wellington Solar Farm is located to the north and west of Goolma Road with the BESS development located to the south of Goolma Road.

The site is currently accessed from near the Goolma Road and Twelve Mile Road intersection. A new entry point is being constructed further to the east with access provided from Twelve Mile Road.

The site will be installing the Fluence BESS Cubes, and these have been tested in accordance with the UL9540A standards. The Cubes have a range of fire safety systems including battery management systems that are key to preventing fire ignitions within the Cubes.

The FSS has been prepared following an assessment of the site, analysis of supplied information from the Client and discussions with technical experts in relation to the design, commissioning and operation of a BESS. In summary, the outcomes of the FSS are outlined within Table 1. A more detailed 'line by line' response to the FRNSW Guideline is contained in Appendix E – Response to FRNSW Guideline

Table 3 - Response to NSW Fire Safety Study Guideline – key sections

Section 2 summary	Response
Identification of fire hazards and the consequences of possible fire incidents	The analysis of the fire hazards and consequences is contained within Section 4 and 5. The analysis will explore the fire hazards that may cause fire ignitions within the BESS Cubes, inverters and transformers. The hazard analysis will also consider the surrounding landscape.
Fire prevention strategies and measures	The outcome of the assessment of risk and the design will outline a number of fire prevention strategies and measures. These strategies and measures have been outlined within Section 5.3.
Analysis of the requirements for fire	The outline of the fire detection and protection and other fire safety measures is provided in Section 5.3. A number of measures have been

Section 2 summary	Response
detection and protection and identification of the specific measures to be implemented	incorporated into the design to assist with the management of any fire ignitions.
Calculation of firefighting water supply and demand	The analysis of fire water demand is outlined within Section 6.
Containment of contaminated firefighting water	The analysis of fire water containment is considered in Section 6.4.2.
First aid fire protection requirements.	The provision of first aid firefighting equipment is outlined in Section 6.4.

Following the finalisation of the Fire Safety Study, FRNSW will be requested to assess the Fire Safety Study to meet the Instrument of Consent requirements that requires the Fire Safety Study to be to the satisfaction of FRNSW.

Note: 'to the satisfaction of FRNSW' above means confirmation in writing from FRNSW that the study meets the requirements of FRNSW as required by the Department's Hazardous Industry Planning Advisory Paper No. 2 'Fire Safety Study' guideline.

The Fire Safety Study will utilise the following publications to guide the identification of hazards, assessment of risk and the determination of appropriate fire safety strategies:

- NFPA 850 - Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations (NFPA 850)
- NFPA 855 - Standard for the Installation of Stationary Energy Storage Systems (NFPA855)
- UL9540 – Test Methods for Evaluating Thermal Runaway Fire propagation in Battery Energy Storage Systems (UL9540
- FM Global Property Loss Prevention Data Sheet 5-33Electrical Energy Storage Systems (FM Global)
- Fluence UL9540A and large scale fire test reports relating to the BESS Unit.

The site and surrounding area are shown in Figure 1.

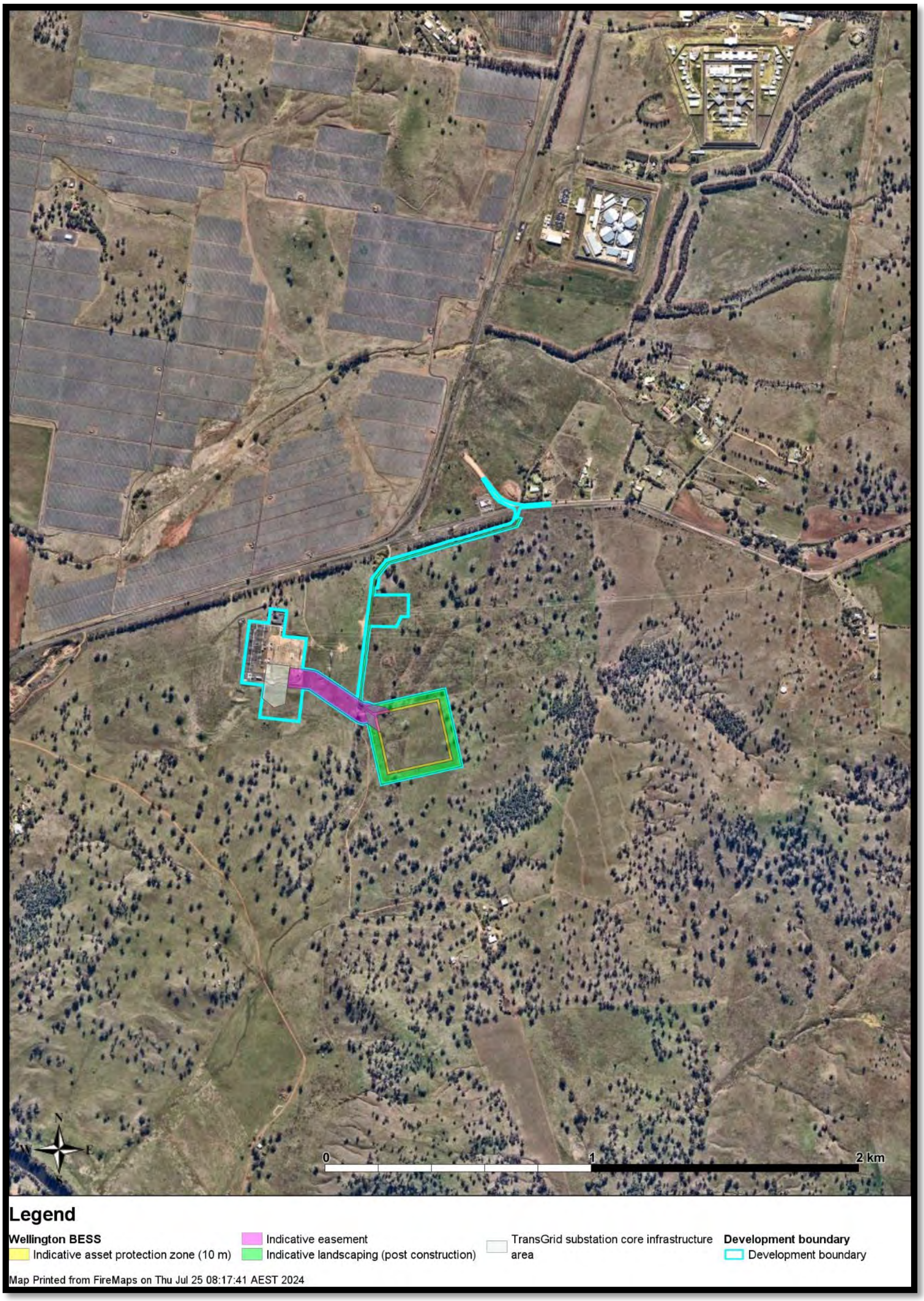


Figure 1 - Site and surrounding area

3 Project Overview

3.1 Site development

The project is to the northeast of Wellington and to the south of Wellington Solar Farm. The Wellington Solar Farm is located to the north and west of Goolma Road with the BESS development located to the south of Goolma Road.

The Project generally includes the following:

- A 300 MW BESS compound including battery enclosures and electrical conversion systems (e.g. inverters and transformers).
- A new access point and access road from Twelve Mile Road.
- Car parking areas
- An onsite substation.
- An aboveground transmission line connecting the BESS and the adjoining TransGrid Wellington substation.
- Ancillary infrastructure (e.g. security fencing, lighting and closed-circuit television).
- Internal access roads
- Permanent weather station
- Security equipment and systems.
- Fire protection equipment including static water tanks, pump, booster assembly and tank fill connections.
- Establishment of a 40 metre wide vegetation screen that surrounds the development.

Additionally, the following buildings will be constructed:

- Switch Rooms - Two switch rooms are located north of the BESS compound. These buildings house critical electrical equipment used to control and monitor BESS operations.
- Operations and Maintenance (O&M) Building - Positioned west of the BESS, adjacent to the fire water tanks and pumps, the O&M building is intended for daily onsite work and contains fewer electrical components.
- Control Room - Contains SCADA equipment, communication servers, and protection relays. Built on a concrete slab with non-combustible cladding and fire-rated internal partitions. Will also include office facilities and lunchrooms. The control and office building will be a prefabricated building. The building will be equipped with a fire detection and fire suppressant systems.
- Workshop and Storeroom - Houses spare parts and tools. Constructed using steel frame and sandwich panels.

The indicative site layout is shown in Figure 2.

3.1.1 Site occupancy

The BESS site will operate with a minimal daily presence but will support increased activity during construction, maintenance and inspection. Staffing levels are based on normal and peak conditions:

- 2 staff are present during normal operation, typically for monitoring and general oversight.
- Up to 10 staff may be on-site during scheduled maintenance, inspections or in the event of operational events.
- Staff will operate between 7am and 6pm from Monday to Saturday, with emergency after-hours access arranged as needed.

3.1.2 Surrounding land uses

The site is located in a rural area with low population density, primarily surrounded by cleared agricultural land. The township of Wellington is approximately 2.1 km to the southwest and has a population of around 4,096 (2021 Census). The site of the development is identified as a greenfield site.

Approximately 640 metres north of the BESS footprint is the Wellington Solar Farm. To the northeast, across Twelve Mile Road, there is a small cluster of large-lot residential properties. The nearest dwelling in this area is about 880 metres from the BESS footprint.

Macquarie Correctional Centre is located 1.78 km to the north of the site. Most of the land surrounding the site is used for primary production.

The closest sensitive receptors, such as schools, childcare centres, or hospitals, are more than 2.1 km away, located within the township of Wellington

In summary, the following landmarks are located nearby:

- Wellington township is 2.1 km southwest (population approx. 4,096 per 2021 Census)
- Wellington Solar Farm is 640 m north of the BESS footprint
- A small cluster of large-lot residential properties is northeast across Twelve Mile Road
- Closest residential dwelling is approx. 880 m from the BESS footprint
- Macquarie Correctional Centre is 1.78 km north of the site
- Closest sensitive receptors (schools, childcare centres, hospitals) are more than 2.1 km away in Wellington

3.1.3 Site layout enhancements

The updated site layout supports emergency access and fire protection, in line with FRNSW and HIPAP2 guidelines. The design includes:

- Perimeter hardstand for FRNSW vehicle access and clear paths for staging
- Internal access roads linking fire tanks, switch rooms and the BESS compound
- Clear demarcation of fire infrastructure including hydrants and boosters

- Dedicated firewater tank with tanker refill access point
- Separation distances maintained between all buildings, BESS Cubes and site boundaries

3.2 Fluence BESS fire safety

3.2.1 Overview

The Project will be installing the Fluence battery system. The Battery is assembled within the factory and arrives with a small charge and largely a plug-in type of arrangement. The product is fitted with a range of systems that manage the battery and receives and responds to various alerts. The Battery Management System (BMS) can be regularly updated as new technologies or learnings are introduced into the software.

The Fluence system is provided with a range of Manuals that address installation, maintenance and safety. The existing Manuals outline the outcomes of the various tests including UL9540A that demonstrates that the design of the system meets the requirements of UL9540.

The Units are fitted with a range of sensors that connect through a SCADA system to a monitoring centre. The sensors will detect various activities that may allow a cell to commence the process to go into thermal runaway if no intervention occurs. Due to the remote monitoring capability, the monitoring centre can remotely commence shut down procedures if required. The Units are also fitted with gas detection devices and an E-stop system that allows for the Unit to be shut down externally.

Table 4 - Overview of fire safety systems

Fire Safety System	Description
Battery Management System (BMS)	The BMS constantly monitors cell and pack level voltage, temperature, State of Charge (SOC), and other parameters to ensure early detection of pre fault conditions, and immediate detection of fault events. Should any parameter exceed a permissible value, the BMS will disconnect the effected Units and send an alarm to the Monitoring Centre.
Emergency Stop (Estop)	Each Unit contains Estop buttons that when pushed, will immediately commence shut down, and the BMS will isolate the battery strings from the main system bus.
Fire detection and alarms	The Unit is equipped with smoke and heat detectors calibrated to detect early signs of fire. The Unit contains both an audible fire alarm and visual fire strobe located on the outside of the Unit. If the smoke and heat detectors are triggered, both alarms will activate, and corresponding alarms will be sent to the Monitoring Centre through the SCADA system.

Emergency system shutdown	In the event of an emergency on site, the Unit can be shut down locally, or remotely. A system shutdown will result in electrical isolation of the battery strings and cessation of battery charging or discharging.
IP Rating	The IP (Ingress Protection) rating for this product is IP55. The rating is defined by the international standard EN 60529 (British Standard BS EN 60529:1992). The first digit relates to the ability for solids to enter the enclosure and the second digit indicates the ability for liquids to enter the enclosure. The IP55 rating is classified as: • Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the safe operation of the equipment. • Water projected by a nozzle (6.3 mm) against enclosure from any direction shall have no harmful effects.

The fire safety systems (where applicable) will be connected to the sites uninterruptible power supply UPS which will provide power supply as per the requirements of NFPA72.

3.2.2 Large scale fire test

In 2023, Fluence undertook a large scale fire test. The test ensured that 52 cells within the battery module initiated thermal runaway.

The main outcome of the test was that there was no fire spread between the cubes when separated in accordance with the manufacturer specifications. There were very minor temperature changes in the adjoining cubes. The outcome of the large fire test indicates that the design of the cubes to prevent fire spreading either out of the initiating cube or impacting on an adjoining cube is highly unlikely.

The test report is available at Appendix C.

3.2.3 Off gassing and smoke

In the unlikely event that a BESS Cube goes into thermal runaway, it is certain that the battery will release gases that are flammable. The cell and module UL9540A test reports indicate the products that are emitted from the thermal runaway event. During both tests, the gases did not ignite and as such there is no analysis of any smoke.

This assessment considers the impact on staff, contractors and firefighters during a thermal runaway event.

Test results

The UL9540A test has identified the composition of the gases that are emitted from the cell and module during a test. The results of the cell and module tests are consistent, and Table 3 provides the module test results. The dominant products within the gases emitted during a thermal runaway event are predominantly Hydrogen (46%), Carbon Dioxide (29%), Carbon Monoxide (11%), Methane (6%) and Ethylene (3%).

Table 5 - Gas composition of a thermal runaway event (results from UL9540A test report)

Gas		Measured %
Carbon Monoxide	CO	11.416
Carbon Dioxide	CO_2	29.352
Hydrogen	H_2	46.707
Methane	CH_4	6.196
Acetylene	C_2H_2	0.107
Ethylene	C_2H_4	2.856
Ethane	C_2H_6	1.073
Propadiene (Allene)	C_3H_4	0.002
Propene	C_3H_6	0.530
Propane	C_3H_8	0.296
-	C4 (Total)	0.528
-	C5 (Total)	0.134
-	C6 (Total)	0.013
1-Heptene	C_7H_{14}	0.006
Benzene	C_6H_6	0.011
Toluene	C_7H_8	0.001
Dimethyl Carbonate	$C_3H_6O_3$	0.652
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.121
Total	-	100

The products generated from a thermal runaway event are considered dangerous to humans and consideration is required to ensure staff, contractors and firefighters are able to evacuate or approach the location of the thermal runaway event safely. However, the following assumptions are relied upon in the assessment of the risk:

- Staff, contractors and firefighters will know that a thermal runaway event has occurred. Staff and Contractors will receive notifications from the Control Centre informing them of the alarms that have been triggered well prior to a thermal runaway event occurring. They will have multiple opportunities to consider evacuation from the site and the implementation of the EMP.
- Firefighters when arriving at the site, will have the ability to source weather information both current and forecast to then determine the strategy of either approaching the thermal runaway event or to remain away from the site.
- Firefighters will likely respond with air sensing equipment or be able to source the equipment to monitor the gases resulting from the thermal runaway event.
- Firefighters will respond with breathing apparatus, chemical and gas suits and will be able to undertake an initial assessment of the site, protected from inhaling gases.
- The UL9540A and other testing indicates that it is unlikely for a thermal runaway event to occur that results in the loss of the cube. The testing at the unit level (Appendix A) indicates that the fire has not spread to adjoining cells and modules. The reasons for this include the design of the casing around the cells and modules preventing fire spread and the thermal mass of the casing that is preventing the temperature in the adjoining cells and modules to increase to its thermal runaway trigger point.
- Firefighters will be familiar with the site and attended site familiarisation opportunities. They will also have received training from their fire agency on the response to large scale BESS incidents.

The assessment of risk relating to the exposure of off gassing and smoke to staff, contractors and firefighters has indicated a low residual risk. It is acknowledged that the management of this risk involves early detection of the conditions that may lead to a thermal runaway event and the correct procedures being followed by on-site personnel including staff, contractors and firefighters.

The treatments proposed will both reduce the risk of a thermal runaway event and ensure that onsite personnel have multiple opportunities to make informed decisions.

3.3 Power Transformers

The selection of the power transformers is largely influenced by their ability to resist fire ignitions and to limit fire spread within the unit. Power transformers will use synthetic biodegradable insulation with a fire point above 310° C and flash point above 250° C.

The power transformers are arranged to achieve recommended clearances in *AS 2067 Substations and high voltage installations exceeding 1 kV a.c.* to allow safe egress of personnel and minimise the propagation of fire to un-faulted components. The transformers are provided with appropriate oil bunding, containment and/or separation systems to meet environmental and standard requirements including but not limited to AS 2067 and relevant parts of *AS 1940 - The storage and handling of flammable and combustible liquid*s.

The type of equipment and the safety systems are outlined in Table 6.

Table 6 - Transformer oil details.

Equipment item	Separation distance to other infrastructure	Australian Standard separation requirement	Compliance	Layout reference
330kV/33kV/33 kV, 340MVA oil type transformer	The WBESS main power transformer required clearances have been considered in the current WBESS 330/33 kV substation design. This aligns with the AS 2067.2016 standard specified requirements and AS 1940 standard specified requirements. These clearance contours can be found in the 5987-321-7000 Rev E (1541-DRW-FLN-03-005) document. All transformer bunds are designed as per AS1940. The oil water separator which will be provided for the main transformer is the TS Oil Water Separator from Clean water or an equivalent product.	AS 2067. 2016 AS1530	*Yes*	1541-DRW-FLN-03-005 5987-222-1000 Rev C

	The switch room is more than 30m away from Main Tx – as shown in attached PNG file The materials utilised for the external walls of the switch-room is 12 mm GRC (refer attached construction notes 5987-222-1000 Rev C). The external walls have been tested to AS1530, fire assessment report is attached for reference. All internal and external surfaces of the switch-room are non-combustible.			

3.4 Dangerous Goods Quantities

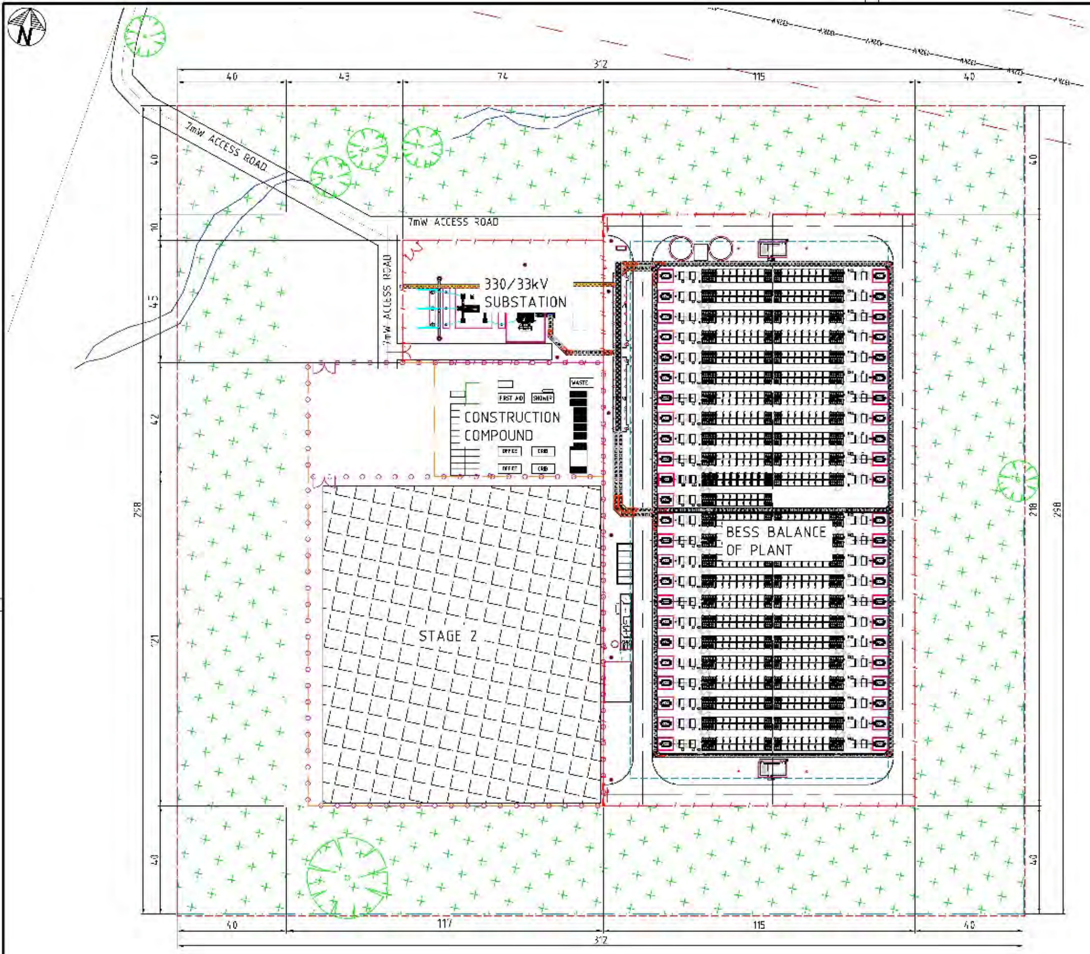
The dangerous goods quantities proposed for the site are as per the table below. The quantities are based on manufacturer design data and BESS supplier datasheets. Variations within ±10 % may occur due to module state-of-charge and maintenance conditions.

Table 7 - Dangerous goods summary

Dangerous Good	Description / Use	Packaging/ Container Type	Storage Location	Average Quantity (L or kg)	Maximum Quantity (L or kg)	Dangerous Goods Class	UN Number
Lithium-ion battery modules	Contained within BESS units	Fixed modules within enclosures	Within Cube enclosures	5600kg (per unit)	5648kg (per unit)	Class 9	UN 3480
Electrolyte (within cells)	Non-aqueous organic solvent mix	Sealed in modules	Within Cube enclosures	1960kg (per Cube)	2240kg (per Cube)	Class 3	UN 1993
Power Transformer oil	Mineral oil within transformers	Sealed system	Transformer compound	75000L (per unit)	75000L (per unit) 75000L total project (qty x 1 unit)	N/A	N/A
Core Transformer oil	FR3 Ester oil within	Sealed system	Transformer compound	4350L (per unit)	4350L (per unit)	N/A	N/A

Dangerous Good	Description / Use	Packaging/ Container Type	Storage Location	Average Quantity (L or kg)	Maximum Quantity (L or kg)	Dangerous Goods Class	UN Number
	transformer s				204450L total project (qty x 47 units)		
Chiller R-104A	Refrigerant gas within the BESS Unit		BESS Unit	2.4 kg per BESS Unit (940 Cubes) = 2,256kg.	2,256kg	Class 2.2	2857
HVAC R-134A	Refrigerant gas within the BESS Unit		BESS Unit	0.22kg across 940 cubes = 206.8kg	206.8kg	Class 2.2	3159
Fire suppression unit – Potassium Nitrate	Fire suppressant within the Cube.		BESS Unit	1kg per canister = 940kg.	940kg	Class 5.1	3268

It should be noted that quantities of dangerous goods will be isolated, and the products listed above are largely stored within the Unit and are constantly in use. During maintenance periods, quantities will be brought on site if required to replace the existing products.



LEGEND

- PROJECT BOUNDARY
- BESS SUBSTATION & BALLANCE OF PLANT
- STAGE 2
- EXISTING EASEMENT
- EXISTING OVERHEAD LINE
- FENCE
- TEMPORARY CONSTRUCTION FENCE
- LANDSCAPING ZONE (40m)
- BOUNDARY CLEARANCE (RFS 10m)
- LANDSCAPING (POST CONSTRUCTION)
- EXISTING TREES TO BE RETAINED

SCALE 0 8 16 24 32 40 80
SCALE 1:800
MGA55 GDA2020

NOTES:

1. ALL DIMENSIONS IN METRES UNLESS NOTED OTHERWISE.
2. COORDINATE SYSTEM IS MAP GRID OF AUSTRALIA ZONE 55 USING GDA 2020 DATUM.

DOCUMENT No. 1541-DRW-FLN-01-002

AMPYR
FLUENCE
A Siemens and AES Company

REFERENCE DRAWINGS

DRAWING NUMBER	DRAWING TITLE
5987-321-8000	BESS EQUIPMENT LAYOUT
5987-321-7000	330/33kV SUBSTATION LAYOUT
5987-321-0002	CONSTRUCTION COMPOUND
5987-321-0000	OVERALL SITE LAYOUT

REVISIONS & APPROVALS

REV	DATE	DESCRIPTION	DRN.	CHK'D.	C.E.	CLIENT
D	06.07.25	BAY MOVED	MC	CM	RAJ	
C	14.03.25	SUBSTATION & BESS SITES MOVED	MC			
B	06.05.24	CONSTRUCTION COMPOUND	MC			
A	18.04.24	PRELIMINARY	MC			

SCALE 1:800

	APPROVED	DATE
DRAWN	MC	18.04.24
CHECKED	CM	05.06.25
DESIGNED	MC	18.04.24
RJE C.E.	RAJ	05.06.25
CLIENT L.E.		
CLIENT P.E.		
CLIENT M.E.		

APPROVALS

PRELIMINARY

RJE Global
A Lighthouse Industries Company

ACAD FILE:S-RJE (A01-2MB)

FLUENCE ENERGY

SIZE A1

WELLINGTON 300MW BESS
OVERALL PROJECT
GENERAL SITE
LAYOUT

PROJECT No.	DRAWING No.	REV.
5987	5987-321-0001	D

4 Fire Hazards

4.1 Introduction

The identification of hazards is influenced by a range of inputs including the following:

- Information supplied by the developer including client specifications and fire test reports as per UL9540A.
- NFPA 850 - Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations (NFPA850)
- NFPA 855 - Standard for the Installation of Stationary Energy Storage Systems (NFPA855)
- UL9540 - Energy Storage Systems and Equipment
- UL9540A – Test Methods for Evaluating Thermal Runaway Fire propagation in Battery Energy Storage Systems (UL9540)
- Fluence Large Scale Fire Test Report

The identified standards are used as a guide. The design, manufacture, installation and maintenance of the equipment that is installed within this project is

4.2 Hazard analysis

Utilising the available information, the identified hazards include the following:

Table 8 - Hazard analysis

Hazard title	Detail	Description
Fire and explosive hazards	Combustible/flammable products	The BESS installation includes various combustible and/or flammable products that includes dangerous goods including lithium ion and transformer oils. The lithium-ion casing and other equipment within the BESS Unit can support fire activity. Lithium ion when it reaches are certain temperature can commence the off-gassing phase. The produced gas is considered as toxic and flammable.
	Fire spread between units	There is the potential for fires that originate within a Unit to then spread to other Units or infrastructure.
	Thermal Runaway	Thermal runaway is the result of a chemical reaction within a lithium-ion battery where the cell produces more heat than can be dissipated by the colling system.

Hazard title	Detail	Description
	Bushfire	There is the potential for a bushfire to be burning in the surrounding landscape and threaten the site or a fire that starts within the site spreads externally to the site.
Chemical hazards	Liquid hazards	At a BESS site, various pieces of equipment contain chemicals that are classified as either hazardous substances, dangerous goods or both. A leak of liquids can cause health and safety issues for onsite personnel and emergency responders.
	Toxic gases	Lithium ion when it enters the off-gassing phase can generate gases that are both flammable and toxic.
Electrical hazards	Electrical shock	The BESS Units and other infrastructure are considered 'live' and any unauthorised access or people traveling through the site who are not aware of the dangers could be exposed to an electrical shock.
	Arc flash	Arc flash can occur if site personnel or emergency service responders walk too close to an area that has been identified as potentially causing n arc flash.
	Stranded or stored energy	Even when the BESS Unit has been shut down, they will still store energy. This also occurs if they are involved in a fire or other damage.
Physical hazards	Burn hazards	High temperature surfaces are present within a BESS site and if a person comes into contact, they can receive a burn.
	Damage	During transport and installation, the Unit can be mishandled or damaged causing faults to occur within the Unit.

4.3 Fire Hazard Scenarios

4.3.1 Fire and explosive hazards

As with any infrastructure, there is always the potential for fires to ignite and spread under the right conditions. The most discussed hazard is a fire involving lithium-ion batteries within the BESS Units. The common causes of fires within lithium-ion batteries is overheating. Overheating can be caused by a range of precursors including overcharging, mechanical damage, external short circuit, forced discharge and other activities. Overheating can also occur because of a fire in an adjacent Unit or equipment or bushfire.

The outcome of an overheating event where intervention by the Battery Management System does not occur, can be off gassing and thermal runaway. If the BESS Unit enters these phases, it is likely that the fire will burn until the Unit has been consumed. Advice from the manufacturer is that the Unit should not be opened when it is off-gassing or burning and no action should be taken in relation to the actual Unit until it has burnt out or the off-gassing process has completed. This may take hours and in some cases days before the Unit can be considered safe.

Testing undertaken by Fluence, has determined that the ability for fire spread to occur between the BESS Units is considered highly unlikely. The BESS enclosure has been designed to contain fires and to limit their spread potential. This has been supported through large scale fire testing as described within this report.

A bushfire burning within the surrounding landscape can cause embers to land on and around the site. The provision of an Asset Protection Zone around the entire site along with the management of the vegetation screen area will reduce the potential for bushfire impact to occur.

4.3.2 Chemical hazards

Throughout the site there are areas where the presence of chemicals may cause a risk to site personnel and fire fighters. The chemicals are all contained within equipment, and it would be highly unlikely for these to leak without any alarm or notification to the site operators.

The main chemical hazards include:

- Lithium ion within the batteries.
- Refrigerant
- Oils contained within the transformers and other equipment
- Toxic gas as a result of a thermal runaway event.

Apart from the toxic gas release, the other chemical hazards are all contained within equipment and cannot come into contact with people apart from maintenance periods. Even during maintenance periods, the likelihood of chemicals coming into contact is limited.

If a thermal runaway event occurs, the release of toxic gases can occur if a fire has not occurred. The toxic gases are highly flammable due to the high levels of Hydrogen. Table 5 outlines the gas composition of a thermal runaway event. Depending on the number of cells that enter the thermal runaway process, the amount of gas can vary that has been released.

Table 7 provides an overview of the chemicals on site, noting that many of these will be inside infrastructure and not readily accessible unless an event occurs. Due to the nature of testing, gas compositions are not likely to be significantly different from the composition shown in Table 5 because of cross-reacting and producing byproducts.

Table 9 - Chemical likely to be on site

Chemical	DG Class	Likely quantity	Use	Key Hazards	Source Document
Lithium Ion Phosphate	Class 9	Contained within the Battery Unit.	Battery cell	Chemically stable but hazardous if damaged	Fluence Cube Safety Datasheet
Lithium hexafluorophosphate	Class 8	Contained within the Battery Unit.	Electrolyte salt	Toxic if swallowed. Causes severe skin burns and eye damage. Causes damage to organs through prolonged or repeated exposure if inhaled	Fluence Cube Safety Datasheet
Dimethyl carbonate	Class 3	Contained within the Battery Unit.	Electrolyte solvent	Flammable liquid and vapour	Fluence Cube Safety Datasheet
Ethylene Carbonate	N/a	Contained within the Battery Unit.	Electrolyte solvent	Causes serious eye irritation	Fluence Cube Safety Datasheet
Diethyl Carbonate	Class 3	Contained within the Battery Unit.	Electrolyte solvent	Flammable liquid and vapour	Fluence Cube Safety Datasheet
Ethyl methyl carbonate	Class 3	Contained within the Battery Unit.	Electrolyte solvent	Highly flammable liquid and vapour.	Fluence Cube Safety Datasheet
Propylene carbonate	N/a	Contained within the Battery Unit.	Electrolyte solvent	Causes serious eye irritation	Fluence Cube Safety Datasheet

Chemical	DG Class	Likely quantity	Use	Key Hazards	Source Document
Acetylene black	N/a	Contained within the Battery Unit.	Conductive carbon additive	-	Fluence Cube Safety Datasheet
Hexafluoropropylene-vinylidene fluoride copolymer	N/a	Contained within the Battery Unit.	Binder (PVDF-type)	-	Fluence Cube Safety Datasheet
Metallic lead, lead alloy with traces of AS, SB	Class 9	Part of UPS.	Lead/acid battery and UPS ingredients	May damage fertility or the unborn child. May cause harm to breast-fed children. Harmful if inhaled. Harmful if swallowed. Causes damage to organs through prolonged or repeated exposure if inhaled. Suspected of causing cancer.	Fluence Cube Safety Datasheet
Lead-containing battery paste	Class 9	Part of UPS	Lead/acid battery and UPS ingredients	May damage fertility or the unborn child. Harmful if swallowed.	Fluence Cube Safety Datasheet
Sulphuric acid	Class 8	Part of Ups	Lead/acid battery and UPS ingredients	Causes severe skin burns and eye damage. May be corrosive to metals.	Fluence Cube Safety Datasheet
Potassium nitrate	Class 5.1	Contained within the Battery Unit.	Aerosol fire suppression ingredient	May intensify fire; oxidizer	Fluence Cube Safety Datasheet

Chemical	DG Class	Likely quantity	Use	Key Hazards	Source Document
Dicyandiamide	N/a	Contained within the Battery Unit.	Aerosol fire suppression ingredient	-	Fluence Cube Safety Datasheet
Phenol-formaldehyde resin	N/a	Contained within the Battery Unit.	Aerosol fire suppression ingredient		Fluence Cube Safety Datasheet
FR3 Fluid (Soy-based)	N/a	Contained within Transformers	Transformer oil	-	FR3 SDS
HyVolt I Oil	Class 3	Contained within Transformers	Transformer oil	Aspiration and lung hazard	HyVolt I SDS
Chiller Coolant	N/a	Contained within the Battery Unit.	HVAC refrigerant	Toxic if ingested or inhaled	Fluence Cube Safety Datasheet
Chiller Refrigerant (Envicool) - R134a	Class 2.1	Contained within the Battery Unit.	HVAC refrigerant	Mildly toxic. Asphyxiation if excessively inhaled. Contact with the liquid form may cause frostbite.	Fluence Cube Safety Datasheet
HVAC Refrigerant (Envicool) - R410a	Class 2.2	Contained within the Battery Unit.	HVAC refrigerant	Asphyxiation if excessively inhaled. Contact with the liquid form may cause frostbite.	Fluence Cube Safety Datasheet
Chiller Refrigerant (Bergstrom) - R32		Contained within the Battery Unit.	HVAC refrigerant	R32 can explode if confined; others displace oxygen and require monitoring after leaks	Fluence Cube Safety Datasheet
HVAC Refrigerant (Bergstrom) - R513A		Contained within the Battery Unit.	HVAC refrigerant	Asphyxiation if excessively inhaled. Contact with the	Fluence Cube

Chemical	DG Class	Likely quantity	Use	Key Hazards	Source Document
				liquid form may cause frostbite.	Safety Datasheet

4.3.3 Electrical hazards

Due to the nature of the development, electrical hazards are an ongoing safety consideration. The importance of ensuring people who are not familiar with the site to be escorted and supervised is critical to ensuring electrical caused health impacts are limited.

The most important message for responding firefighters is that even if the emergency stop function has been activated, the BESS Units will still contain energy, and they should always be treated as if they are live. The absolute importance of waiting for a site technician to be at the site before the fire brigade enters is critical and will be clearly articulated within the Emergency Information Book and Emergency Management Plan.

4.3.4 Physical hazards

The physical hazards include burns and the effects of any damage that occurs to the equipment. As described previously, the importance of people being within the site being supervised is critical to their personal safety. This includes firefighters who are responding to an emergency.

The manufacturers design guidelines including installation clearly outlines the procedures that must be followed in the process of transporting and installing the BESS Units. Key safety measures must be implemented to ensure the BESS Unit is not damaged through this process as this may cause failures to occur that can result in thermal runaway or other emergencies.

5 Fire Consequences

5.1 Introduction

The hazards identified in Section 4 can result in consequences associated with fires. This consequence analysis has been undertaken using a qualitative approach. The types of fire events include:

- Fire involving a Cube, including generation of heat radiation, overpressure effects and toxic combustion products.
- Fire involving medium/high voltage equipment, including heat radiation and overpressure effects from arc flash.
- General fires in buildings including those housing electrical equipment and cabling.
- Bushfire burning in the local area.

5.2 Consequence analysis

5.2.1 Fires involving a BESS Unit

Fluence have undertaken a range of fire tests to demonstrate that the design of the BESS Unit complies with UL9540 and NFPA855. Both Standards identify UL9540A as the appropriate test standard for the performance of the Units when forced into a thermal runaway event. In addition to the UL9540A testing (Appendix C), Fluence have also undertaken a large-scale fire test (Appendix D) which involves the Unit being exposed to sufficient heat to force the entire Units battery cells into thermal runaway.

The large-scale fire test was based on the following configuration shown in Figure 3. The test was setup to include a series of thermocouples both within the Unit and between the Units along with video cameras interlay and externally. The thermocouples record the levels of radiant heat that is experienced at various points and throughout the test.

The most important aspect of the test for this report is to identify the data that indicates the amount of temperature and radiant heat impact on and within an adjoining Unit. This indicates the potential for any fire spread to occur when the Units are placed in a similar configuration. The separation between the Units for this test was 7 inches (177.8 mm) at the closest point. Figure 3 shows the typical separation between the Cubes at their closest point.

The result of the test indicates that the devices recording radiant heat on an adjoining Unit were more influenced by direct sunlight than the effects of the fire within the initiating Unit. One of the recording devices did indicate a slight rise on two occasions. The radiant heat impact is shown in Figure 5 and indicates that the maximum radiant heat impact on the adjoining Unit was approximately 0.4 – 0.5 kW/m². For context, the likely radiant heat that a person will fill when standing in direct sunlight on a warm summer's day is approximately 1.5 kW/m².

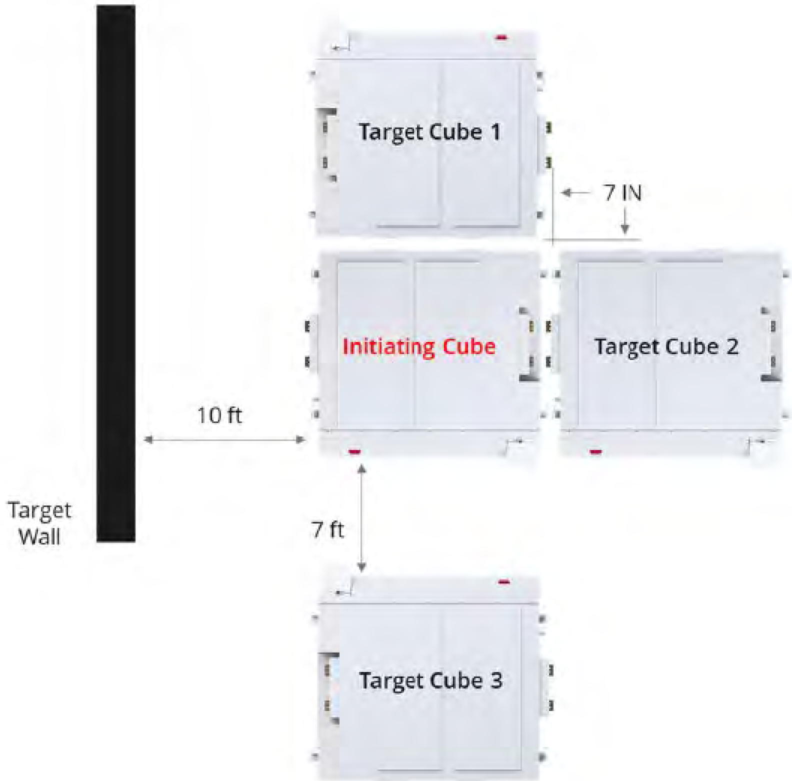


Figure 2 - Large scale fire test layout (sourced from AESC report)

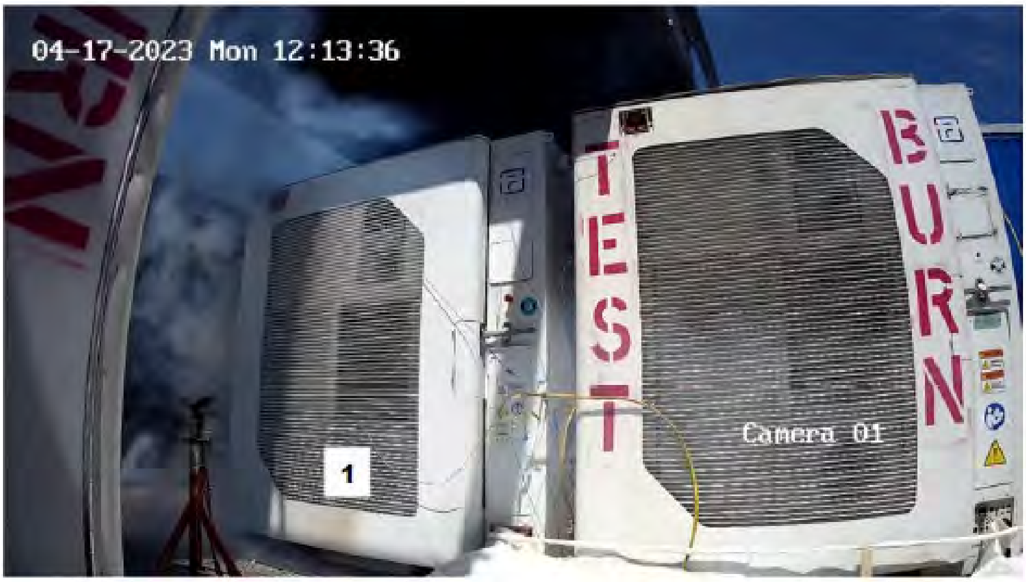


Figure 3 - Photo showing smoke releasing from the Unit during the test and the 7 inch gap (sourced from AESC report)

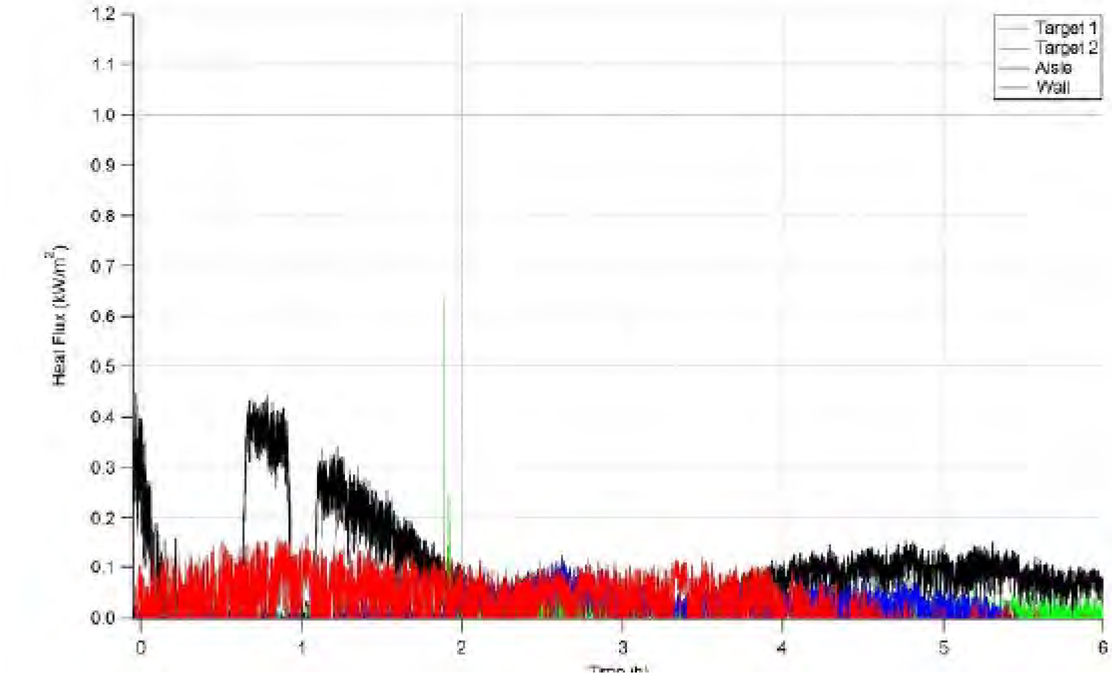


Figure 4 - Radiant heat output during the large scale fire test (sourced from the AESC report)

The temperature within the Units surrounding the initiating Unit did not exceed 30°C. this is well below the critical temperatures where an LFP battery will likely show signs of distress and entering the off gassing and thermal runway process.

As outlined previously, the test demonstrated that the presence of flames externally did not occur, and this is due to the improved Unit design which limits the ability for flames to emit the Unit. This further ensures the integrity of the Unit and the need to consider the impact of radiant heat from flames emitting from the source Unit is not required. This is supported by the various test results that indicates that the fire was contained to the Unit and there was limited to no external radiant heat impact recorded and the temperature rise in the adjoining Units was limited.

In the context of gases that were released from the Unit during the fire test, the AESC report contained in Appendix D outlines the types of gases and the quantities that were captured.

5.2.2 Environmental condition impact

As outlined within the FRNSW Guideline, consideration must be given to the impact of environmental conditions. For this development, the environmental conditions that are required to be considered is associated with wind and its impact on spreading fires to an adjoining Unit. These types of conditions will also result in FRNSW potentially having difficulties with gaining access to the area and if required, protecting exposures.

It should be noted that the Fluence Cube has successfully demonstrated that the impact of wind on a fire would be negligible as approved for the Lidell and Broken Hill BESS developments.

In accordance with Section 5.6.5 of the FRNSW Guideline, a hand-based analysis was carried out to quantify the impact of wind on flame behaviour and radiant heat transfer for the BESS development. The analysis considered the combined effects of flame tilt, drag and downwind displacement, and assessed how these influence separation requirements and potential exposures.

Unlike software fire models, the approach here is deliberately transparent and conservative, ensuring repeatability for regulatory review.

Methodology

A hand-based 'solid-flame' radiation model was applied in accordance with HIPAP 4 (See Appendix 1) to estimate the radiant exposure between adjacent BESS enclosures when subjected to wind-driven flame tilt. As outlined in HIPAP 4 (see Appendix 1), the heat-flux levels used for injury, damage and propagation criteria have been adopted as reference benchmarks in the absence of industry-specific propagation limits.

The outputs of the analysis are contained within Appendix G.

The approach idealises the burning enclosure as a rectangular radiating surface that tilts under wind, with heat transfer to neighbouring façades determined using view-factor geometry. No computational fire modelling was undertaken; all equations and assumptions are transparent and traceable.

Geometric Configuration

- Front (door-to-door) spacing: 3.5 m (main access aisle).
- Back-to-back and side-to-side spacing: 150 mm (shared-wall condition).
- Enclosure height: 2.6 m
- Enclosure width/depth: 2.6 m.

Because the rear and side façades are effectively contiguous, radiant coupling through these interfaces is negligible. The door-to-door orientation therefore governs potential radiant exposure and has been used for all quantitative evaluation.

$$L_f = k\,H, \qquad \theta = \tan^{-1}\left(\frac{U}{U_c}\right), \qquad \dot{q}'' = \varepsilon\,\sigma\,T_f^4\,\frac{\Omega}{\pi}$$

Governing equations

Where:

Symbol	Definition	Value / Source
Lf	Flame length	(kH)
k	Flame-length factor	1.2 (derived from SAFE Labs full-scale testing)
H	Enclosure height	2.6 m
U	Wind speed	0 / 8.3 / 11.1 m/s (site wind-rose data)
Uc	Characteristic plume velocity	3 m/s
ε	Flame emissivity	0.9
Tf	Flame temperature	973 K (≈ 700 °C)

Ω	Solid-angle view factor	Calculated for a rectangular panel at separation
σ	Stefan-Boltzmann constant	5.67×10^{-8} W/m²K⁴

Assumptions and Justifications

- Flame length factor (k = 1.2 H): Conservative envelope based on SAFE Labs (2024) large-scale burn tests, where visible flame heights ranged ≈ 1.0–1.3 H.
- Flame temperature (T = 973 K / 700 °C): Chosen as a sustained-burn upper bound. SAFE Labs recorded external target temperatures < 30 °C, confirming the assumption is conservative.
- Emissivity (ε = 0.9): Typical for luminous hydrocarbon diffusion flames.
- Wind speeds: Selected from the Wellington site wind-rose datasets (9 am / 3 pm) to represent calm, moderate, and severe adverse cases.
- Acceptance limit: ≤ 20 kW/m² for durations ≤ 30 min – manufacturer/SAFE Labs criterion for preventing thermal runaway propagation.

Analysis

The methodology for this assessment was based on the flame being represented as a rectangular radiating surface, sized using a flame length factor $k = 1.2H$ where H is the enclosure height (2.6 m). Tilt was determined from the ratio of ambient wind velocity U to a characteristic buoyant plume velocity ($U_c = 3$ m/s), yielding a tilt angle $\theta = \arctan\,(U/U_c)$. This provided a rational basis for three wind cases:

Calm: 0 m/s (upright plume)

Moderate adverse: 8.3 m/s (≈ 30 km/h)

Severe adverse: 11.1 m/s (≈ 40 km/h)

The development of wind velocities was drawn from the wind roses for the Wagga Wagga weather station using the 9am and 3pm data.

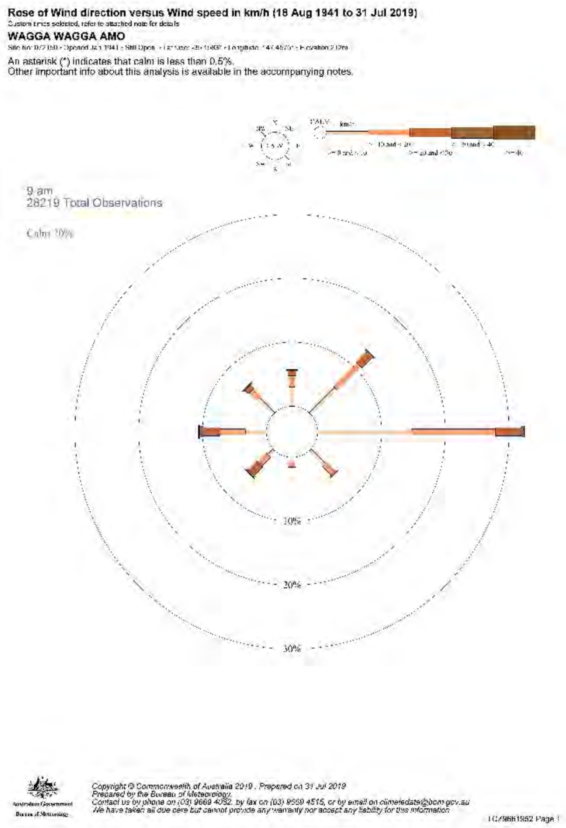


Figure 5 - 9am wind rose

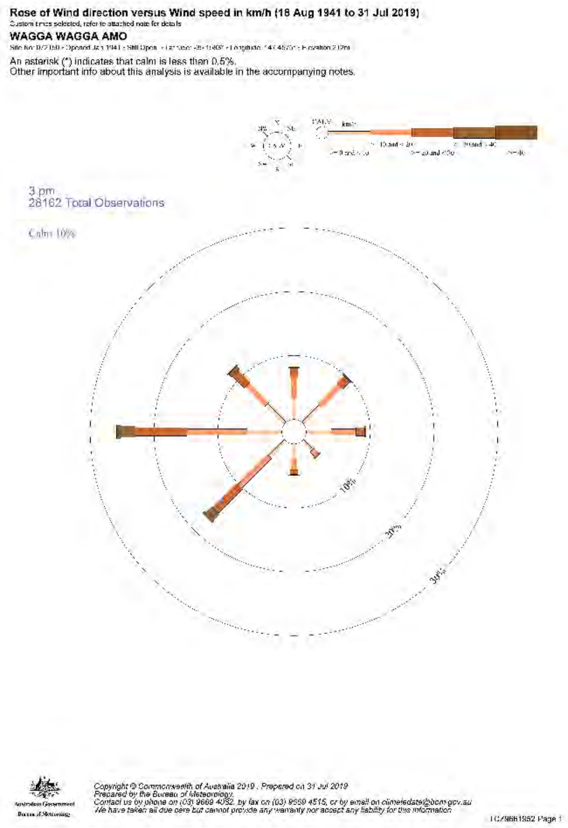


Figure 6 - 3pm Wind Rose

For each case, the effective separation was reduced according to the downwind flame displacement, and the solid-angle method was applied to determine the view factor between the flame panel and a point on the facing façade at 1.5 m above grade (representative of firefighter tenability). Radiant flux was then calculated as:

$$q'' = \varepsilon \sigma T^4 \frac{\Omega}{\pi}$$

with flame emissivity $\varepsilon = 0.9$, flame temperature $T = 973$K (≈ 700 °C), and Ω the solid angle subtended at the observation point.

The result of this analysis is summarised below:

- **Calm** (0 m/s): radiant heat flux of 7.1 kW/m²
- **Moderate** (8.3 m/s): radiant heat flux approaching 19.2 kW/m²
- **Severe** (11.1 m/s): radiant heat flux in the range 19.9 kW/m²

The outcome of the analysis can be summarised as:

- Under calm or typical day conditions, the radiant flux at the adjacent unit remains near or below the 12.5 kW/m² threshold, meaning secondary ignition of non-combustible façades is unlikely.

- Under adverse wind (≥ 8 m/s), the flux increases but remains broadly consistent with observed test outcomes, with transient peaks close to 22 kW/m². This remains below levels associated with assured propagation to non-combustible construction.
- The effective gap is notably reduced under strong winds, but the design separation of 3.5 m continues to provide effective separation between the BESS Units.
- Radiant heat fluxes reduce rapidly with distance, and firefighter tenability is not exceeded beyond 2–3 m from the façade.

5.2.3 Fire involving equipment

Fires involving other major electrical equipment on site, such as transformers and inverters, are recognised as a credible risk. These events are typically associated with internal failure or loss of containment of insulating or cooling oils (e.g. FR3 natural ester or HyVolt mineral oil). The most common contributing factors include poor or delayed maintenance, particularly in relation to oil quality, seals, or thermal performance.

In response to FRNSW's comment and the requirements of HIPAP2, the following items are noted.

- A transformer fire is expected to be allowed to burn out, consistent with guidance for FR3 and HyVolt-oil filled transformers.
- Exposure protection to nearby infrastructure will be provided, if required, by firefighter intervention, separation distance, and hardstand buffers.

5.2.4 Radiant heat impact

Large-scale fire testing was undertaken, as detailed in Appendix C, which confirms that flaming combustion was confined entirely within the initiating unit. At no point during the test was external flaming observed. The flames remained internal and self-extinguished in less than one minute after ignition. There was no deflagration or detonation recorded throughout the event.

The test used water-cooled heat flux transducers placed between the initiating unit and the surrounding target cubes, as well as within the target cubes themselves and on a nearby exposure wall. These sensors showed no significant heat flux resulting from the internal fire. The only notable external increase occurred on the heat flux transducer nearest Target Cube 1, which detected two brief spikes. These correlated with the short duration of visible internal flames and measured only 0.225 kW/m² above background levels, which were primarily influenced by solar radiation rather than the fire itself. As detailed in Table 8, a 0.225 kW/m² increase in radiant heat exposure is considered negligible and an acceptable risk.

Thermocouples installed inside the target cubes also confirmed that temperatures remained well below levels of concern. No thermocouple in the target cubes recorded temperatures above 30°C during the test. These low readings suggest that any heat experienced by the surrounding units was more likely due to ambient weather conditions than heat transfer from the initiating unit.

Visual inspections following the test supported this data. There was no visible damage to the external structure of the adjacent cubes. Only soot staining was observed on a fire blanket in front of the initiating unit, attributed to smoke escaping through a cable penetration. Importantly, no physical signs of radiant heat impact were evident on the surrounding cubes or the target wall.

These findings demonstrate that the Fluence Cube's containment design is effective at limiting the release of flames and heat. The fire remained controlled within the unit, validating the post-test design modifications and confirming that radiant heat exposure to adjacent units or nearby exposures is negligible under worst-case failure conditions.

Table 8 indicates the radiation impact at various levels. The radiant heat determined from the large scale fire test indicates that the levels are well below what is deemed to be hazardous to personnel.

Table 10 - Radiant heat impacts summary

Heat Radiation [kW/m^2]	Effect
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will result)
12.6	Significant chance of fatality for extended exposure. High chance of injury After long exposure, causes the temperature of wood to rise to a point where it can be readily ignited by a naked flame Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failures Pressure vessel needs to be relieved or failure will occur
35	Cellulosic material will pilot ignite within one minute's exposure Significant chance of fatality for people exposed instantaneously

The BESS Units are constructed with a sheet of steel and an insulation layer to provide for the containment of radiant heat and flames within the Unit. This will also provide the protection from an external fire event onto the adjoining Unit. As the likely flaming activity external to the Unit is to be no more than seconds, the ability for fire spread to occur is considered highly limited.

5.2.5 General fires

Fires within the onsite buildings is a possibility. The main building types are the storage shed, 33kV switch room and the control room. Fires may be caused by electrical faults, poor maintenance or poor housekeeping.

The likely fire within the Control Room will start small and due to the fire safety systems installed within the enclosure including smoke detection systems will ensure that any detection of smoke will activate the fire alarm quickly. This alert will then be sent through the onsite monitoring systems to both the onsite personnel and the monitoring centre.

Any fires within the buildings are likely to be detected quickly and if onsite personnel are present, may be able to undertake first attack firefighting using the fire extinguishers. They will also contact emergency services as per the Emergency Management Plan to ensure the fire brigade responds as well.

The water supply is compliant with AS 2419.1 and includes:

- AS 2419.1-compliant suction connections and adapters

- A dedicated hardstand for firefighting vehicles
- Clear access for appliance entry and hose deployment
- Dual pump system
- 432,000 litres of fire water.

Likely Firefighting Scenarios – Ancillary Buildings

As identified earlier, ancillary buildings are fitted with smoke detection systems and audible alarms. These systems are expected to provide early notification of fire, allowing prompt first attack by trained personnel and notification to FRNSW.

In the event that FRNSW undertakes fire suppression, standard external attack techniques are expected. As a guide, 10 l/s is likely to support a minimum of two branches that would operate at approximately 500 l/m. However, it is acknowledged that modern fire appliances may have a monitor mounted on the appliance that would enable much greater flows. The expected flow rates and durations are outlined below.

Table 11 - Water Supply and Demand Analysis

Scenario Type	Flow Rate (L/s)	Expected Duration	Volume Required
Light attack (1 hose)	5 L/s	3 hours	54,000 L
Moderate attack (2 hoses)	10 L/s	2 hours	72,000 L
Heavy attack (4 hoses)	20 L/s	1 hour	72,000 L

The AS2419.1 fire hydrant systems provides sufficient capacity to support fire suppression efforts involving up to four hoses for 1 to 1.5 hours, or medium to light operations for up to medium to light attack for approximately 3 hours (assuming the branch is always on and operating at approximately 500 l/min, which is unlikely for a rural structure fire).

5.2.6 Bushfire in the local area

As with large areas of NSW, there is a risk of a bushfire burning in the surrounding landscape and under elevated fire danger conditions, travel towards the development. Due to the location of the BESS development in relation to the Solar Farm to the north and northwest and the Wellington township to the south and southwest, the development is, to some extent, protected from a bushfire travelling for long distances.

An indicator of bushfire risk within NSW is the Bushfire Prone Area mapping. This is outlined in Figure 6.

The likely bushfire scenario is for a bushfire starting in the local area and travelling towards the site. This would be in the area between Wellington and the BESS site. The bushfire scenarios are shown in Figure 7.

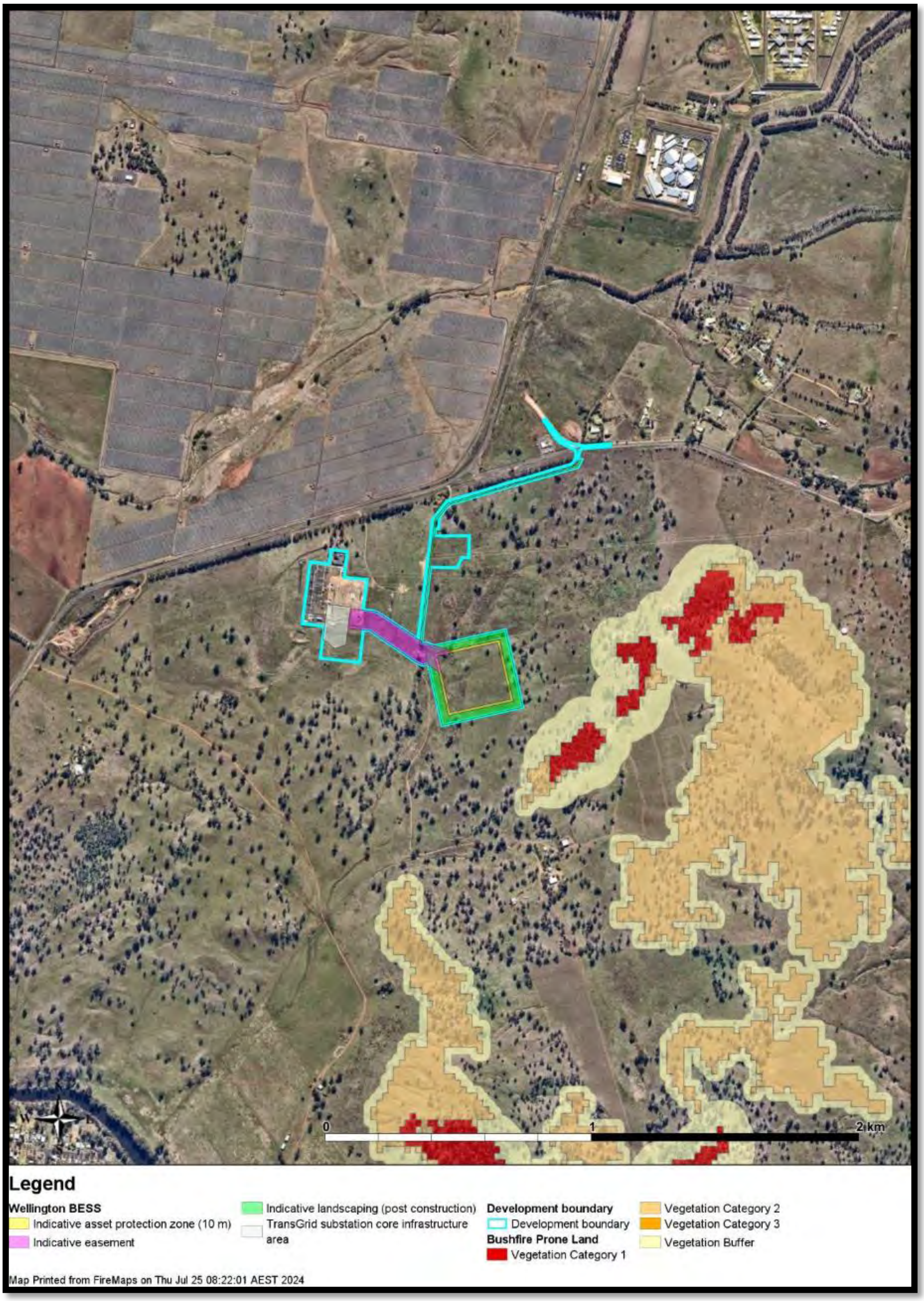


Figure 7 - Bushfire Prone Area in the local area

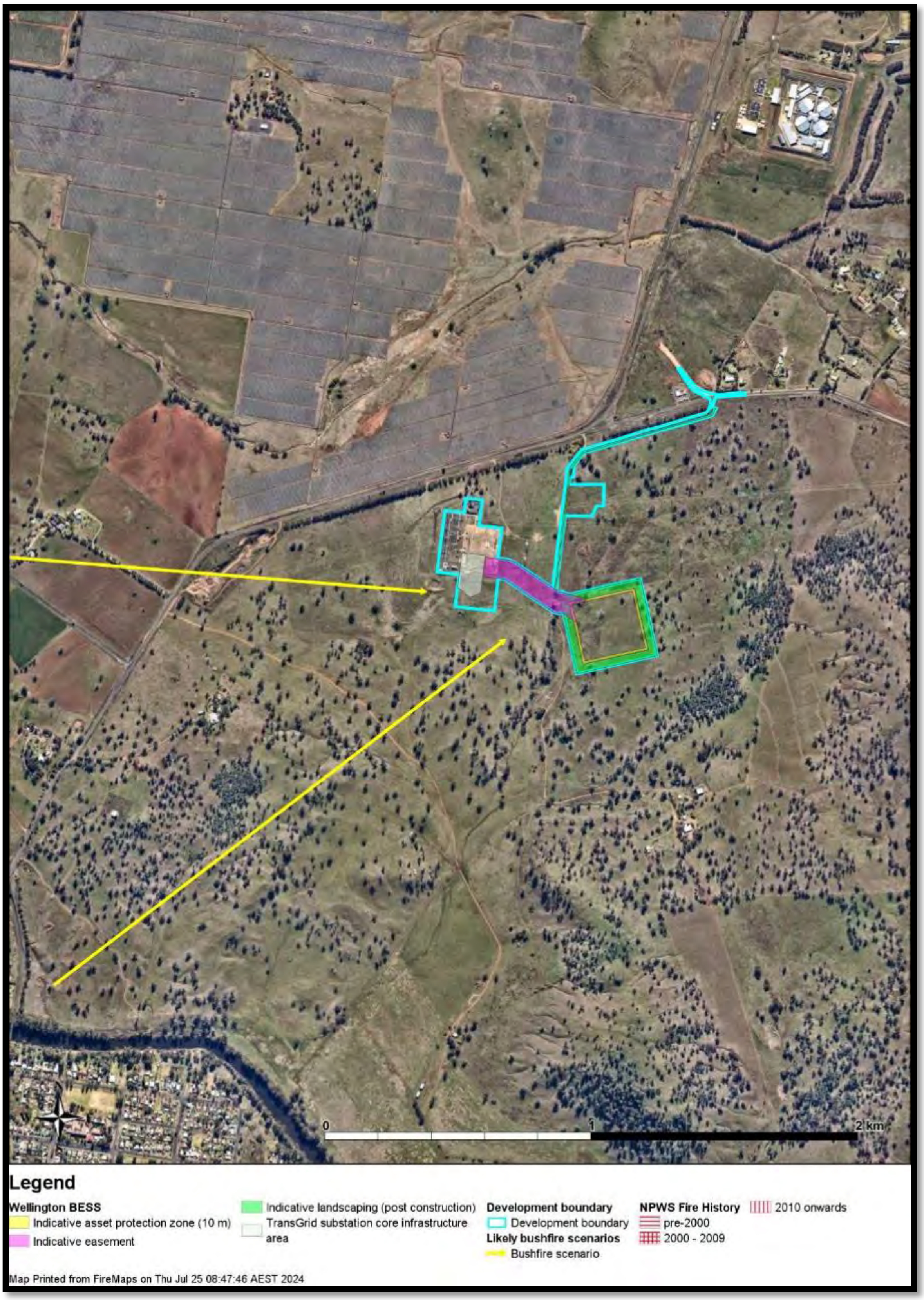


Figure 8 - Likely bushfire scenarios

5.3 Quantitative Risk Modelling

The Fluence Liquid-Cooled Cube underwent a large scale fire test performed by certified third-party laboratories including CSA Group. The tested system had a capacity of 745 kWh and used LFP chemistry. Testing was conducted under worst-case conditions, including 100% state of charge and the deliberate initiation of thermal runaway without active fire suppression.

The test results demonstrated that the system did not propagate fire to adjacent Cubes located only 7 inches (17cm) away and did not present a hazard from flame jets, projectiles or high radiant heat beyond the unit itself. There was no external structural failure, and gas emissions including carbon monoxide and hydrogen were passively ventilated. No deflagration or fire spread occurred.

While no formal consequence modelling has been completed, this full-scale physical testing satisfies the intent of HIPAP2 Section 2.3. The exposures to nearby targets, such as personnel, buildings, or other equipment have been evaluated under real test conditions. This avoids reliance on assumptions or probability-based methods.

Based on the test evidence:

- Fire propagation to adjacent Cubes is not expected.
- No explosion risk was observed or inferred.
- Exposure protection can focus on passive separation and firewater for nearby structures.

This supports a non-intervention strategy during a BESS Cube fire and provides a sufficient basis for risk justification of this project.

6 Fire Safety Strategy

6.1 Introduction

The fire safety strategy for the BESS development is influenced by the publications listed previously. These documents outline an approach to the management of fire risk.

The Fire Safety Strategy at its simplest involves the combined effect of multiple layers of protection that include prevention, preparedness and response initiatives. The protective layer also extends to multiple types of mitigations within each of the three categories.

In summary, the three layers includes the following:

Table 12 - Overview of the fire safety strategy

Prevention	Preparedness	Response
Battery Management System	Battery Management System	Battery Management System
Fuel breaks	Emergency Management Plan	Static water supply
Vegetation management	Staff training	Fire water containment
Site inductions	Site inductions	Fire extinguishers
F Stop system	Fire agency engagement and site tours	Emergency Management Plan
Battery characteristics and design	24/7 monitoring	Smoke detection systems
Site layout and reduced risk surroundings	Site security systems including CCTV	Suppression systems
Equipment design and safety systems.		Access roads for emergency vehicles
Battery enclosure design to prevent fire spread.		Emergency Information Container and Emergency Information Book
24/7 monitoring		F Stop system
Site security systems including CCTV		Deflagration and explosion management systems,
Maintenance of all fire safety systems, equipment and BESS Units.		Emergency response

Prevention	Preparedness	Response
		Fire Indicator Panels throughout the site
		Occupant Warning System

6.2 Prevention strategies

Prevention is the most critical of all activities within the fire safety strategy. The prevention of fires should always be the most important focus as it ensures the largest return on the investment. The prevention strategies outlined in Table 10 are considered further in this section.

6.2.1 Battery Management System

The Battery Management System (BMS) is the key monitoring system for the BESS Unit. It provides the ability to connect to the numerous sensors that are spread throughout the Unit that provide alerts and warnings if required to the central monitoring centre. The BMS, providing the communications networks are active, will transmit data to the monitoring centre including any fault messages. The system will also interpret fault or alerts and depending on the severity will either raise an alarm or commence shutdown procedures as per pre-configured arrangements.

The BMS will also obtain data from the fire monitoring systems including the smoke detection system and send alerts and act if required.

6.2.2 Emergency stop function

Each Unit contains Estop buttons that when pushed, will immediately commence shut down, and the BMS will isolate the battery strings from the main system bus. Whilst the Unit will continue to hold a charge, the charging function will be stopped immediately.

6.2.3 Emergency system shutdown

In the event of an emergency on site, the Unit can be shut down locally, or remotely. A system shutdown will result in electrical isolation of the battery strings and cessation of battery charging or discharging.

The battery Units will continue to hold a charge and will continue to maintain the operation of the cooling system and detection and suppression systems.

6.2.4 Design based on identified standards

The identified publications provide an approach to demonstrating that the site design can manage the risk of fire. The publications outline a range of requirements, and these have been implemented within this report.

In summary, the publications require the following to be implemented:

- Facility design to be reflective of the bushfire risk in the surrounding landscape.
- Emergency vehicle access and egress.
- Firefighting water supply.

- Design requirements for the BESS Units including detection and suppression systems.
- Fire breaks
- Emergency and fire management planning arrangements.

The above mitigation treatments are outlined within this report and the site plans.

6.2.5 Bushfire prevention

The development will include bushfire prevention measures that are aimed at limiting a fire starting within the development spreading to the surrounding landscape and to reduce the impact of a bushfire impacting the site. The key management strategies to reduce bushfire risk include:

- Setbacks from the boundary.
- Weed removal and vegetation management programs to be ongoing.
- Static water supply can also be utilised for bushfire protection.

The development conforms with Clause 8.3.5 of the NSW Rural Fire Service – Planning for Bushfire Protection 2019.

6.3 Preparedness strategies

Preparedness strategies that are outlined in Table 8 are aimed at ensuring both site personnel and responding emergency services are prepared for an event at the BESS site. The below list outlines the activities that will be undertaken by site management to ensure an effective response to an emergency occurs.

6.3.1 Staff training

The site will undertake staff training in accordance with the requirements of the Emergency Management Plan. The training will as a minimum include the following:

- Response to emergencies including first attack firefighting, evacuation procedures and emergency service liaison.
- Basic bushfire awareness.

The training will equip site-based personnel with the ability to undertake first attack firefighting if safe to do so and to then assist with the evacuation of the site and providing support to emergency responders.

6.3.2 Site induction

Site inductions will be developed and be reflective of the various risks associated with visiting and working at the site. As a minimum the inductions will include information about how to respond to emergencies and site based personnel responsibilities in preventing emergencies.

The induction process will also include other information including the management of risks, not undertaking activities that will cause an ignition and other requirements.

6.3.3 Fire agency engagement and site tours

To ensure fire service personnel are familiar with the site and are aware of the fire safety systems installed, site management is encouraged to invite the local Fire Brigade to undertake familiarisation visits at least annually. This will ensure the local firefighters understand the fire safety systems installed at the site along with the general layout.

6.3.4 24/7 monitoring

The site is monitored 24/7 by a variety of means. Most importantly and as described previously, the site is monitored 24/7 remotely and any alert or alarm activation will be identified quickly. The monitoring centre will have in place a procedure on how to respond to the various alerts and alarms.

The site is also supplied with a CCTV system that enables the monitoring centre and others to remotely check on the status of an alarm or alert and to assist them with determining an appropriate action.

An Alarm Signalling Equipment (ASE) device will be installed on site and the fire detection equipment to ensure early notification of FRNSW.

6.4 Response strategies

A number of the response strategies have been described in Section 3.2 and the list within this section outlines additional systems that are being installed to protect the site occupants including firefighters. The outcomes of the Fluence fire testing program have resulted in the development of instructions to let the BESS Unit burn out. This is a guide for first responders however, it is an effective strategy that ensures firefighter safety is maintained.

6.4.1 Firefighting water supply

The site is provided with an AS2419.1 fire hydrant system that complies with the open yard provisions. The fire hydrant system will include the following as a minimum:

- 432,000 litres water supply
- Suction connection and adapters as per AS2419.1
- Hardstand area adjacent to the suction outlet for a firefighting vehicle to park and not block passing traffic.
- Booster assembly
- Dual pumps.

For further detail, refer to Section 7.

6.4.2 Fire water containment

The site is required to provide the ability to contain fire water until it has been tested and an appropriate disposal mechanism has been determined. The disposal mechanism is outlined within the Emergency Management Plan.

An analysis has occurred against the NSW Government *Best Practice Guidelines for Contaminated Water Retention and Treatment Systems* (July 1994). This is contained within Appendix F. The outcome of the assessment has identified the following mitigation measures:

1. Fire water containment system consisting of 415,000 storages within the culverts and a 100,000 litre water tank.
2. Isolation valve installed to close the stormwater runoff system and to contain fire water.
3. Isolation controls to be outlined within the Emergency Management Plan.
4. Fire water testing and removal process to be within the Emergency Management Plan.
5. The isolation valves and culvert will be checked annually to ensure it is in working order.

As the fire water is unlikely to be contaminated due to the desired firefighting activities not being directed to the internal sections of the Cube. The firefighting guidance is to not open the Cubes whilst they are on fire and heat can be detected using thermal imaging cameras.

As it is likely for the suppression activity to gradually escalate as appliances arrive on scene. It is highly unlikely that the full 30l/s will be utilised immediately. As a guide each 10 l/s is likely to support a minimum of two branches that would operate at approximately 500 l/m. However, it is acknowledged that modern fire appliances may have a monitor mounted on the appliance that would enable much greater flows.

The containment system has been designed to isolate all firefighting runoff for appropriate management after an incident. A dedicated firewater containment tank is proposed to hold runoff generated during emergency firefighting.

The site’s firewater management strategy also includes the following features:

- Automatic sluice valve on the stormwater system to prevent uncontrolled discharge during a fire event. The valve will shut automatically in response to alarms or site command to isolate contaminated flows.
- Transformer bunds are individually sealed and fitted with passive oil-water filters to capture hydrocarbons and delay any release.
- General site stormwater drains to a natural waterway but remains isolated during fire conditions due to the valve system and diversion controls.

All collected firewater will be retained in the tank and only discharged after sampling, testing and FRNSW approval.

6.4.3 BESS detection and suppression

The BESS Units are each fitted with a detection system that includes smoke and gas along with a gas suppression system. The detection system will upon activation alert the monitoring centre, activate the local alarms and strobes and automatically commence shutdown procedures.

6.4.4 Emergency Services Information

The NSW fire agency requirements include the requirement for an emergency services information package and tactical fire plans. This information is available for responding firefighters to obtain when they arrive and will include as a minimum the following:

- Overview information
- Contact list
- Evacuation overview
- Tactical checklists
- Hazardous chemical list
- Site plans

For further information on the fire agency requirements reefer to the following:

https://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/03%20Emergency%20services%20information%20package%20and%20tactical%20fire%20plans.pdf

6.4.5 Occupant warning system

The site will be provided with an Occupant Warning System that will activate upon the activation of a smoke or gas detector within the Cube or buildings. The Occupant Warning System will enable site occupants to be immediately notified of an emergency and to then respond appropriately.

The Occupant Warning System will be provided so that personnel working inside the site buildings and within the BESS area can be warned of a fire or other emergency.

7 Fire Water

7.1 Likely firefighter requirements

To assist with the determination of fire water demand, it is important to understand the likely firefighter response to a fire within the BESS development. The firefighter response is predicated on the following assumptions:

- The likely fire within the BESS development will involve a single piece of infrastructure, i.e. a single BESS Unit, inverter, etc.
- The firefighting appliance can access the site through the provided access road network.
- Site plans will be provided within the Emergency Information Container.
- It is highly likely that a technician will be at the site before the fire brigade arrives.
- The Fluence battery has undergone testing and has demonstrated the highly unlikely potential for fire spread to occur between the Units and other infrastructure.

The firefighter response to a fire is likely to involve the following:

- The first responding appliance will approach the main gate and if no staff are there to meet them, they will access the Emergency Information Container. The Emergency Information Container will be mounted adjacent to the main gate and accessed externally. If it can't be located adjacent to the main gate and within view of the main gate, appropriate signage will be provided directing firefighters to the location of the Emergency Information Container.
- Upon finding the contact details for the Control Room, they will contact the number and engage in a discussion in relation to what is happening and who will be meeting them at the site.
- It is unlikely for the responding firefighters to enter the site without an escort. This will be advised within the Emergency Information Book.
- The firefighters will seek information on the potential for the fire to spread from its equipment of origin.
- They will be advised that if the fire is within a BESS Unit or other electrically charged equipment, to stand back and monitor the situation. The only time fire water will be utilised is if the firefighters believe that fire spread is likely to other parts of the site.
- There is the potential that firefighters will not utilise any fire water and monitor the situation.
- If fire water is selected to be used, the information within the Emergency Information Container will advise them how to isolate the fire water and contain it. They will be supported by the onsite personnel.
- If firefighters will need access to fire water, they will position their firefighting appliance on the hardstand at the static water supply and connect to the suction point. They will then run hoses to the fire from the firefighting appliance as required.

Due to the high likelihood of the fire being contained to the Unit of origin and the surrounding separation distances preventing fire spread, firefighters are not likely to have to undertake any activities. The fire will be permitted to burn out before the Unit is removed from the site. This is also consistent with other electrically charged equipment on the site. Information will be provided within the Emergency Information Container that outlines the procedures for firefighters to follow to determine when the Unit has burnt out and is safe to commence disposal arrangements.

If the fire involves a structure such as a storage shed or the Control Room, firefighters will treat this as per normal arrangements and likely to undertake their normal risk analysis requirements before accessing the buildings and undertaking fire suppression activities.

The minimum separation distances are outlined in Table 11:

Table 13 - Separation distances between equipment and other areas.

Items	Separation distance to other infrastructure	Comments
BESS Unit	2.5m	This is in accordance with the manufacturers specifications that is based on the outcome of fire testing.
Inverter	2.5m	Separation distance to adjacent core transformers, compliant with AS2067
Substation	25m	Separation distance from main power transformer and switchroom and control rooms, compliant with AS2067
Occupiable buildings including amenities.	10.5m	Separation distance from O&M building and closest core transformers, compliant with AS2067
Control Room	10.5m	Separation distance from Control Room and closest core transformers, compliant with AS2067
Switch Room	10.5m	Separation distance from Switch Room and closest core transformers, compliant with AS2067

Items	Separation distance to other infrastructure	Comments
Main Gate	32m to Main Power Transformer 25m to closest Core Transformer 14m to Switchroom	The main gate is deemed to be the location where firefighters will stage prior to accessing the site. This is the separation between the main access gate at the perimeter road to the BESS area, and the closest adjacent infrastructure, compliant with AS2067
Fire hydrant system tanks, pumps and booster assembly	Minimum 10m away from any high voltage electrical distribution equipment, such as transformer and distribution boards. Min. 10m away from any combustible dangerous good. Hydrant to be minimum 10m away from any building. Booster assembly minimum 10m away from any building.	Complaint with AS2419.

7.2 Transformer Fire Response

The proposed strategy for transformer fire events on site is to adopt a controlled 'burnout and exposure protection' approach. This reflects the fire characteristics of the installed systems, site layout, and available firefighting infrastructure.

7.3 Fire water demand

The requirement for fire water at this site has been based on the type of risk and providing sufficient water supplies that enables firefighters to provide cooling water if required. Whilst this is considered unlikely as demonstrated in the large-scale fire testing (Section 2.2.2) that has been undertaken by Fluence, it is acknowledged that responding firefighters may see the need to provide a level of protection.

Using the information contained within Section 7.1, the firefighting strategies in relation to using fire water would include the following:

- The UL9540A test results (Section 3.2) indicates that a thermal runaway event in a single cell does not cause catastrophic failure of the Unit.

- The large-scale fire testing (Section 3.2.2) outlines the unlikely potential for fire spread to occur between the BESS Units if catastrophic failure does occur.
- To provide a water stream that supports the prevention of fire spread between the Units will be influenced by a range of factors including, location of adjoining Unit, weather conditions including wind and the length of time the fire is burning before the fire brigade arrives at the site.
- The monitoring system will ensure an early notification to site technicians and the Emergency Response Plan will outline the suggested triggers to notify the fire brigade of a fire event.
- Traditionally firefighters will carry a mix of hose sizes and monitors.

The provision of an AS2419.1 fire hydrant system will enable firefighters to deliver an effective water supply for four hours at 30l/s.

FRNSW has requested a quantitative fire water demand assessment to demonstrate that the water supply is adequate for the worst-case exposure protection scenario. While no formal quantitative hydraulic modelling has yet been undertaken yet, the following response is provided using conservative operational assumptions consistent with typical fire service deployment and site layout conditions.

Assumed Worst-Case Fire Scenario

- The worst-case scenario involves a fully developed transformer or BESS fire**,** with simultaneous exposure threat to the nearest BESS Cube or building façade.
- The chosen strategy is exposure protection only. Direct suppression of transformers or BESS Cubes is not proposed.
- A 'burnout and protect' response is adopted (see Section 6.4), limiting water demand to cooling streams on adjacent structures or vegetation.

Conservative Fire Water Demand

- A single FRNSW or RFS appliance typically deploys two lines of 38mm hose, with each operating at approximately 500 L/min.
- Use of two branches at a total of 1,000 L/min equates to 17 L/s.
- If two appliances are on site, 34 L/s is the worst-case scenario, noting that sustained water delivery is unlikely in firefighting conditions.

Conservative Static Water Supply Analysis

- 432,000 litres will support:
  - 8 hours at 17 L/s (one appliance with maximum water usage), or
  - 4 hours at 34 L/s (two appliances with maximum water usage).
- This is expected to be adequate for exposure protection under site-specific conditions:
  - Appropriate separation between transformers and adjacent BESS Cubes
  - Use of hardstand and setback to enable safe appliance positioning and setbacks from surrounding vegetation.

- Wind-driven radiant exposure will remain below actionable thresholds beyond 10 m (based on standard fire engineering references)
- This is a highly conservative approach for exposure protection.

Likely static water supply analysis

- It is likely that branches will be set at approximately 115 L/min for exposure protection, equating to approximately 3.8 L/s per hose length.
- Using this figure, 432,000 will support:
  - Approximately 38 hours at 3.8 L/s (one appliance at likely water usage), or
  - Approximately 19 hours at 7.6 L/s (two appliances at likely water usage).

7.4 Fire water retention

The consideration of fire water runoff containment is outlined in Section 6.4.2. The intention is to limit the contaminated water leaving the area and entering waterways. Based on the analysis, the site will be providing fire water retention of 251,000 litres.

Based on the likely firefighter response described in Section 7.1, the likelihood of contaminated water being generated is extremely low. The water will only become contaminated if the fire water meets the burning products, particularly the lithium-ion. On the basis that the units will not be opened until fire activity has subsided and the detected temperatures are low, then fire water cannot come into direct contact with the burning products and therefore, limits the potential for fire water to become contaminated.

8 Emergency management

The management of emergencies is a critical component of the sites procedures to ensure that when a fire occurs, site occupants will have a detailed understanding of what to do. It will also ensure the site occupants are guided on how they respond to the event and make contact and then interact with emergency services.

An Emergency Management Plan will be established that addresses the following:

- Developed consistent with AS 3745-2010: *Planning for emergencies in facilities*.
- Adapted to the facility's specific infrastructure, hazards and arrangements.
  - Emergency prevention, preparedness and mitigation activities.
  - Activities for preparing for emergencies.
  - Control and coordination arrangements for emergency response (e.g., evacuation procedures, shelter-in-place arrangements, emergency assembly areas and emergency response procedures).
  - The agreed roles and responsibilities of on-site personnel (e.g., equipment isolation, fire brigade liaison, evacuation management, shelter-in-place management, if applicable).
- Facilitate fire brigade response:
  - Clearly state that responding fire services should not deliver fire water onto affected BESS Units or Transformers.
  - Outline the location and process to isolate the stormwater management system to prevent fire water runoff from occurring.
  - State that firefighters should not enter the site without a site technician being present.
  - A facility description, including infrastructure details, operations, number of personnel, and operating hours.
  - Identification of potential hazards on site for responding firefighters, including but not limited to, the risk of toxic gas or explosion.
  - A site plan depicting infrastructure including inverters, battery energy storage systems, generators, substations, grid connection points, transmission lines, dangerous goods storages, buildings, bunds, site access points and internal roads, fire services (static water supply) drainage and neighbouring properties.
  - An emergency response procedure for each credible emergency event and scenario, based on a comprehensive risk management process. This will include as a minimum building, infrastructure, vehicle fires and bushfire.
  - Up-to-date contact details for facility personnel, and any relevant off-site personnel that could provide technical support during an emergency.
  - Evacuation procedures and where appropriate, shelter-in-place procedures for facilities at-risk of bushfire or grassfire, if it is too late to evacuate.

- Details of emergency resources, including fire detection and suppression systems and equipment; gas detection; emergency eyewash and shower facilities; spill containment systems and equipment; emergency warning systems; communication systems; personal protective equipment; and first aid.
- A manifest of dangerous goods (if required).

In addition to the above, the Emergency Management Plan will be developed in accordance with the requirements of HIPAP No. 1. This document will be supported by an Emergency Services Information Package (ESIP) prepared in line with FRNSW's Fire Safety Guideline – Emergency Services Information Package and Tactical Fire Plans. The Plan will address:

a) Details on how the owner / operator is alerted to abnormal operation, fault or hazard in a BESS.
b) Details on how fire services are notified of an incident. This should be described as part of the fire safety strategy. Upon detection of a fire in a BESS or on the site via an automatic detection system, notification of the fire services should be automatic.
c) Detail effective communication strategy with remote operator representative for incident duration.
d) Suitable arrangements for attendance on site by an appropriately qualified representative during any incident.
e) Details on how battery status and information is relayed to emergency services, including items such as deployment of deflagration panels, etc.
f) Firefighting strategy proposed for the site and intended use of the firefighting system onsite (e.g. intention for it is to provide cooling water to surrounding equipment at a certain point in a fire or for a particular fire).

8.1 Fire mitigation measures

In accordance with Section 2.9 of HIPAP2 and the FRNSW Fire Safety Guideline, further detail is provided below regarding first aid fire protection systems, personnel training, signage, and site access for firefighting operations.

8.1.1 Fire Extinguishers

Fire extinguishers will be provided throughout the site at key risk areas in accordance with the following specifications:

- **Type**: ABE dry chemical powder (4.5 kg) and CO_2 extinguishers (2.0 kg)
- **Quantity**: Minimum of 8 extinguishers distributed as follows:
    - 2 at the O&M Building
    - 2 at switch rooms
    - 2 at the transformer yard perimeter
    - 2 near the BESS Cube clusters
- **Maintenance**: Visual inspections carried out monthly; full service every 6 months in accordance with AS 1851.

8.1.2 Hose Reels

Hose reels will be installed at the O&M building only. This will include:

- **Type**: 36 m, 19 mm hose reels
- **Location**: Mounted externally near main entry point of the O&M building
- **Maintenance**: Annual pressure and function test as per AS 2441.

8.1.3 Signage

Safety signage will be installed in line with Clause 5.3.3 of the FRNSW BESS Guideline:

- Fire equipment signage will be mounted at each extinguisher and hose reel location
- Hazardous goods placards will be displayed at battery Cubes and transformer bunds for FR3 and HyVolt oils
- FRNSW Site Entry Signage will be installed at the primary site access, including:
    - Site plan
    - Emergency contact details
    - Hazard overview
- Exit signs and emergency wayfinding will be located in the O&M and switch room buildings, with photoluminescent backing

8.1.4 Training of Operators and Staff

All site-based personnel will be trained in:

- BESS system risks and alarms
- Site-specific emergency response procedures
- Fire extinguisher use
- Manual shutdown procedures
- High-voltage isolation (via switch room systems)

Training will be conducted during induction and refreshed every 12 months. Site familiarisation sessions will also be offered to FRNSW and RFS prior to commissioning and at least every 12 months.

8.1.5 FRNSW Site Access

The site layout and access arrangements are consistent with the FRNSW Fire Safety Guideline – Access for Fire Brigade Vehicles and Firefighters. The following features apply:

- **Main internal roads**: Sealed and maintained at a minimum width of 6.0 m, allowing safe two-way access.
- **Gradients**: Expected to remain <1:8 throughout, consistent with FRNSW requirements for vehicle stability
- **Turning areas**: Provided near the transformer compound and at key junctions within the BESS site as a T junction.

- **Hardstand**: Provided as compacted gravel around critical areas (transformers, Cubes, and switch room), supporting fire appliance weight.
- **Access gates**: Located to allow direct entry from the internal road, with minimum clear opening width of at least 3.5 m

These features provide compliant emergency access around high-risk equipment, with clear paths for hose deployment and thermal isolation during a fire event.

9 Summary of mitigation treatments

No.	Mitigation treatment	Comments (if required)
1	Battery Management System (BMS): Implement a real-time monitoring system that detects early signs of faults, overheating, or potential fire hazards.	Supplied by Fluence as part of the specifications.
2	Emergency Stop Function (E-Stop): Ensure each BESS unit is equipped with an emergency stop button to initiate an immediate shutdown.	
3	Emergency System Shutdown: Establish a remote and local shutdown mechanism to isolate affected battery units in an emergency.	
4	Site Security & Monitoring: Install CCTV cameras to monitor potential hazards. Ensure 24/7 remote monitoring with an established alert and response system.	
5	Bushfire Prevention: Implement regular vegetation management and weed removal programs. Establish and maintain firebreaks to prevent fire spread.	
6	Training & Inductions: Conduct regular fire safety training for staff and contractors. Provide site-specific fire safety inductions for visitors and workers.	
7	Fire Agency Engagement:	

No.	Mitigation treatment	Comments (if required)
	Facilitate annual site tours for Fire and Rescue NSW (FRNSW) and NSW Rural Fire Service to ensure responders are familiar with the site layout. Develop emergency response plans in coordination with fire agencies.	
8	Emergency Information Accessibility: Install an Emergency Information Container at the main entrance with site plans, hazard maps, and emergency contact details that complies with the NSW Guideline.	
9	Occupant Warning System (OWS): Ensure the site has an audible and visual alarm system activated in case of smoke, fire, or toxic gas detection that alerts people within the Switch Room, Control Room and the BESS area.	
10	Firefighting Water Supply: Maintain a fire hydrant system in accordance with AS2419.1 and AS1851. Provide AS2419.1-compliant suction connections for firefighter access to the static water supply. Ensure a hardstand area is available for firefighting vehicles.	
11	Firewater Containment & Disposal: Implement firewater retention systems (minimum 251,000 litres) to prevent contaminated runoff. Establish procedures for safe disposal of firewater following testing that are included within the Emergency Response Plan.	
12	Detection & Suppression Systems: Equip BESS units with gas and smoke detection systems linked to automated alerts.	

No.	Mitigation treatment	Comments (if required)
	Install smoke detection systems in the switch and control rooms.	
13	Emergency Planning Develop an Emergency Response Plan aligned with AS 3745-2010. Provide fire agencies with: • Evacuation plans • Tactical fire checklists • Hazardous chemical manifests • Site and firefighting water access maps	
14	First Aid Fire Protection: Ensure fire extinguishers are available throughout the site. Train personnel in basic firefighting and evacuation procedures.	
15	FRNSW Access Requirements: Ensure access roads meet fire brigade standards for emergency vehicle entry.	
17	An Alarm Signalling Equipment (ASE) device will be installed on site and the fire detection equipment to ensure early notification of FRNSW.	

10 Conclusion

The development of this Fire Safety Study has identified a range of measures that are required to ensure the site occupants including staff, contractors, visitors and emergency services can effectively manage fire risk. The importance of ensuring all fire safety strategies is installed and maintained for the life of the project is critical to ensure the ongoing management of fire risk.

Whilst the occurrence of fires within battery developments is considered unlikely, the consequences can be severe if the response to the event is not managed, and clear advice is available for site-based personnel and firefighters and other emergency services. The management of fires within battery developments is acknowledged as being new and the need for information and technical advice is considered critical.

The treatments outlined within this report align with the various international and local standards and ensure that suitable mitigation measures are in place to prevent fires from occurring. If a fire does occur, there are systems also in place to alert occupants and to support the response to the fire event. The systems and procedures that are being implemented during design, construction, commissioning and operation will ensure that any risk is managed to an acceptable level. The key items including detection and suppression systems, fire safety design of the BESS Unit and the site layout all contribute to the management of fire risk.

Historically, fire events involving these types of facilities are due to inappropriate procedures that include having not considered the risk of fire effectively. This Fire Safety Study has considered these examples in the development of risk mitigation treatments for the Wellington BESS. However, as technology changes and more is learnt about the performance of lithium ion and large-scale battery development, a culture of adaptive management is considered critical to ensure the ongoing management of fire risk in a best practice environment.

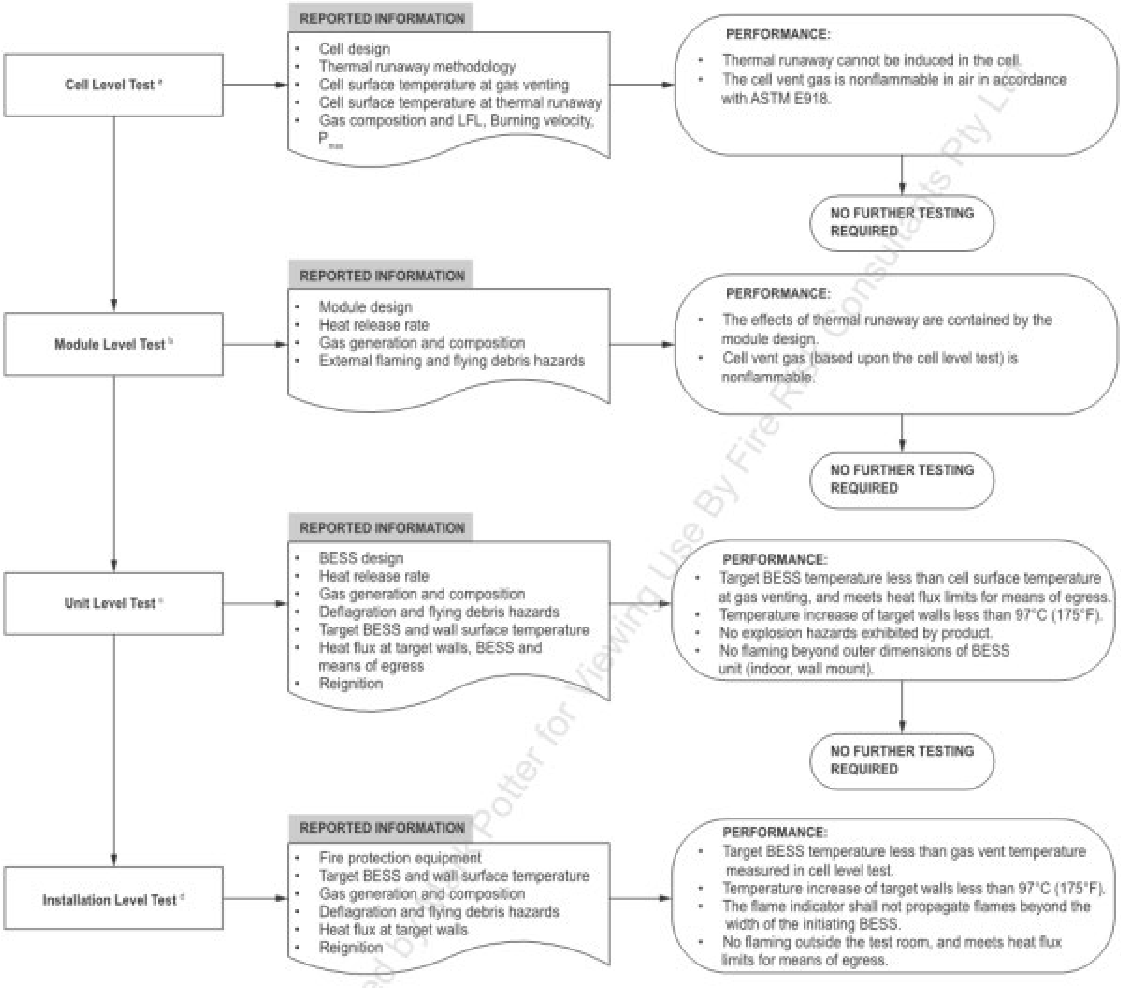
BESS facilities can present fire risks if not designed, constructed, commissioned and operated effectively. The importance of following design requirements and committing to the ongoing maintenance of the system is critical to reduce fire risk.

11 Codes and References

Code / Document	Description
HIPAP No. 2	Hazardous Industry Planning Advisory Paper No 2 - Fire Safety Study Guidelines
NFPA 850	Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations
NFPA 855	Standard for the Installation of Stationary Energy Storage Systems
AS 2067:2016	Substations and high voltage installations exceeding 1 kV a.c.
AS 2419.1:2021	Fire hydrant installations – System design, installation and commissioning
AS 1940:2017	The storage and handling of flammable and combustible liquids
AS 3745:2010	Planning for emergencies in facilities
AS 3959:2018	Construction of buildings in bushfire-prone areas
FM Global Data Sheet 5-33	Electrical Energy Storage Systems
FRNSW BESS Guideline	Large-scale external Lithium-ion battery energy storage systems – Fire safety study considerations
Fluence Cube Safety Datasheet (Rev 04.3)	Manufacturer safety specifications for BESS enclosures
UL9540A	Thermal runaway and fire propagation test method for battery systems
SDS – FR3 Fluid	Material Safety Data Sheet for transformer insulating fluid
SDS – HyVolt I	Material Safety Data Sheet for transformer oil

Appendix A – UL9540A test sequence

Figure 1.1
Schematic of Test Sequence



Appendix B – UL9540A test report – Unit

CSA GROUP
Laboratory Test Data - UL 9540A

Master Contract: 301546
Report: 80149894
Project: 80149894

2023-05-30

Fluence Energy LLC
4601 N. Fairfax Drive, Suite
600 Arlington, Virginia
22203-1546 United States

Subject: Fluence Cube Unit Level (UL 9540A Test Report)

To Whom It May Concern:

We are pleased to inform you that testing of your product per UL 9540A 4th Edition, Section 9 has been completed. Applicable tests were witnessed at SAFE Laboratories and Engineering Corp. by CSA – Cleveland on 2023-04-15. The Unit Level Testing per Section 9 of UL 9540a 4th Edition was conducted on the sample you provided, and the results are enclosed in the test report.

> Note: This Test Report is not an Authorization to apply the CSA Mark to the product. The results contained in the report(s) provided are contingent upon the characteristics of the actual sample(s) used in the investigation. In the absence of a continuing inspection service, CSA provides no assurance, expressed or implied, that the contents of the report are applicable to reproductions of the sample(s). Use or reproduction of the CSA name, logo, or trademark is not permitted without the prior written consent of CSA. No references can be made to this report when using the results of this investigation for the purposes of advertising, promotion or litigation, without the prior written consent of CSA.

Please examine the enclosed documents and contact me if you have any questions or would like us to make any changes.

On behalf of CSA, I would like to thank you for your business and offer our services for your future needs.

Sincerely,

Chris Reed

Chris Reed
Product Safety Engineer - Certifier I
Energy Storage

CSA – Cleveland
8801 E Pleasant Valley Rd.
Cleveland, OH 44131
USA

Encl. [UL 9540A Unit Level Test Report]

Test Data Cover Letter (2020-08-28)

CSA GROUP

Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

ORIGINAL TEST DATA

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Master Contract:	301546	Model:	06-01-0071-16	Page number 1 of 45
Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Standard(s): ANSI/CAN/UL 9540A:2019 Fourth Edition, Dated November 12, 2019 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Testing Laboratory Name:	CSA Group Cleveland
Address:	8801 E Pleasant Valley Rd. Cleveland, OH 44131
Testing Program:	**Custom Test** : Cover Letter ☒, Testing Only ☐

If tests were performed at another facility, then described below:

Testing Laboratory Name:	SAFE Laboratories and Engineering Corp
Address:	5901 Elwin Buchanan Dr Sanford, NC 27330
Facility Qualification Number:	N/A

	As above / or describe otherwise
Customer:	Fluence Energy, LLC
Address:	4601 N. Fairfax Drive, Suite 600 Arlington, Virginia 22203-1546 United States

Tested By: John Cavaroc, Electrical Engineer
Name, Title

Signature on file — 2023-05-11
Signature — *Date (YYYY-MM-DD)*

☒ **Reviewed by:**
☒ **Witnessed by:** Chris Reed, Product Safety Engineer I
Name, Title

Chris Reed — 2023-05-30
Signature — *Date (YYYY-MM-DD)*

Version6 : 2022-08-02

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Cell Level Test Summary	
Name of test laboratory perform cell level testing:	UL(Changzhou) Quality Technical Service Co., LTD
Unique identification of test report:	4790027966
Standard and its edition used for testing:	UL 9540A 4th Edition
Manufacturer:	Envision Dynamics Technology (Jiangsu) CO., LTD
Brand name / Trademark:	N/A
Model number:	ESS 4LH3L7 280A
Nominal cell voltage, (V)	3.2
Cell capacity, (Ah)	280
Cell chemistry:	LiFePO4
Physical format of cell:	Prismatic
Approximate dimension, (mm)	71.65 mm(depth) by 173.93 mm(width) by 207.23 mm(height)
Mass, (g)	5430±150 g
Method used to initiate thermal runaway:	External Film Heater
Average temperature at which cell first vented excluding gas collection sample, (°C)	160
Average temperature prior to thermal runaway excluding gas collection sample, (°C)	239
Flammable gas generation, (Liter)	111.4
Total gas generation, (Liter)	157.7
Lower flammability limit (LFL) at ambient temperature (25 ± 5°C), (%)	7.25
Lower flammability limit (LFL) at average gas vent temperature, (%)	6.05
Burning velocity, (Cm/Sec)	67.1
Maximum pressure P_{max}, (psig)	98.3
Gas composition:	See below

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Cell Level Test Summary

Gas		Measured %
Carbon Monoxide	CO	11.416
Carbon Dioxide	CO_2	29.352
Hydrogen	H_2	46.707
Methane	CH_4	6.196
Acetylene	C_2H_2	0.107
Ethylene	C_2H_4	2.856
Ethane	C_2H_6	1.073
Propadiene (Allene)	C_3H_4	0.002
Propene	C_3H_6	0.530
Propane	C_3H_8	0.296
-	C4 (Total)	0.528
-	C5 (Total)	0.134
-	C6 (Total)	0.013
1-Heptene	C_7H_{14}	0.006
Benzene	C_6H_6	0.011
Toluene	C_7H_8	0.001
Dimethyl Carbonate	$C_3H_6O_3$	0.652
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.121
Total	-	100

Module Level Test Summary

Name of test laboratory perform module level testing:	UL(Changzhou) Quality Technical Service Co., LTD
Unique identification of test report:	4790637679.1
Standard and its edition used for testing:	UL9540A 4th Edition
Manufacturer:	ENVISION DYNAMICS TECHNOLOGY (JIANGSU) CO., LTD
Brand name / Trademark:	N/A
Model number:	EACH-1P52S-280Ah
Nominal voltage rating, (V)	166.4
Nominal capacity rating, (Ah)	280
Approximate dimension, (mm)	1180mm x 808mm x 240mm
Method used to initiate thermal runaway:	External Film Heater
Number of cells used for initiating thermal runaway:	1

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Number of cells exhibited thermal runaway within module:	3
Cell to cell propagation condition:	Propagation occurred
Peak chemical heat release rate, (kW)	No flaming occurred
Flammable gas generation, (Liter)	254.95
Total gas generation, (Liter)	354.49
Weight loss, (kg)	2
Gas composition:	See below

Gas Component	Gas Type	During Pre-flaming (L)
Total Hydrocarbons	Hydrocarbons	95
Carbon Dioxide	Carbon Containing	99.54
Carbon Monoxide	Carbon Containing	39.11
Hydrogen	Hydrogen	120.84

Additional Information:	None

Unit Level Test Summary	
Manufacturer:	Fluence Energy
Brand name / Trademark:	Fluence Energy
Model number:	06-01-0071-16
Nominal voltage rating, (V)	1331
Nominal capacity rating, (Ah)	560
Approximate dimension, (mm)	2,549mm x 2,566mm x 2,160 mm
BESS test configuration/intended installation:	Outdoor Ground Mounted
(If residential installation) Smallest room volume specified by manufacturer, (m^3)	N/A
Unit certification available?, (Yes/No)	No
Standard(s) used to certify product:	N/A
Certification organization name and its certificate number:	N/A
Electrical configuration of module in BESS:	52s-1p
Number of modules in BESS:	16

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Unit Level Test Summary	
Fire detection and suppression system integral part of BESS: (Yes/No)	BESS has integral fire detection system but suppression system is optional.
Test conducted with fire detection and suppression system: (Yes/No/Not Applicable)	Test conducted with fire detection system active but with no fire suppression system.
Method used to initiate thermal runaway:	External film heater
Number of cells used for initiating thermal runaway:	One cell used for initiating thermal runaway.
Number of cells exhibited thermal runaway within initiating module:	3
Number of modules exhibited thermal runaway within initiating BESS:	1
Cell to cell propagation condition:	Propagation occurred.
Peak chemical heat release rate, (kW)	Not required for outdoor installations.
Peak convective heat release Rate, (kw)	Not required for outdoor installations.
Flammable gas generation, (Liter)	Not required for outdoor installations.
Total gas generation, (Liter)	Not required for outdoor installations.
Gas composition:	Not required for outdoor installations.
Maximum wall surface temperature, (°C)	47.2
Maximum target BESS temperature, (°C)	32.1
Maximum ceiling or soffit surface temperatures, (°C)	32.8
Maximum incident heat flux on target wall surfaces, (kw/m^2)	0.179
Maximum incident heat flux on target BESS, (kw/m^2)	0.074
Maximum incident heat flux of egress path, (kw/m^2)	0.122
Maximum incident heat flux on target ceiling or soffit surfaces, (kw/m^2)	N/A.
Total smoke release, (m^2)	Not required for outdoor installations.
Peak smoke release rate, (m^2/s)	Not required for outdoor installations.
Additional Information:	Target units used live alternate LFP modules to stand in for Envision modules due to logistical concerns.

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Master Contract:	301546	Model:	06-01-0071-16	Page number 6 of 45
Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Performance Unit Level Test (Non – Residential Outdoor Ground Mounted)		
Requirement	**Comments**	**Verdict**
If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	There was no flaming outside of the unit observed.	P
Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs	Maximum target module temperature was 28.4 °C	P
For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient	Maximum wall temperature was 47.2 °C over 23.1° C ambient, which is less than a 97° C rise.	P
Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases	No explosion hazards were observed during the test.	P
Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2	Maximum heat flux was 0.122 kW/m^2	P
Summary of Result: A unit level test meets the applicable performance criteria noted above from section 9.8 of UL 9540A 4th Edition is considered compliant.		

Possible test case verdicts:

- Test object does not apply to the test object:	N/A
- Test object does meet the requirement:	P (Pass)
- Test object does not meet the requirement:	F (Fail)
- Test object waived based construction detail:	W (Waived)

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Clause	Requirement + Test	Result - Remark	Verdict
	Construction		
5	**General**	---	---
5.3	**Battery energy storage system unit**	---	---
5.3.1	BESS certification available? (Yes/No)	No	---
	Standard(s) used to certify product:	N/A	---
5.3.2	BESS component documentation	☐ BESS certification was available – Component detail not documented. ☐ BESS certification was not available – See list of critical components in attachment section. ☒ Other(explain): See required information in this report.	---
	BESS enclosure approximate dimension, (mm)	2,549 x 2,566 x 2,160 mm	---
	BESS enclosure material:	Sheet metal module enclosure Galvanized Hot Steel Coil (SGHC) Rack frames	---
	Based on configuration of BESS, test conducted on:	☒ BESS ☐ Battery system	---
5.3.3	Fire detection system	☒ Integral part of DUT, test conducted with fire detection system. ☐ Integral part of DUT, test conducted without fire detection system. ☐ Not integral part of DUT	---
	Fire suppression system	☐ Integral part of DUT, test conducted with fire suppression system. ☐ Integral part of DUT, test conducted without fire suppression system. ☒ Not integral part of DUT	---
5.3.4	Unit level test report	See the following report.	---
	Performance		
9	**Unit level**	---	---
9.1	**Sample and test configuration**	---	---
9.1.1	The unit level test was conducted with BESS units installed as described in the manufacturer's instructions and this section.	Confirmed.	P
	BESS test configuration:	Non-residential Outdoor Ground Mounted	---

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Clause	Requirement + Test	Result - Remark	Verdict
9.1.2	Unit level test was conducted in which internal fire condition created as per module level test.	Confirmed.	P
	Test setup include initiating BESS unit and target BESS unit representative of an installation.	Confirmed. See Attachment 3.	P
	Additional representative test configuration based on test configuration.	N/A	---
	Separation distances between initiating and target units were representative of the installation.	Confirmed. See Attachment 3.	P
	Testing conducted outdoor for BESS intended for outdoor installation only. Following controls and environmental conditions were in place.	Confirmed.	P
	a) Wind screens were utilized with a maximum wind speed maintained at ≤ 12 mph	Test setup is surrounded on three sides by walls made of shipping containers stacked two high. The fourth side has the test wall. Wind speed was measured at 1 mph.	P
	b) Temperature range was within 10°C to 40°C	Confirmed. Ambient temp was between 11.9° C to 24.4° C.	P
	c) The humidity was < 90% RH	Confirmed. Humidity was 66% RH.	P
	d) There was sufficient light to observe the testing;	Confirmed.	P
	e) There was no precipitation during the testing;	Confirmed.	P
	f) There was control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and	Confirmed, testing area ground was gravel and no vegetation was growing.	P
	g) There were protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.	Confirmed.	P
9.1.2.1	For a container system BESS including those intended for outdoor installation only, the unit level test performed in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test	Not a container system BESS.	N/A

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Clause	Requirement + Test	Result - Remark	Verdict
	installation set up in accordance with the installation layout within the container.		
9.1.3	Based on configuration and design of BESS, test conducted on:	☒ BESS ☐ Battery system	---
9.1.4	Initiating BESS unit contain components representative of a BESS unit in a complete installation.	Confirmed.	P
	Combustible components that interconnect the initiating and target BESS units were included.	Confirmed.	P
9.1.5	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.	Confirmed.	P
	The target BESS unit module enclosures did not contain cells.	Live alternate LFP modules were used in the targets with PTL approval and permission of testing facility.	N/A
9.1.6	Initiating BESS unit was at the maximum operating state of charge (MOSOC).	Confirmed. See Attachment 1.	P
	After charging and prior to testing, the initiating BESS was rested for a maximum period of 8 h at room ambient.	Confirmed.	P
9.1.7	BESS unit test conducted as per following condition.	Tested per b).	P
	a) Integral fire suppression system provided with the DUT.	No integral fire suppression system.	N/A
	b) Without Integral fire suppression system.	Confirmed.	P
9.1.8	Electronic and software control were not relied upon for this testing.	Confirmed.	P
	BESS unit test conducted with Integral fire suppression system meet UL 840 and considered reliable for this testing.	No integral fire suppression system.	N/A
9.2	**Test method – Indoor floor mounted BESS units**	---	---
9.2.1	Test room environment was controlled to prevent drafts that may affect test results.	Test was conducted outdoors, test installation was surrounded on three sides by shipping container walls so no drafts could impinge on units.	P
	At the start of the test, the room ambient temperature was not less than 10°C (50°F) nor more than 32°C (90°F).	Confirmed. Ambient temperature was 23°C.	P
	Ambient temperature range during test, °C	11.9 – 24.9	P

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Clause	Requirement + Test	Result - Remark	Verdict
9.2.2	Any access door(s) or panels were closed, latched and locked at the beginning and duration of the test.	Confirmed.	P
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	Test was conducted as an outdoor ground mount with test wall configured per 9.3.3.	P
9.2.4	Instrumented wall sections were extended not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.	Confirmed.	P
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Test wall was 12 ft tall per 9.3.3.	P
9.2.6	The surface of the instrumented wall sections was covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	Test wall was covered in ¾" plywood painted flat black per 9.3.3.	P
9.2.7	The initiating BESS unit was centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.	Confirmed, although gas collection was not required for outdoor installations.	N/A
9.2.8	The light transmission in the calorimeter's exhaust duct was measured.	Confirmed, but gas was collected for reference only.	N/A
	White light source and photo detector was used for the duration of the test.	Confirmed, but gas was collected for reference only.	N/A
	Smoke release rate was calculated as per following formula. $SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_0}{I}\right)$	Confirmed, but gas was collected for reference only.	N/A
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	Installation is outdoor only, so heat release rate is not required.	N/A
	Chemical heat release rate was calculated as per following formula. [illegible]	Installation is outdoor only, so heat release rate is not required.	N/A
9.2.10	The heat release rate measurement system shall be calibrated using an atomized heptane diffusion burner.	Installation is outdoor only, so heat release rate is not required.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
9.2.11	The convective heat release rate was measured during test.	Installation is outdoor only, so heat release rate is not required.	N/A
	Thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct were used for measurement.	Installation is outdoor only, so heat release rate is not required.	N/A
9.2.12	Convective heat release rate was calculated as per following formula. $HRR_c = V_s A \frac{353.22}{T_0} \int_{T_0}^{T} C_p dT$	Installation is outdoor only, so heat release rate is not required.	N/A
9.2.13	Physical spacing between BESS units (both initiating and target) and adjacent walls were representative of the intended installation.	Confirmed. See Attachment 3.	P
9.2.14	Separation distances was specified by the manufacturer for distance between:	Confirmed. See Attachment 3.	P
	a) The BESS units and the instrumented wall sections.	Confirmed. Separation distance was 10 ft. See Attachment 3.	P
	b) Adjacent BESS units.	Confirmed. Separation distance was 7". See Attachment 3.	P
9.2.15	Wall surface temperature measurements was collected for BESS intended for installation in locations with combustible construction.	Confirmed.	P
9.2.16	Wall surface temperatures was measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections.	Confirmed.	P
	No. 24-gauge or smaller, Type-K exposed junction thermocouples were used for measurement.	Confirmed.	P
	The thermocouples were placed horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure.	Confirmed.	P
9.2.17	Thermocouples were secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires.	Confirmed.	P
	The thermocouple tip was depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and held in thermal contact	Confirmed.	P

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Clause	Requirement + Test	Result - Remark	Verdict
	with the surface at that point by the use of pressure-sensitive paper tape.		
9.2.18	Heat flux was measured with the sensing element of at least two water-cooled Schmidt- Boelter or Gardon gauges at the surface of each instrumented wall.	Confirmed.	P
	a) Both were collinear with the vertical thermocouple array.	Confirmed.	P
	b) One was positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module	Confirmed.	P
	c) One was positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.	The position estimated to receive the greatest heat flux during module propagation was in front of the door, so the heat flux gauge was placed there.	P
9.2.18.1	Heat flux measurements on walls were waived for residential units that are tested with the cheesecloth indicator.	Unit not tested with cheesecloth indicator.	N/A
9.2.18.2	With reference to 9.2.18, if b) and c) were deemed to be at the same location, only one gauge was installed on the wall for the measurement.	They were not deemed the same location, however the location determined for greatest heat flux during module propagation was in front of the door, so the gauge was placed there.	N/A
9.2.19	Heat flux was measured with the sensing element of at least two water-cooled Schmidt- Boelter or Gardon gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:	Confirmed.	P
	a) One was positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS	Confirmed.	P
	b) One was positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.	Same location as a)	N/A
9.2.19.1	Heat flux measurements on target units were waived for residential units that are tested with the cheesecloth indicator.	Unit was not tested with cheesecloth indicator.	N/A
9.2.19.2	With reference to 9.2.19, if a) and b) were deemed to be at the same location, only	These were determined to be the same location for the target units, so only one heat flux gauge was placed	P

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Clause	Requirement + Test	Result - Remark	Verdict
	one gauge was installed on the target unit for the measurement.	facing the initiating unit. Additional heat flux gauges were placed inside the target units per customer's request.	
9.2.20	For non-residential use BESS, heat flux was measured with the sensing element of at least one water-cooled Schmidt-Boelter or Gardon gauge positioned at one for the following location.	Confirmed.	P
	a. At the mid height of the initiating unit in the center of the accessible means of egress.	Confirmed.	P
	b. At the point where the majority of off-gas venting was expected from the initiating unit in the center of the accessible means of egress.	Confirmed.	P
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples was installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.	Confirmed.	P
	Each non-initiating module enclosure within the initiating BESS unit was instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) to provide data to monitor the thermal conditions within non-initiating modules.	Confirmed.	P
	Additional thermocouples shall be placed to account for convoluted enclosure interior geometries.	Additional thermocouples were placed on the backside of modules, on the inside of the door of the enclosure, and on the module exhaust ports. See Attachment 2 for more detail.	P
9.2.22	For residential use BESS, the DUT was covered with a single layer of cheese cloth ignition indicator.	Outdoor installation does not require cheesecloth indicator.	N/A
	The cheesecloth was untreated cotton cloth running 26 – 28 m^2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.	Outdoor installation does not require cheesecloth indicator.	N/A
9.2.23	An internal fire condition in accordance with the module level test was created within a single module in the initiating BESS unit.	Confirmed. See Attachment 2.	P

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Clause	Requirement + Test	Result - Remark	Verdict
	a) The position of the module was selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test;	The initiating module was placed in the left string, third module from the bottom.	P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module was same as that used to initiate and propagate thermal runaway within the module level test.	Confirmed.	P
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases was measured within the calorimeter's exhaust duct.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
	The hydrocarbon content of the vent gas was measured using flame ionization detection.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
	Hydrogen gas was measured with a palladium-nickel thin-film solid state sensor.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
	Composition, velocity and temperature instrumentation were collocated with heat release rate calorimetry instrumentation.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
9.2.25	The hydrocarbon content of the vent gas was additionally measured a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm^{-1} and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
9.2.26	The test was terminated at:	Per end criteria a).	P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	Confirmed. Temperatures in each module were monitored over 19 hours and 48 minutes and all returned to ambient condition. After test termination, initiating module was removed from the BESS and placed in the storage area under a plastic tarp. Sometime between April 16-25, an unknown overpressure event occurred that caused the module lid to bulge and the corners to lift. No exterior thermal damage or displacement of the plastic tarp was observed. The cause of this event	P

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Clause	Requirement + Test	Result - Remark	Verdict
		cannot be definitively attributed to the test exposure, the removal, transport or storage position of the module. The event is noted as an observation, but is not expected to have affected the outcome of the test.	
	b) The fire propagates to adjacent units or to adjacent walls; or	Test was ended according to a)	N/A
	c) A condition hazardous to test staff or the test facility requires mitigation.	Test was ended according to a)	N/A
9.2.27	For residential use systems, the gas collection data gathered was compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Not an indoor installation.	N/A
9.3	**Test method – Outdoor ground mounted units**		
9.3.1	Test method described in Section 9.2 was used for non-residential use BESS testing.	Confirmed.	P
	Smoke release rate, convective and chemical heat release rate and content, velocity and temperature of the released vent gases were not measured for outdoor ground mounted installation only.	Gas composition was measured for reference purposes only, it is not required for outdoor installations.	N/A
9.3.2	Test method described in Section 9.2 except noted in 9.3.3 and 9.3.4 was used for residential use BESS testing.	Confirmed.	P
	Heat flux measurements for the accessible means of egress was measured in accordance with 9.2.20.	Confirmed.	P
	The heat flux measurement for the accessible means of egress was waived for outdoor ground mounted residential use BESS because the BESS was draped with cheesecloth.	Cheesecloth was not used.	N/A
	Smoke release rate, convective and chemical heat release rate and content, velocity and temperature of the released vent gases were not measured for outdoor ground mounted installation only.	Gas was measured for reference purposes only, it is not required for outdoor installations.	N/A

Clause	Requirement + Test	Result - Remark	Verdict
9.3.3	Test samples was installed in proximity to an instrumented wall section that was 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit.	Confirmed.	P
	The sample was mounted on a support substrate and spaced from the wall in accordance with the minimum separation distances specified by the manufacturer.	Confirmed. See Attachment 3.	P
	The wall and soffit were constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black.	Confirmed.	P
	The instrumented wall was extended not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units.	Confirmed.	P
	The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls were extended to the surface of the soffit	Confirmed.	P
	Manufacturer requires installation against non-flammable material, the test setup included with manufacturer recommended backing material between the unit and plywood wall.	Installation against non-flammable material is not required by manufacturer.	N/A
9.3.4	Target BESS were installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications.	Confirmed. See Attachment 3.	P
	The physical spacing between BESS units (both initiating and target) were the minimum separation distances specified by the manufacturer.	Confirmed. See Attachment 3.	P
9.4	**Test Method – Indoor wall mounted units**	Not an indoor-wall mounted installation.	N/A
9.5	**Test Method – Outdoor wall mounted units**	Not an outdoor-wall mounted installation.	N/A
9.6	**Rooftop and open garage installations**	Not a rooftop or open garage installation.	N/A
9.7	**Unit level test report**		
9.7.1	Type of installation considered during unit level testing:	Information available in this report.	P
9.7.2	Additional installation represented by type of installation considered during unit level testing:	Information available in this report.	P

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9.7.3	Unit level report include following information.	Information available in this report.	P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	Information available in this report.	P
	b) Number of modules in the initiating BESS unit;	Information available in this report.	P
	c) The construction of the initiating BESS unit per 5.3;	Information available in this report.	P
	d) Fire protection features / detection / suppression systems within unit;	Information not available in this report.	N/A
	e) Module voltage(s) corresponding to the tested SOC;	System voltage reported.	P
	f) The thermal runaway initiation method used;	Information available in this report.	P
	g) Location of the initiating module within the BESS unit;	Information available in this report.	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	Information available in this report.	P
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	Information available in this report.	P
	j) Chemical and convective heat release rate versus time data;	Information not available in this report.	N/A
	k) Separation distances from the initiating BESS unit to target walls;	Information available in this report.	P
	l) Separation distances from the initiating BESS unit to target BESS units;	Information available in this report.	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Information available in this report.	P
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	Information not available in this report.	N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	Information available in this report.	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;	Information not available in this report.	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
	q) Gas generation and composition data;	Information not available in this report.	N/A
	r) Peak smoke release rate and total smoke release data;	Information not available in this report.	N/A
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	Information not available in this report.	N/A
	t) Observation of flying debris or explosive discharge of gases;	Information available in this report.	P
	u) Observation of re-ignition(s) from thermal runaway events;	Information available in this report.	P
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	Information available in this report.	P
	w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits	Information available in this report.	P
	x) Photos and video of the test.	Information available in this report.	P

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Table 1 – Unit charge/discharge specification			
Charging method	CC-CV	Discharging method	CC
Charge current, (Adc)	22	Discharge current, (Adc)	N/A
Charge voltage, (Vdc)	1,490	---	---
Charge end current, (Adc)	N/A	Discharge end voltage, (Vdc)	N/A
Manufacturer recommended charge temperature, (°C)	0-50	Manufacturer recommended discharge temperature, (°C)	N/A

Table 2 – Unit rest duration				
Sample Number	Final charge end time		Test start time	
	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)
1	2023-04-15	08:33 AM	2023-04-15	12:32 PM
Ambient temperature during unit conditioning				
Ambient Lab Temperature, (°C)		Relative Humidity, (%RH)		
20.6 to 29.0		24 to 45		

Table 3 – Unit level test	
Sample Number:	Fluence Envision Item 1 and Item 2
Ambient temperature at start of test, (°C)	11.9 °C
Ambient temperature range during test, (°C)	11.9 to 24.4
Relative humidity, (%RH)	66% RH
Number of cells used for initiating thermal runaway:	One cell
Open circuit voltage before test, (Vdc)	1,400.3
External film heater ramp rate, (°C/min)	6°C/min
Other method used to initiate thermal runaway:	External Film heater
Location of cell and module for initiating thermal runaway: See Attachment 2	Initiating cell was cell 20. The initiating module was in the left string, and the third module from the bottom. See Attachment 2.
Number of cells exhibited thermal runaway within initiating module:	3
Number of modules exhibited thermal runaway within initiating BESS:	1
Location of cell and module exhibited thermal runaway within initiating BESS: See Attachment 2	Rack 1, Module 3, Cells 19, 20, and 21.

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Table 3 – Unit level test	
Cell to cell propagation condition:	Propagation occurred.
Peak chemical heat release rate, (kW)	Not required for outdoor installations.
Peak convective heat release rate, (kW)	Not required for outdoor installations.
Flammable gas generation, (Liter)	Not required for outdoor installations.
Total gas generation, (Liter)	Not required for outdoor installations.
Peak smoke release rate, (m^2/sec)	Not required for outdoor installations.
Total smoke release rate, (m^2)	Not required for outdoor installations.

Table 4 – Gas composition
Gas composition not required for outdoor installations.

Table 5 – Critical observation	
Condition	**Comment**
Any flaming outside the initiating BESS enclosure and the maximum flame extension:	No flaming outside initiating BESS observed
Flying debris	No flying debris observed
Explosive discharge of gases	No explosive discharge of gases was observed during the test.
Re-ignition(s) from thermal runaway events	No re-ignition was observed during the test.
Sparks	No sparking observed during the test.
Electrical arcs	No arcs were observed during the test.
Other electrical events (specify event)	No other electrical events were observed during the test.
Damage to the initiating BESS unit	3 cells had gone into thermal runaway in the initiating module of the BESS. There was no damage outside of those cells noted to the initiating BESS during the test.
Damage to target BESS units;	No damage to target BESS observed.
Damage to adjacent walls	No damage to adjacent walls observed
Damage to ceilings	No damage to ceilings observed
Damage to soffits	No damage to soffits observed

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Attachments

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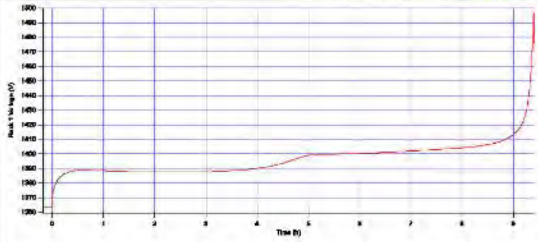
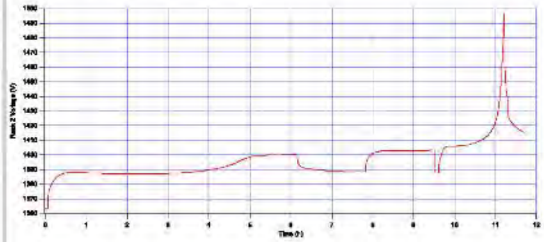
Attachment 1 - Unit charge conditioning graphs





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Attachment 2 – Photos

General sample photos

Figure 1: A photograph of the initiating module with the lid and front panel removed.

Figure 2: A photograph of the initiating module with the cover in place.

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Attachment 2 – Photos

Figure 3: A photograph of the initiating module installed in the initiating unit.

Figure 4: A photograph of the initiating module and video camera location inside the initiating unit.

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Attachment 2 – Photos

Photos with heater and thermocouple installation

Figure 5: At photograph of the initiating unit at test start (12:32 PM).

Figure 6: Another view of the initiating unit.

Photos during test in progress

Figure 7: Test Start (12:32 PM)

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Attachment 2 – Photos

Figure 8: A photograph of the initiating unit during cell venting (01:19 PM).

Figure 9: Another view of the initiating unit during cell venting (01:19 PM).

Figure 10: A screen capture from the video camera inside the initiating unit. (12:32 PM)

Figure 11: A screen capture from the video camera inside the initiating unit during initial venting. (01:19 PM)

Figure 12: A screen capture from the video camera inside the initiating unit during thermal runaway. (01:53 PM)

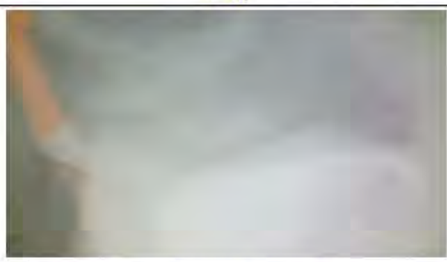

Figure 13: Another screen capture from the video camera inside the initiating unit during thermal runaway. (01:58 PM)

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Attachment 2 – Photos

Photos after test

Figure 14: A photograph of the initiating unit interior after the test.

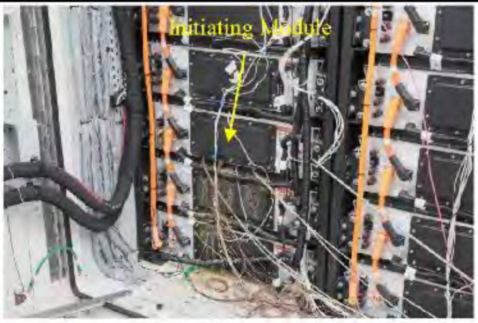

Figure 15: A photograph of the initiating unit interior after the test.

Figure 16: A photograph of the initiating module as it is being removed from the initiating unit after the test.

Figure 17: A photograph of the initiating module after the test and as the lid is being removed.

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Attachment 2 – Photos

Figure 18: A top down photograph of the initiating module after the test with the lid removed.

Figure 19: A top down photograph of the initiating module after the test with the lid and plastic barriers removed.

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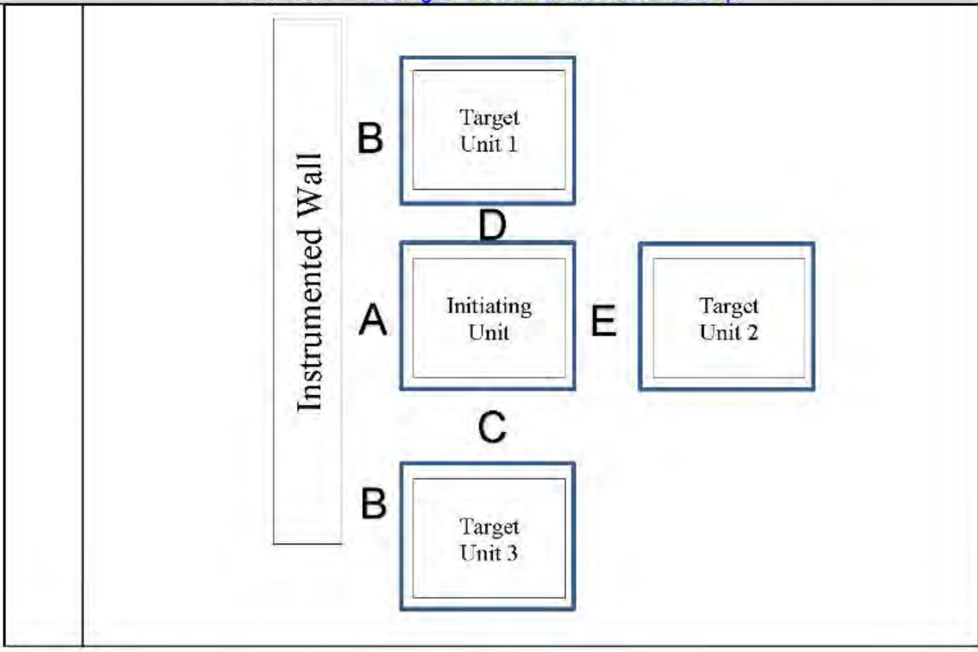
Attachment 3 - Diagram and dimension of test setup



Separation distance and other critical dimension detail		
Location	Required by manufacturer (mm)	Measured (mm)
A- Initiating Unit to Test Wall	3048	3048
B- Target Units 2 and 3 to Test Wall	3048	3048
C- Initiating Unit to Target Unit 3	2134	2146
D- Initiating Unit to Target Unit 1	178	191
E- Initiating Unit to Target Unit 2	178	175

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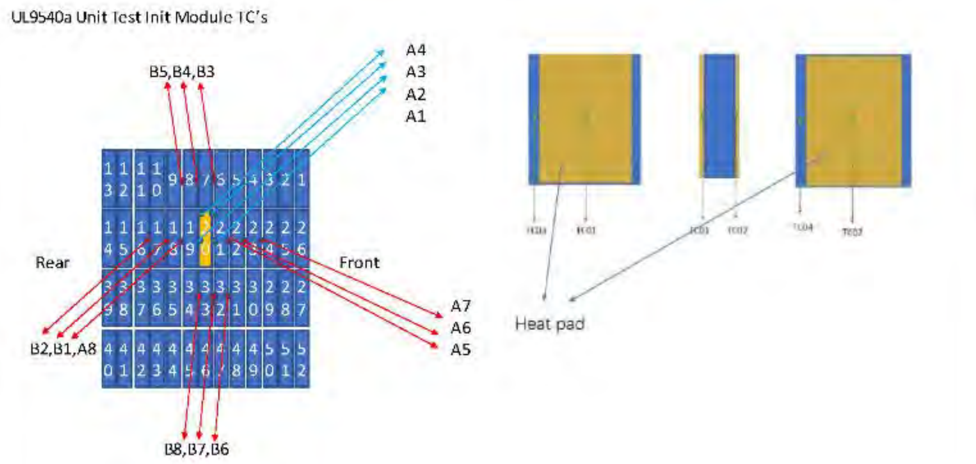
Attachment 3 - Diagram and dimension of test setup



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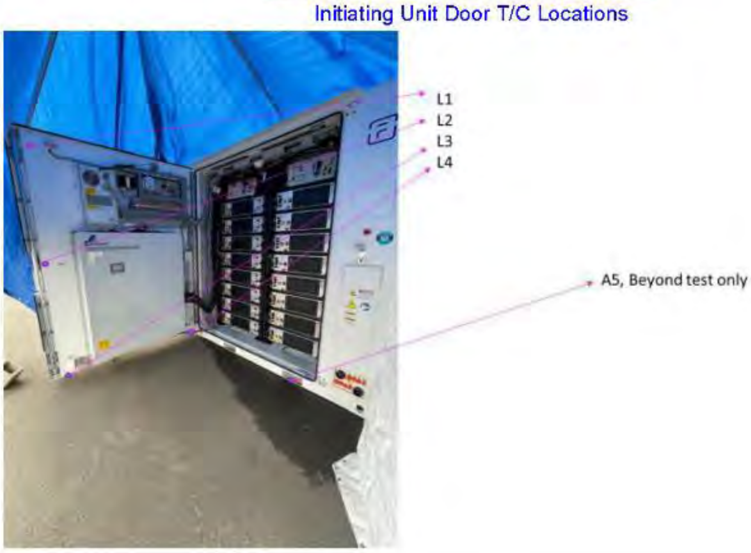
Attachment 3 - Diagram and dimension of test setup

Initiating Unit Interior T/C Locations

Initiating Unit Door T/C Locations



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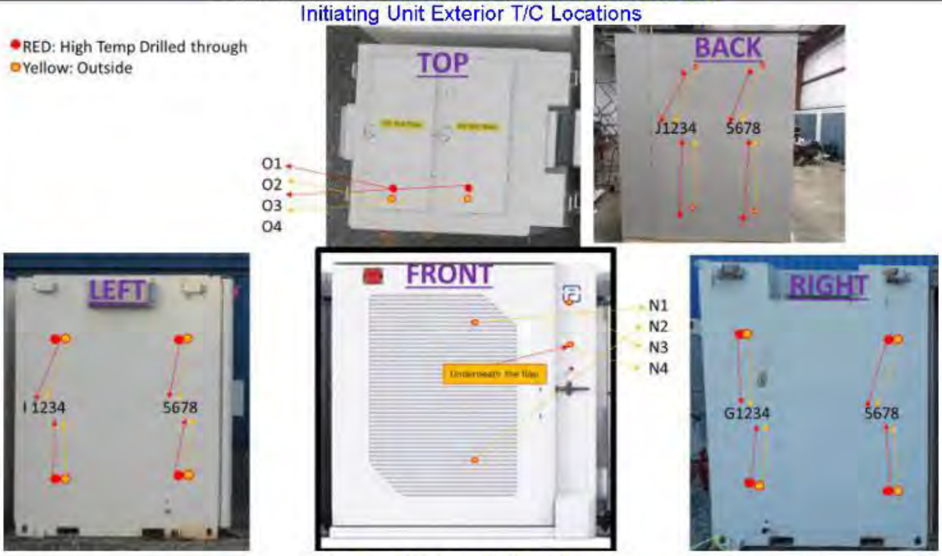
Attachment 3 - Diagram and dimension of test setup

Initiating Unit Exterior T/C Locations



Target Unit 1 T/C Locations

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Attachment 3 - Diagram and dimension of test setup

Target Unit 2 T/C Locations

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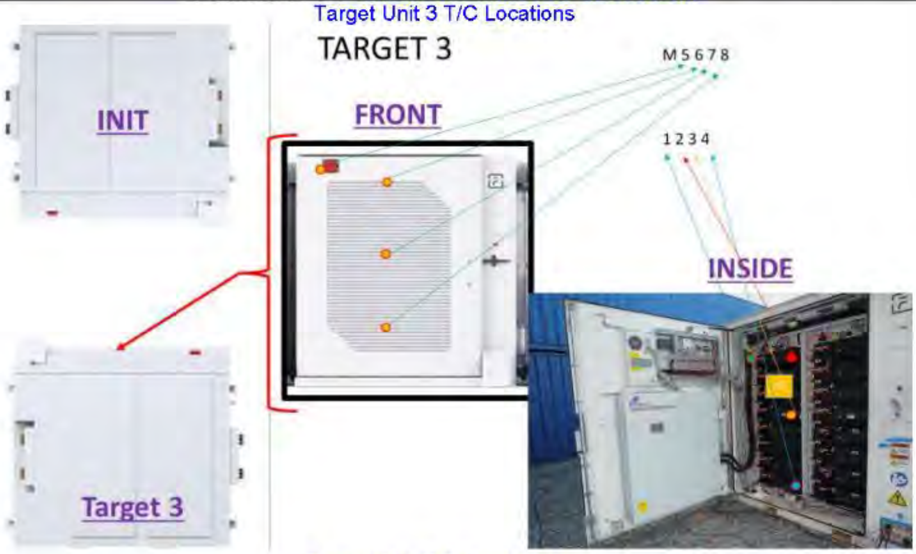
Attachment 3 - Diagram and dimension of test setup

Target Unit 3 T/C Locations



Target Wall T/C Identification

TARGET WALL

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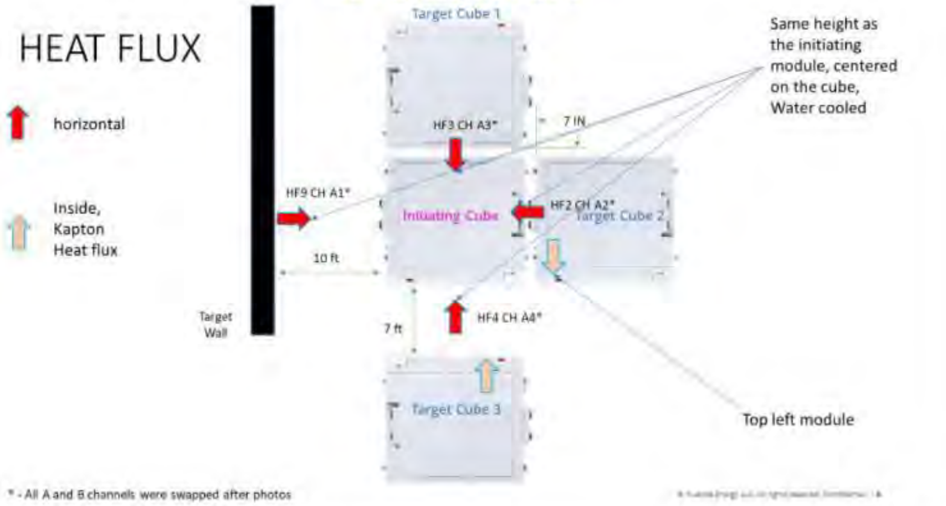
Attachment 3 - Diagram and dimension of test setup

Heat Flux Gauge Locations



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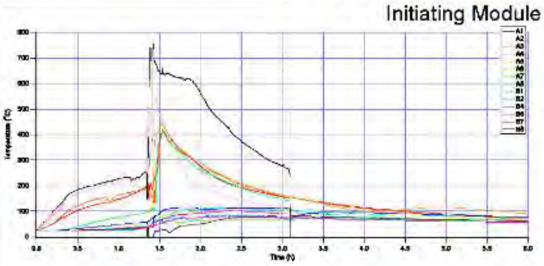
Attachment 4 – Temperature graphs during testing

Initiating Module Temperatures



Maximum temperature measurement		
Location	**Temperature limit (°C)**	**Measured maximum temperature (°C)**
A1 Thermocouple	No criteria	755.7
A2 Thermocouple	No criteria	703.2
A3 Thermocouple	No criteria	411.7
A4 Thermocouple	No criteria	419.1
A5 Thermocouple	No criteria	439.7
A6 Thermocouple	No criteria	113.9
A7 Thermocouple	No criteria	70.83
A8 Thermocouple	No criteria	413.6
B1 Thermocouple	No criteria	112.3
B2 Thermocouple	No criteria	83.66
B3 Thermocouple	No criteria	31.29
B4 Thermocouple	No criteria	115.1
B5 Thermocouple	No criteria	86.69
B6 Thermocouple	No criteria	78.44
B7 Thermocouple	No criteria	102.8
B8 Thermocouple	No criteria	85.44

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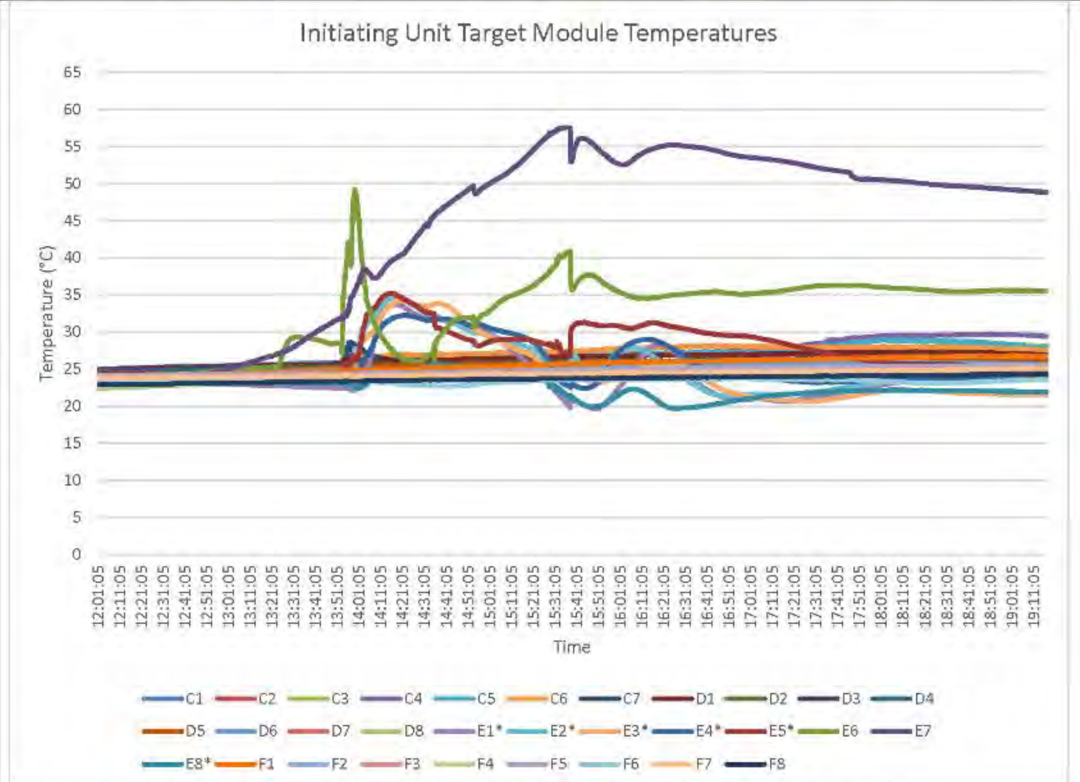

***Note: Thermocouples marked with an asterisk were reversed and had to be corrected.**

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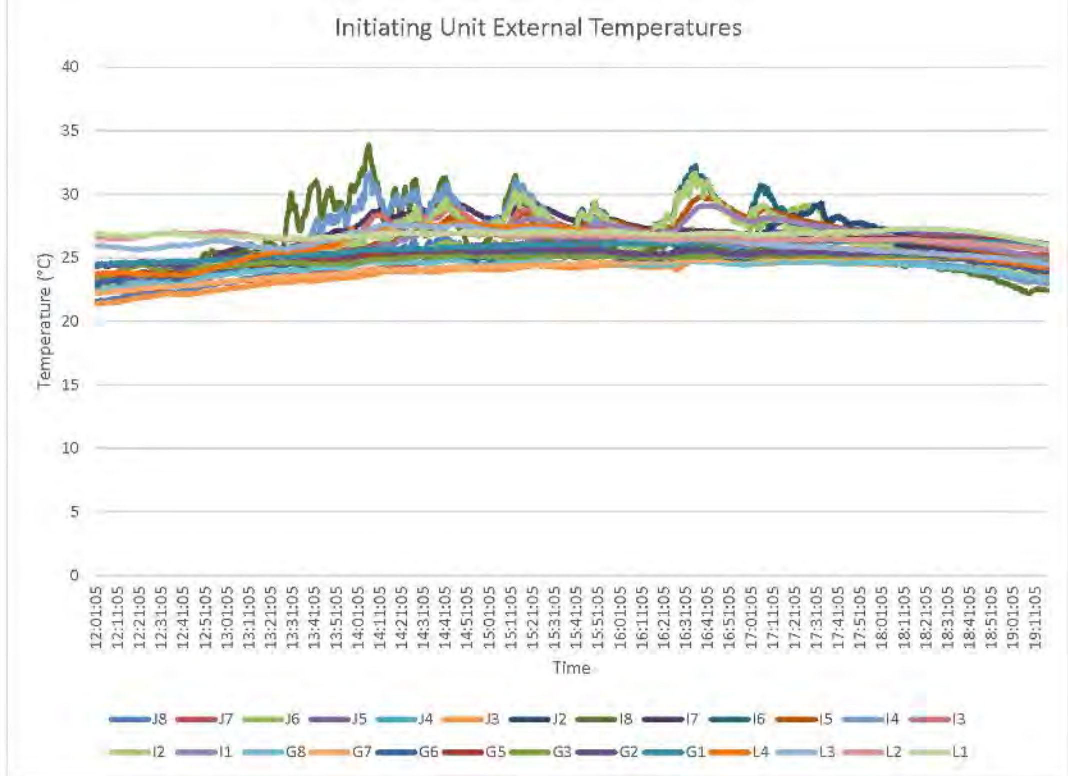
Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Attachment 4 – Temperature graphs during testing



UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

CSA GROUP

Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

ORIGINAL TEST DATA

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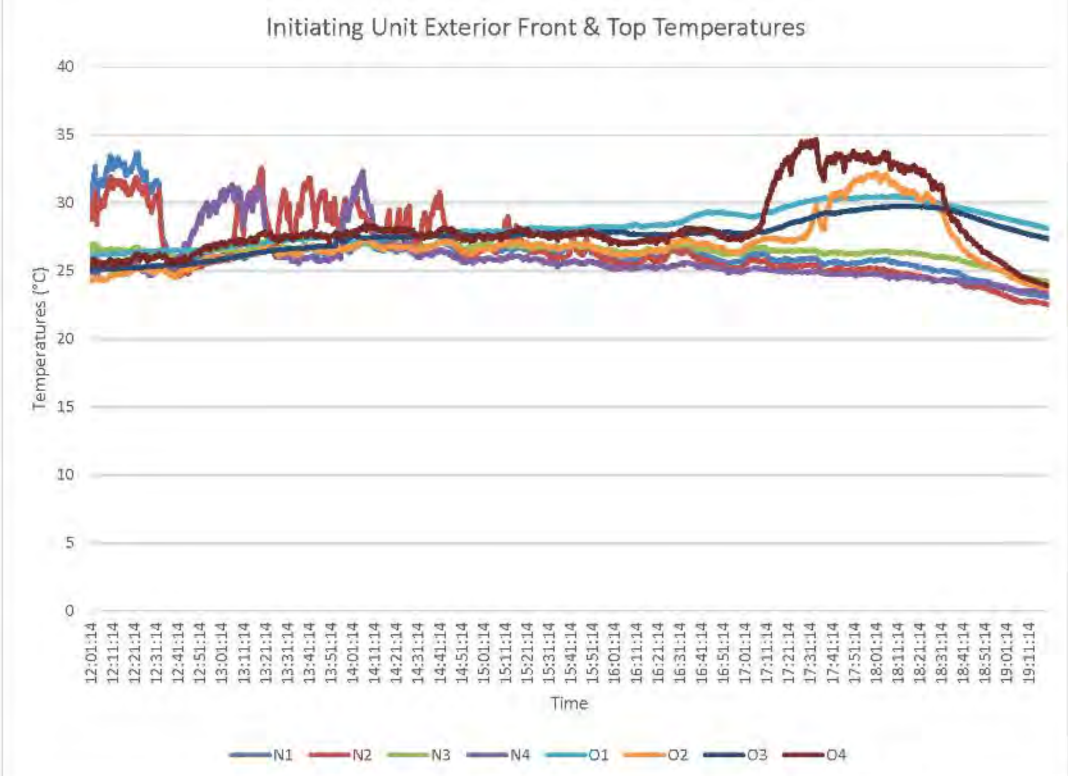
Master Contract:	301546	Model:	06-01-0071-16	Page number 39 of 45
Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Attachment 4 – Temperature graphs during testing



UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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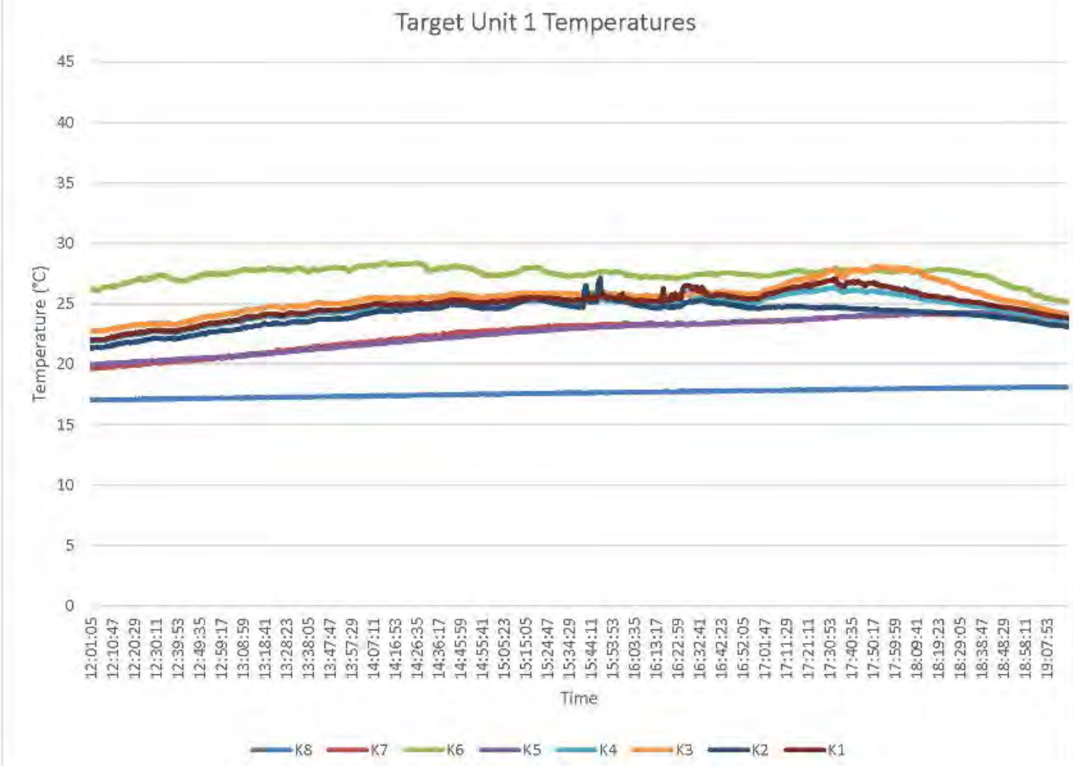
Attachment 4 – Temperature graphs during testing



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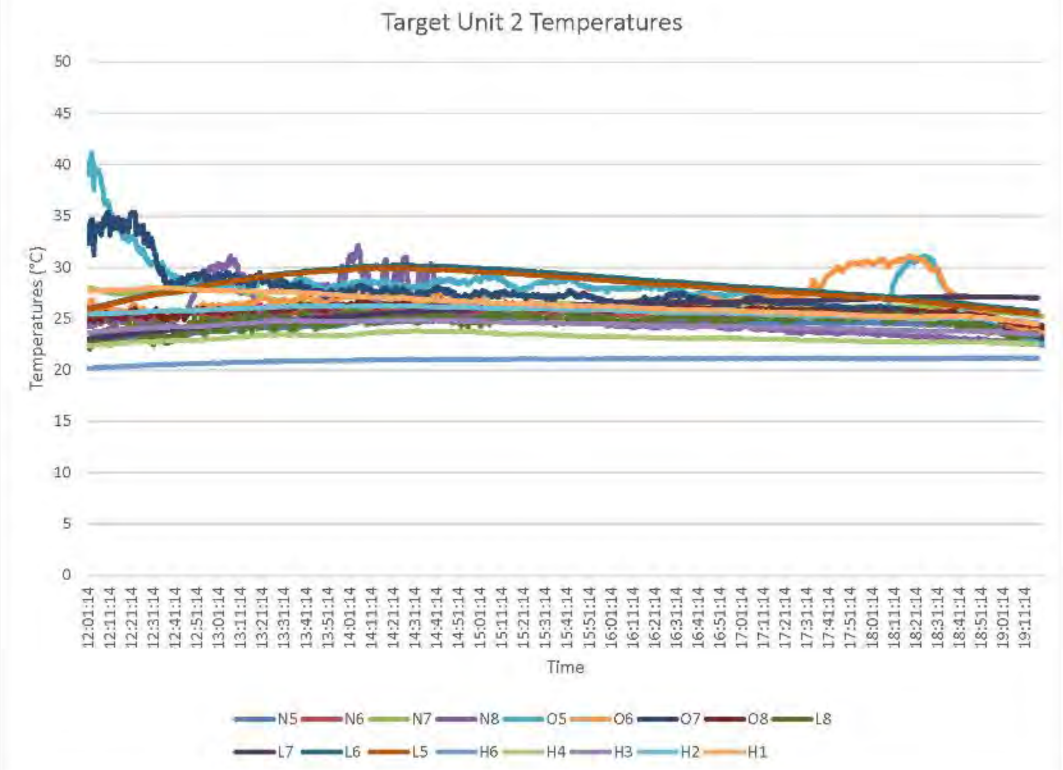
Attachment 4 – Temperature graphs during testing



CSA GROUP

Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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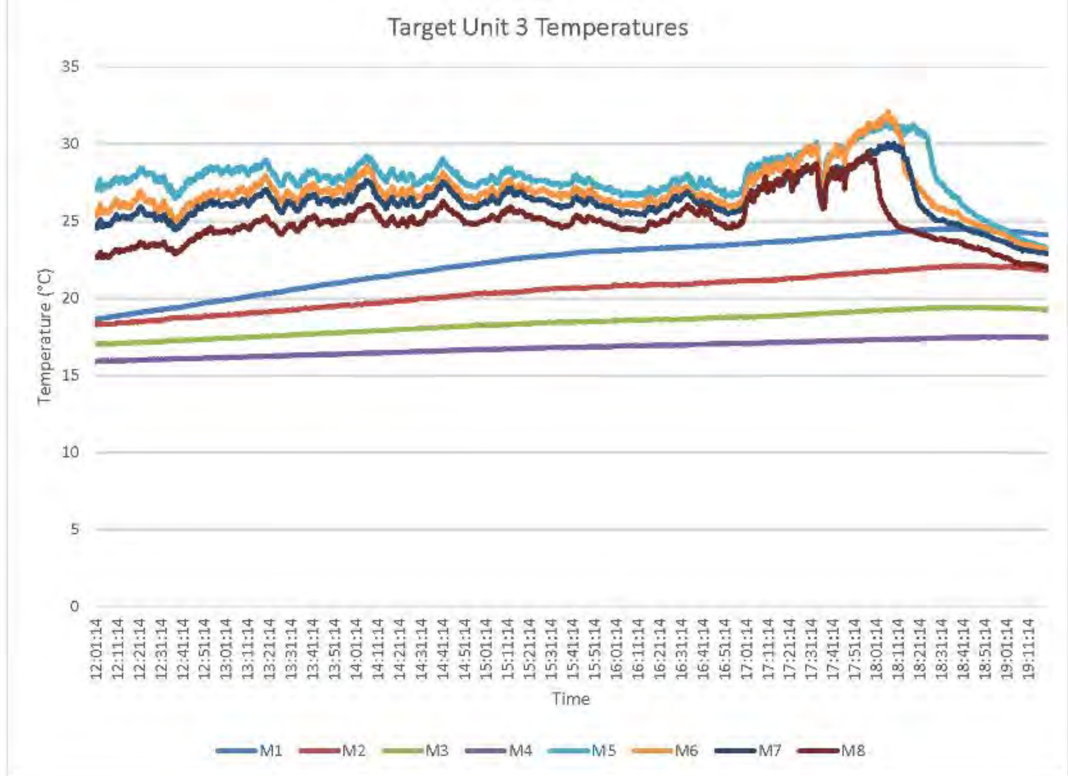
Attachment 4 – Temperature graphs during testing



UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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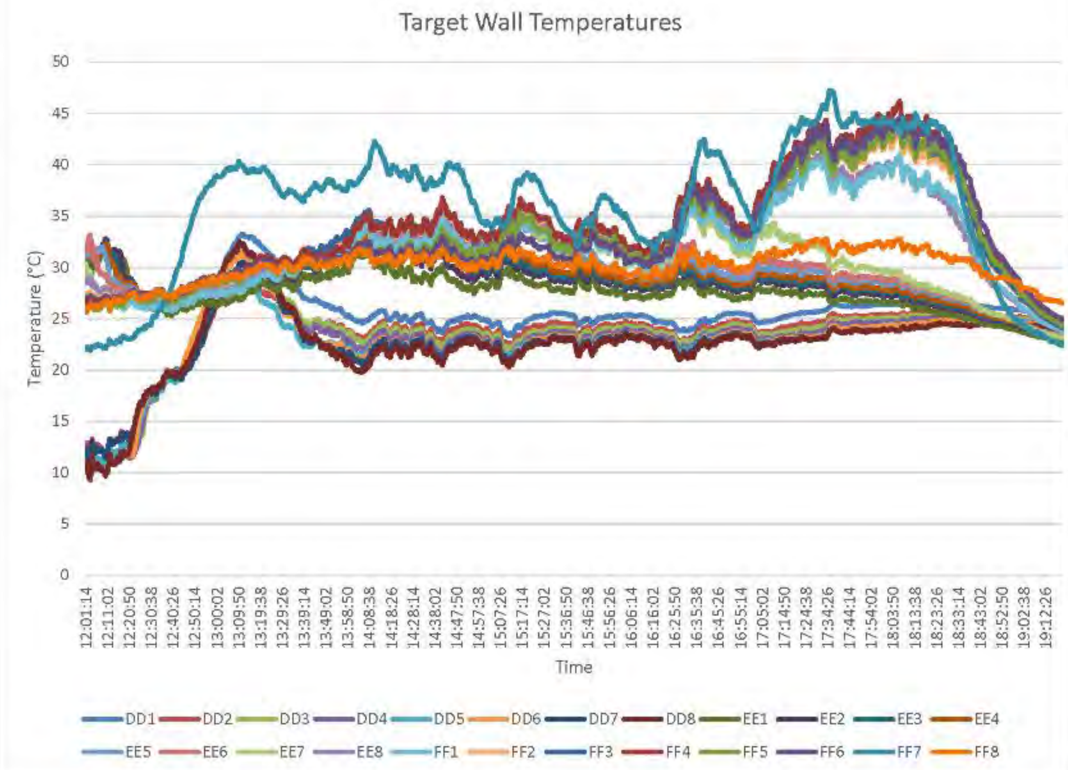
Attachment 4 – Temperature graphs during testing



UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

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Project / Network:	80149894	Description:	Fluence Cube, Long-Duration, Liquid-Cooled	

Attachment 5 - Heat flux graph

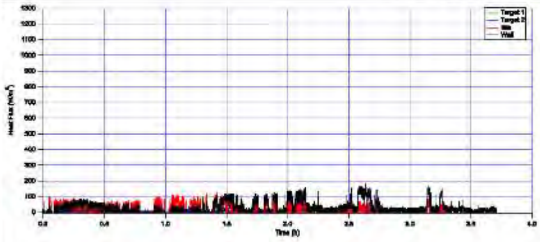

Table 6 – Maximum Heatflux measurement		
Location	Heatflux limit (W/m^2)	Measured maximum Heatflux (W/m^2)
Target 1	No criteria	64.9
Target 2	No criteria	74.1
Isle	1300	121.9
Wall	1300	179.3

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

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Laboratory Test Data - UL 9540A Checklist and Test Result (Unit Level)

ORIGINAL TEST DATA

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Master Contract:	301546	Model:	06-01-0071-16	Page number 45 of 45
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Attachment 6 - Notable observation during test

Observation	Time from test start (HH:MM:SS)	Comment
Test start	(00:00:00)	Power applied to heaters on initiating cell.
First Cell Vent	(00:47:11)	Initiating cell began venting.
Cell 20 TR	(1:20:54)	Initiating cell went into thermal runaway.
Cell 21 TR	(1:25:30)	Thermal runaway propagated to cell in front of initiating cell.
Cell 19 TR	(1:27:18)	Thermal runaway propagated to cell behind initiating cell.
Test end	(19:48:00)	Thermal runaway did not propagate to any other cells in the initiating module, and temperatures had decreased back down to near ambient. Test concluded.

End of Report…

UL 9540A Checklist and Test Result – *Version6 : 2022-08-02*

Appendix C – Large Scale Fire Test

Test Report

Beyond Design Basis Burn Test

Fluence AESC-LFP

Location of Test: 5901 Elwin Buchanan Dr. Sanford, NC 27330

Date of Test: April 17, 2023

Prepared For

Mr. Allan Rhodes

Principal Fire Protection Engineer, Fluence Energy

NORTH CAROLINA PROFESSIONAL SEAL 029412 ENGINEER JOHN P. CAVAROC, JR.

November 7, 2023

Date

AUTHORED BY: John Cavaroc Ph.D., P.E.

SAFE Laboratories and Engineering Corp
5901 Elwin Buchanan Drive, Sanford, NC 27330
Firm License Number: **C-3696**

Table of Contents

I. SUMMARY OF TEST AND RESULTS

1. On April 17, 2023, a Battery Energy Storage System (BESS) manufactured by Fluence was tested at SAFE Laboratories and Engineering Corp (SAFE Labs).
2. The purpose of the test was to determine thermal runaway propagation performance when the BESS is subjected to conditions beyond the design basis and beyond what is required by UL 9540A unit level testing.
3. The BESS, a Fluence Cube, was fully populated with 16 battery modules manufactured by AESC. Each of the AESC modules contained 52 lithium-iron-phosphate (LFP) cells that are series connected.
4. For UL 9540A unit level testing, one cell within an AESC module was heated by film heaters applied to the exterior surface of the cell. For this test, 26 cells in one module are simultaneously heated with strip heaters. Before the test began, all 16 modules within the Fluence Cube were charged to 100% state of charge (SOC).
5. This test resulted in all 52 cells in 1 of the 16 modules experiencing thermal runaway.
6. At the onset of thermal runaway, flaming combustion was observed inside the cube for a short period of time, but there was no deflagration or detonation.
7. Despite triggering thermal runaway in all cells of the module, thermal runaway did not propagate to additional modules. Thermal runaway only occurred in the initiating module.
8. Continuous gas monitoring was performed both inside and outside the initiating unit. A stainless-steel hood was placed over the initiating unit to capture gases escaping the cube and allow for gas monitoring.
9. Alkyl carbonates inside the cube were detected first before thermal runaway occurred. Once thermal runaway occurred, gas generation increased rapidly inside the cube. However, these gases were only present at relatively low levels inside the hood duct.
10. Approximately five minutes after alkyl carbonates were detected, flames were observed and oxygen levels inside the cube dropped to 5%. The flames were brief and self-extinguished in less than one minute. Following the flames, alkyl carbonate rose to 1.8%, followed by elevated levels of ethylene (1.4%), HF (278 ppm), POF_3 (93 ppm), CO_2 (>1%), CO (>3%), CH_4 (8600 ppm), and H_2 (125 ppm). Over an hour later these levels

were still elevated and hydrogen had increased to 13%. The levels inside the cube decreased over several days, while oxygen levels slowly increased over the same time.

11. Hydrogen levels within the cube remained above 4% until almost 23 hours after ignition. The maximum hydrogen detected inside the duct was 385 ppm and all other gases remained below 50 ppm.
12. No deflagration or detonation was observed during or after the test.

II. INTRODUCTION

On April 17, 2023 SAFE Laboratories and Engineering Corp. (SAFE Labs) performed a burn test on a Fluence Cube, a battery energy storage system (BESS) unit manufactured by Fluence. The purpose of the test was to evaluate the battery response to conditions more severe than the conditions required by UL 9540A unit level testing. The test was considered a beyond design basis test (BDBT) that involved initiating thermal runaway in all 52 cells of a battery module within the BESS unit.

III. FLUENCE CUBE DESCRIPTION

The Fluence cube measures approximately 2,549 mm wide, 2,566 mm high, and 2,160 mm deep. The weight when fully populated with 16 AESC modules is 8,250 kg. An example of a Fluence cube is shown in Figure 1.

The door on the front of the cube provides access to the modules, door mounted chiller, UPS, and other controls, as shown in Figure 2. Inside the cube, there are two sets of racks. Each rack accommodates 8 AESC modules. At the top of each rack is a direct current protection module (DCPM). The DCPMs protect and isolate the batteries from the main cube bus bars, located above the DCPMs towards the center of the cube.

The 8 modules in each rack are series connected using cables, with the positive-most terminal and negative-most terminal terminating on the DCPM. The two racks of 8 modules in the cube are paralleled once the manual switch and contactors inside the DCPMs are closed. This connects each battery rack to the internal cube bus bars. In the field, the bus bars would then be electrically connected to the adjacent cube's bus bars so that racks from each cube can all be connected in parallel.

Each of the 16 modules within a cube contains 52 cells. The cube's cell, module, and unit level specification are shown below in Table 1.

Figure 1. A photograph of a Fluence Cube.

Notes:

1. Front door
2. Handle to release front door
3. Access to bus work for cube-to-cube power connections

Figure 2. A photograph inside the BDBT initiating unit.

Notes:

1. Chiller
2. Rack with 8 AESC modules
3. Manual switch on DCPM

Table 1: Initiating unit characteristics.

	Cell	**Module**	**Unit (Cube)**
Model Number	ESS 4LH3L7 280A	EACH-1P52S-280Ah	06-01-0071-16
Chemistry	LFP	LFP	LFP
Configuration	Prismatic	52 Series Connect Cells (52S)	Two racks with 8 series connected modules in each rack (2P8S)
Vdc, Ah	3.2V, 280Ah	166.4V, 280 Ah	1,331.2V, 560Ah
Vmin/max	2.5V/3.65V	145.6V/187.2V	1164.8V/1497.6V

IV. TEST CONFIGURATION

The test was conducted outdoors, with barriers surrounding the test area. A total of 4 cubes were used for the test, one initiating unit and three target cubes. A 12' x 12' stainless steel hood was placed over the initiating unit to capture gases evolved from the initiating unit. A separate, portable probe was also used to capture gases from within the initiating unit.

During the BDBT, modules were installed and connected inside the unit as described above. The DCPMs were both left open during the test, so the unit bus bars were not intentionally energized. Three target cubes were also used during the test, as they were for the UL 9540A unit level test. The DCPMs for the target cubes were also open during the test.

A plan drawing of the cube layout is shown in Figure 3. A photograph of the test area taken from a drone is shown in Figure 4. This photograph was taken shortly before the test started.

A. Target Cubes

The overall test set up was conducted using the four Fluence cubes arranged in a configuration similar to the way they would be configured for field installation. Units were installed with minimum installation distances per the installation manual. There was seven inches spacing between adjacent units and back-to-back units and seven feet spacing between units door to door. A target wall was located 10 feet away from the initiating unit as required by NFPA 855 for installation near exposures. The wall was constructed of ¾" pressure treated plywood that was painted flat black.

The initiating unit bus bars were connected to the adjacent target cube bus bars using flexible jumpers provided. However, the modules in the adjacent cube were not connected to each other or to the cube DCPMs.

All target units were fully populated with 16 live Lithium Iron Phosphate (LFP) modules with similar 280 Ampere-hour (Ah) cells. These cells were charged to approximately 30% SOC. The target modules were not manufactured by AESC but were similar liquid cooled modules. They had an aluminum cooling plate base and were intended to be cooled with the same type of chiller as the AESC modules. The top and sides of the target modules were made of polyethylene. These live, functional modules were placed in the adjacent cube for monitoring temperatures of a thermal mass, thermal conductivity, and density like the AESC modules. Functional AESC modules were not available for the target cube at the time of the test, so this similar substitute was used instead.

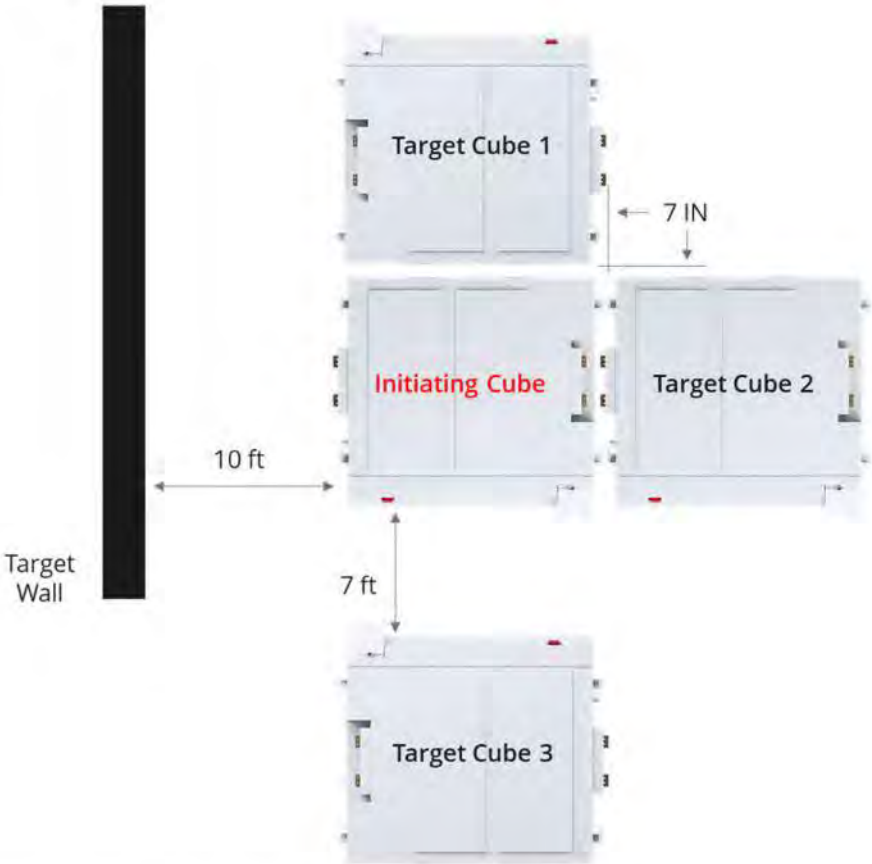

Figure 3: Test site plan view.

Figure 4. A drone photograph of the test site.

Notes:

1. Target cube 1
2. Target cube 2
3. Target cube 3
4. Initiating unit
5. Target wall
6. Hood over initiating unit
7. Ductwork to scrubbers and CEMS

B. Initiating Module

A photograph of the initiating module used for the BDBT is shown in Figure 5. The nameplate for this module is shown in Figure 6. Each module contains 52 LFP 280 Ah cells connected in series. The modules were constructed of aluminum sides and a stamped steel lid. They are liquid cooled using an aluminum cooling plate at the bottom of the module.

The initiating module used for the BDBT was identical to the UL 9540A initiating module, but the initiating heaters were different. Instead of heating a single cell, four stainless steel strip heaters were used, as described below. This provided nearly simultaneous thermal runaway of multiple cells within the initiating module.

The BDBT was performed two days after the UL 9540A unit test. Although the initiating module was replaced, the other modules and cubes were reused. In the UL 9540A unit level test, the initiating module was only partially damaged and did not result in all 52 cells entering thermal runaway. The other modules within the initiating unit survived with little to no observable damage.

Before the BDBT, the replacement initiating module was charged to 100% state of charge (SOC) to match the SOC of the other 15 modules already in the cube. The initiating module position was chosen to be rack 1, module 6, the sixth module from the top in the left rack. This is the same position used for the UL 9540A initiating module and is considered a likely worst-case position for an initiating module. Figure 7 shows the initiating module after it was placed in the initiating unit.

After the initiating module was reinstalled, the liquid cooling system was filled with a mixture of 50/50 glycol and water according to installation instructions. Although the cooling system was filled, the chillers and pump were not energized or operating during the test.

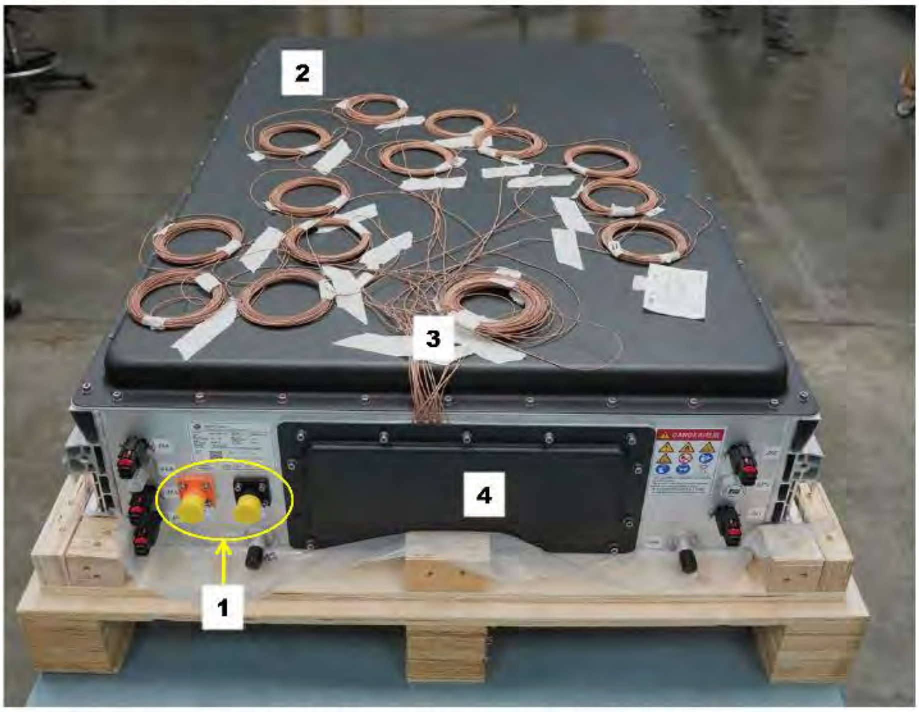

Figure 5. A photograph of the BDBT AESC initiating module as it was being unpackaged.

Notes:

1. Module power connections
2. Module lid
3. Thermocouples for initiating module
4. Module front

Figure 6. AESC BDBT initiating module nameplate.

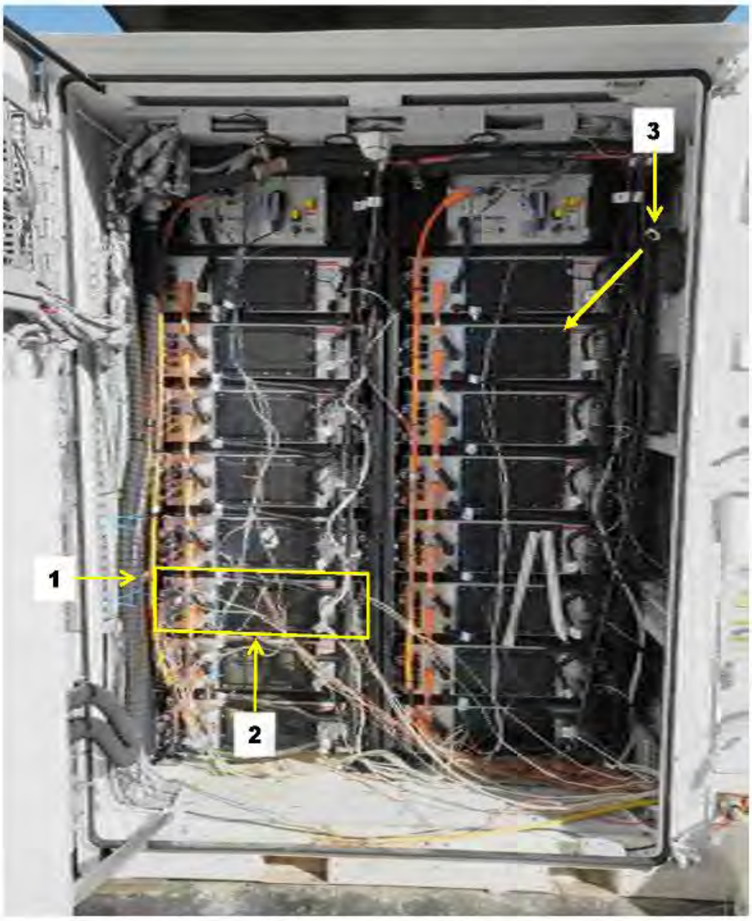

Figure 7: A photograph inside the initiating unit.

Notes

1. Lower RGB camera inside initiating unit (behind coolant lines), pointed towards initiating module
2. Initiating module location
3. Upper RGB camera inside initiating unit (arrow indicating camera angle)

C. Instrumentation

The instrumentation and data acquisition were the same for the UL 9540A unit level test and the BDBT. This instrumentation consisted of equipment and data acquisition listed below.

1. Weather station for monitoring environmental conditions
2. Continuous Emission Monitoring System (CEMS) for measuring various gases evolved during the burn test
3. Isolated K-type thermocouples for measuring temperature
4. Water cooled heat flux transducers for measuring heat flux
5. Red Green Blue (RGB) cameras for video recording
6. Thermal imaging cameras for video recording and monitoring external cube temperatures

1. CEMS

The CEMS contains multiple analyzers and detectors for quantifying and logging various gases. The primary function of the CEMS is to continuously monitor the quantities listed below. Samples are taken from both the hood and associated ductwork over the initiating unit and the portable probe sampling from inside the unit.

Fourier-Transform Infrared Spectrometer (FTIR): FTIR is used to measure toxic and other gases. It uses infrared light to identify and quantify various gas constituents. Inside the FTIR, the instrument's infrared beam interacts with the gas and is partially absorbed. Different gas molecules have atomic bonds with different bond strengths and, in generic terms, the infrared light that is at the same frequency as a molecule's vibration will be absorbed. Therefore, some infrared light is absorbed, and some is transmitted to the detector. The absorbed frequencies are unique for each gas constituent. The intensity of absorption is indicative of the amount/concentration.

An FTIR can simultaneously measure multiple gases. A list of detectable gases is shown below in Table 2. The other analyzers in the CEMS are single-gas analyzers.

Table 2. List of Compounds Detectable by FTIR

Butadiene	
Acetylene	
Methane	
Carbon Monoxide	
Carbon Dioxide	
Carbonyl Sulfide	
Alkyl Carbonates	
Ethane	
Ethylene	
Ethylene Oxide	
Formaldehyde	
Water	
Isobutylene	
MeOH	
N2O	
NH3	
NO	
NO2	
Oil as Octane	
POF3	
Propane	
Propylene	
Acid Gases	H2SO4
	HBr
	HCl
	HCN
	HF

High Temperature Flame Ionization Detector (HFID): The HFID is used to measure total hydrocarbons (THC). It contains a burner situated inside a heated enclosure. Hydrocarbons in the gas are ionized in the flame. The HFID also houses a split-ring detector with two electrodes, one is positively charged and one negatively charged. The ions migrate to their respective electrodes and this migration creates a current between the electrodes. The strength of the current is proportional to the concentration of total hydrocarbons.

Oxygen Detector: Oxygen is paramagnetic, which means it is attracted to a magnetic field. Most other gases are not. The oxygen sensor uses this property and was chosen because it is capable of measuring zero oxygen, whereas most oxygen detectors are not. The instrument contains a non-homogeneous magnetic field that attracts oxygen. Two glass spheres connected by a platinum wire form a dumbbell that is balanced in the non-homogeneous magnetic field but moves with the flow of oxygen. A mirror mounted on the dumbbell communicates movement and an opposing current is applied to return the dumbbell to its neutral position. The amount of compensating current required to return the dumbbell to its initial position is directly proportional to the amount of oxygen. Oxygen was continuously monitored.

Gas Chromatograph with Thermal Conductivity Detector (GC-TCD): The GC-TCD is used to measure hydrogen. A GC separates gas into its individual constituents by carrying the gas through a packed column with what is referred to as a stationary phase. The various constituents of the gas interact with this stationary phase and constituents with strong interactions stay in the column longer. As the components exit the column, or 'elute', they do so at unique times and thus individual components of gas sample are separated into their various components. From there, the sample is carried to a TCD. The TCD detector uses a bridge circuit to compare the variation in resistance between a constituent plus inert carrier gas to that of inert carrier gas alone. The change in resistance is a function of the amount of constituent present. In this way, hydrogen separation occurs through the GC and the amount of hydrogen is determined by the TCD. This standalone GC-TCD is set up to detect only hydrogen, followed by a purge, followed by a repeat detection of hydrogen. This, along with the fact that hydrogen elutes first and elutes quickly, allows this standalone GC-TCD to provide continuous monitoring of hydrogen.

Gas Chromatograph with Mass Spectrometer (GC-MS): The GC-MS is used to further characterize hydrocarbons. The GC works using the same principles described above for separating gas into its individual constituents. Once separated by the GC, the constituents are carried to the MS, where they are bombarded with a beam of electrons. The beam hits with enough force to knock an electron out of the molecule, thus creating an ion. The ion will then quickly fragment into smaller ions. A quadrupole made of two pairs of rods oppositely charged attracts smaller ion fragments and allows larger ones to get to the detector. An imposed AC current is varied so that the quadrupole allows different sized ions to reach the detector. An ion fragmentation pattern is developed and this pattern is unique to the specific gas constituent and amount. GC-MS samples were collected during key events of testing using both a Tedlar bag sampling system and an adsorbent tube sampling system.

Smoke Obscuration: Smoke obscuration is monitored inside the ductwork attached to the hood. This is done by passing a light across the ductwork. The light is obscured by smoke and can be quantified as a percent of obscuration, with 100% being totally obscured by the smoke.

2. Heat Flux Transducers

Heat flux transducers were used to measure the heat flux in various locations in the test area. The heat flux transducers are water cooled, so they can be exposed to high heat flux levels. They work by converting heat flux to a small-scale voltage, which is continuously recorded by a transient recorder.

Two heat flux transducers were placed between the target units and the initiating unit, at the initiating module elevation. Two additional non-water-cooled heat flux transducers were installed inside of Target 2 and Target 3, on battery modules expected to receive the highest heat exposure. A fifth heat flux transducer was installed on the target wall and a sixth was installed in the aisle between the initiating unit and the Target 3 cube. These heat flux locations are shown in Figure 8.

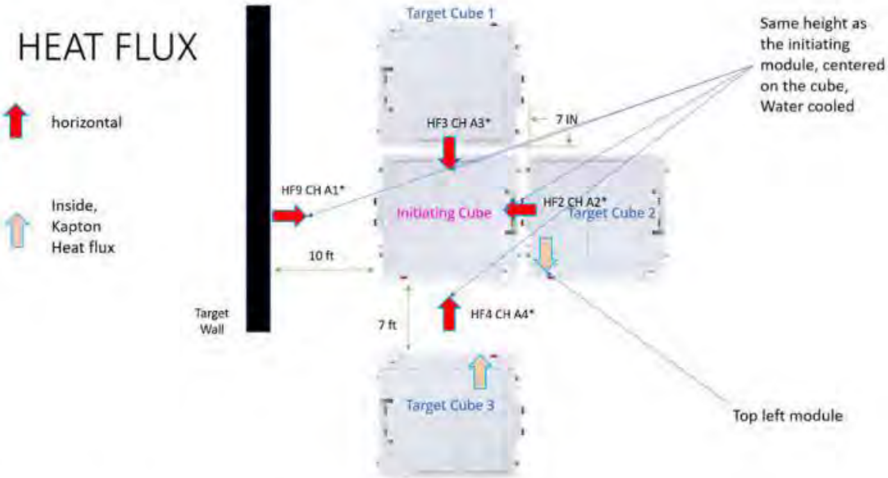

Figure 8. Heat flux transducer locations (red and tan arrows).

3. Thermocouples

A total of 132 type K thermocouples were used to monitor temperature throughout the test. Thermocouple locations complied with UL 9540A unit level testing requirements, and additional thermocouple locations were added. The thermocouple data was logged every six seconds (10 times per minute). Thermocouples were placed in the locations listed below.

1. Initiating module cells
2. Initiating unit modules
3. Initiating unit
4. Target wall
5. Target cubes

Figure 9 shows a diagram representing the 52 cells inside the initiating module and the thermocouple locations. Also shown are the initiating heaters, which will be further described in the initiating method section of this report. One thermocouple was placed on each of the 4 initiating heaters.

Figure 10 shows a photograph of the initiating unit and the thermocouple locations inside the initiating unit. Thermocouples were placed on each module within the initiating unit.

Figure 11 through Figure 13 shows the target units and the thermocouple locations associated with each unit. On the target units, thermocouples were placed in areas expected to receive the greatest temperature rise due to fire inside the initiating unit.

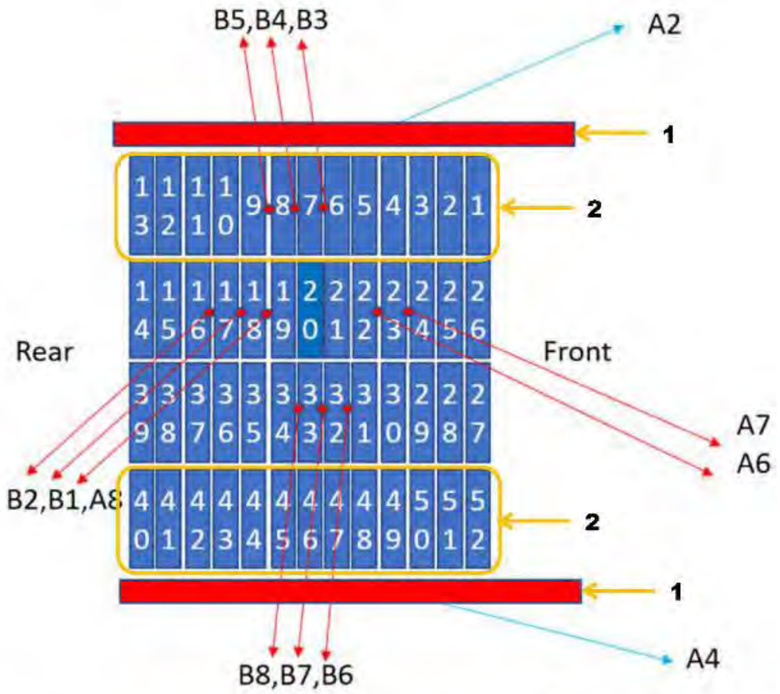

Figure 9. Initiating module internal thermocouple locations (B1-B8; A2, A4, A6, A7, A8).

Notes:

1. Initiating heaters, two on each side, 4 total
2. Outer row of cells in direct contact with heater

Figure 10: Thermocouple locations within initiating unit.

Notes:

1. Blue arrows indicate thermocouples on module exhaust port
2. Pink arrows indicate thermocouples in center of module lid

Figure 11: Thermocouple locations within target 1.

Note: All thermocouples indicated here were placed towards the back of the module as close to the initiating unit as possible

Figure 12: Thermocouple locations inside target 2.

Figure 13: Thermocouple locations inside target 3.

4. Video Cameras

A total of 10 video cameras were used during the test. Five RGB cameras were placed around the test area, directed towards the initiating and target units. Two additional RGB cameras were placed inside of the initiating unit. One RGB camera was placed in a target unit.

Two thermal imaging cameras were placed outside the initiating unit and directed towards it. This provided real-time thermal imaging of the initiating unit cube.

These camera locations are shown below in Figure 14. The RGB cameras inside the initiating unit are shown in Figure 7, above.

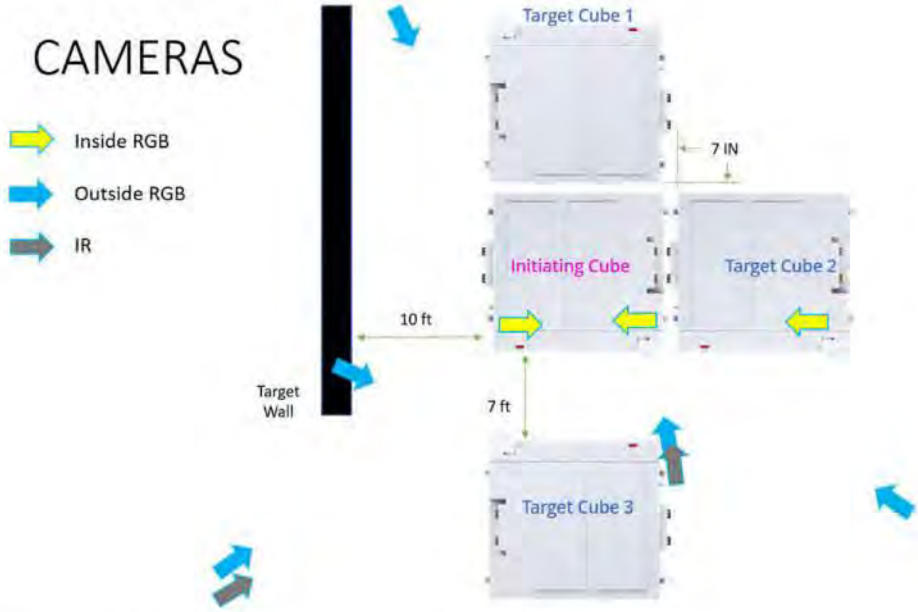

Figure 14. A diagram showing video camera locations.

5. Heater Voltage and Current

Heater voltage and current were acquired when the heaters were energized. The heater current was acquired using hall effect current transducers and the voltage was monitored directly. Both the current and voltage were sampled at 1kHz continuously until the heaters were damaged beyond use and disconnected.

D. Initiating Method

Four 2.25kW strip heaters were used to initiate thermal runaway of multiple cells inside one module, the initiating module. This module was a spare initiating module previously provided for UL 9540A unit level testing. As such, it contained heaters for heating one single cell and thermocouples on the cells around that initiating cell. For this test the cell initiating heaters were left in place but were not used. The cell thermocouples were used.

A diagram showing the internal initiating module thermocouples and the 2.25kW heater locations is shown in Figure 9.

To accommodate the four 2.25 kW heaters, the initiating module enclosure front wall was modified. Each heater measured approximately 48" long and 1.5" wide, so slots were cut into the front of the module. This allowed the heaters to slide between the outer aluminum enclosure wall and the outer row of cells. There was a pre-existing air gap between the cells and the module enclosure side wall. The heaters filled this gap, simultaneously contacting both the cells and the aluminum module side wall.

Two surface mount thermocouples were placed on each set of heaters using Kapton tape. The thermocouples were routed out of the module through small gaps created in the lid gasket material. This is shown in Figure 15.

Two temperature controllers were used to control the 4 initiating heaters. Electrically, the two heaters on each side of the module were connected in parallel. These two paralleled sets of heaters were each controlled with a separate temperature controller. The two temperature controllers used a proportional, integral, differential (PID) control approach. At the start of the test, the temperature controllers were set to ramp the temperature at a rate of 4 degree C/min. This ramp rate continued until the heater overcurrent protection opened or the heaters reached 600 degrees C. Each set of paralleled heaters was individually fused. Once thermal runaway was confirmed, the heaters were disconnected.

Each set of heaters operated at 240 Vac, applied in pulses of varying time by solid state relays controlled by the temperature controllers. The temperature controllers modulated the pulse width, also known as pulse width modulation (PWM), to achieve the desired 4 degrees C ramp rate.

The input for each of the two PID temperature controllers was a thermocouple affixed to one of the heaters. The thermocouple on the other heater of each paralleled heater set was logged with the initiating and target thermocouples. The two thermocouples that were input into the PID temperature controllers and used for control of the ramp rate were re-transmitted and logged on a separate data acquisition system.

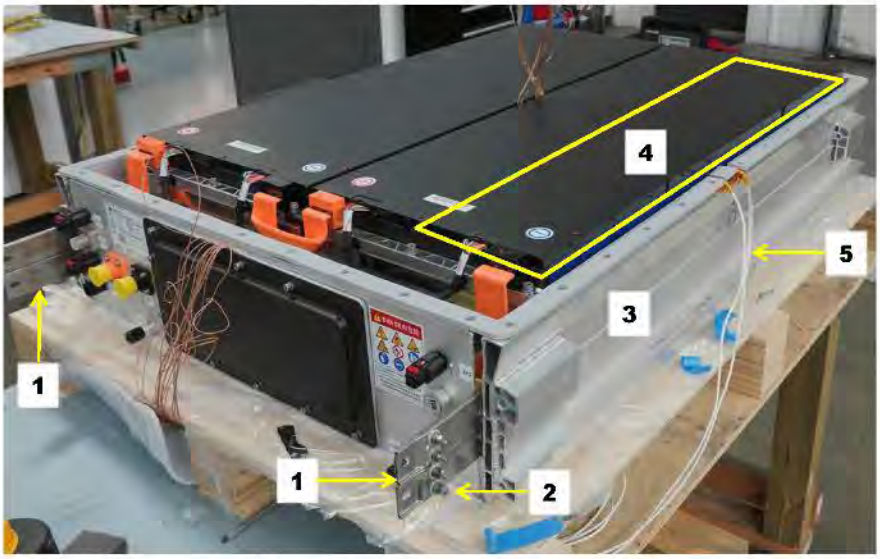

Figure 15: Initiating module with the lid removed.

Notes:

1. Initiating heaters, slid down module side, two on each side
2. Electrical terminals for heaters
3. Aluminum side of module
4. Outer row of cells
5. Thermocouple wires affixed to heaters

V. TEST DATA

On the day of the BDBT, the heaters were first energized at 10:20 AM. Approximately 2 hours later, the first cells entered thermal runaway. Ultimately, all cells within the initiating module entered thermal runaway, but no cells in other modules entered thermal runaway. Observable events lasted for approximately six hours, after which the temperatures slowly returned to ambient and the gas concentration inside the cube slowly progressed towards normal.

A. Weather

At the start of the test, the outdoor temperature was 65 degrees Fahrenheit with 35 % relative humidity and a 7 mph wind speed. Wind gusts were below 12 miles per hour (mph) during the beginning of the test and less than 2 mph by early afternoon.

B. Video

A timeline summarizing the significant observable events is shown below in Table 3. Corresponding screen captures from the videos follow the table.

During the test, gases are seen escaping out of the cable penetrations where data acquisition was routed into the cube. These penetrations would normally be sealed during field installation.

Table 3. Timeline

	Time (HH:MM)	Event	Figure
1	0:00	Heaters turned on	Figure 16
2	1:53	First cell experiences thermal runaway; thermocouple was at 138 C before thermal runaway and 436 C approximately 6 seconds later (6 second sample time)	
3		Flames visible inside the cube	Figure 17
4		First signs of gas exiting cube	Figure 18
5		Coolant lines inside the cube are ruptured and begin to leak coolant	Figure 19
6		Flames self extinguish after less than a minute	
7		Internal cameras are obscured by smoke for the duration of the test	Figure 20
8	1:54	Gas escapes from the cable penetration (duration 3 min)	Figure 21
9	2:01	Gas escapes from the cable penetration (duration 3 min)	Figure 22
10	2:13	Gas escapes from the cable penetration (duration 1 min)	Figure 23
11	2:15	Gas escapes from the cable penetration (duration 7 min)	Figure 24
12	2:24	Gas escapes from the cable penetration (duration 7 min)	Figure 25
13	2:31	Gas escapes from the cable penetration (duration 1 min)	Figure 26
14	2:34	Gas escapes from the cable penetration (duration 3 min)	Figure 27
15	2:44	Gas escapes from the cable penetration (duration 2 min)	Figure 28
16	2:48	No more gasses are visible exiting the cube. (hydrogen levels were 13%)	
17	13:12	Hydrogen levels were 7%	

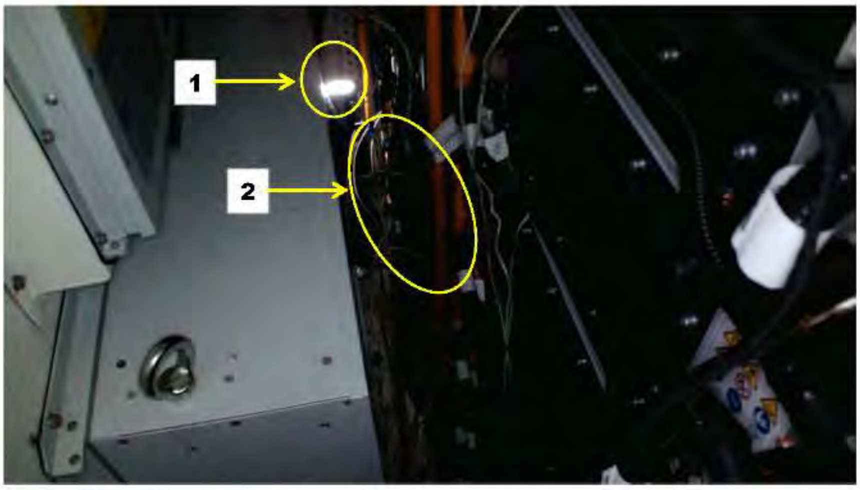

Figure 16. A screen capture from the upper RGB camera inside of initiating unit (0:00).

Notes

1. Light from lower internal camera
2. Initiating module

Figure 17. A screen capture from the upper RGB camera shows flames from the initiating module after the first cell undergoes thermal runaway (1:53).

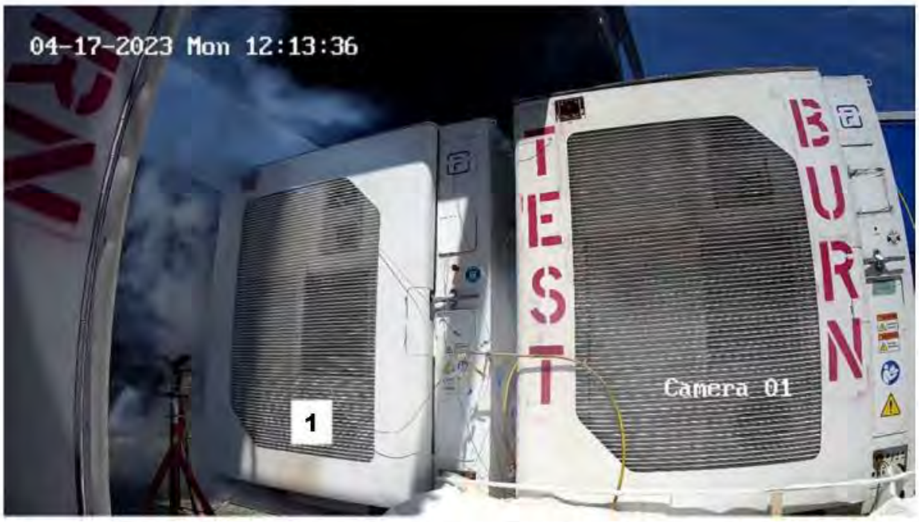

Figure 18. A screen capture showing smoke and gases escaping the initiating unit (1:53).

Notes:

1. Initiating unit

Figure 19. A screen capture shows coolant lines leaking inside the initiating unit while flames are also visible (1:53).

Notes

1. Liquid spraying from coolant lines

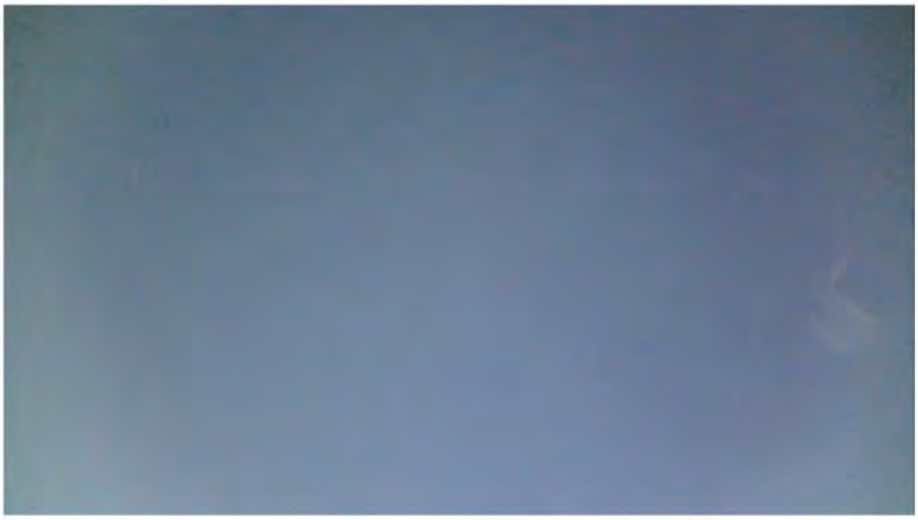

Figure 20. A screen capture showing smoke obscured internal cameras (1:53).

Figure 21. A screen capture showing timeline event 8 (1:54).

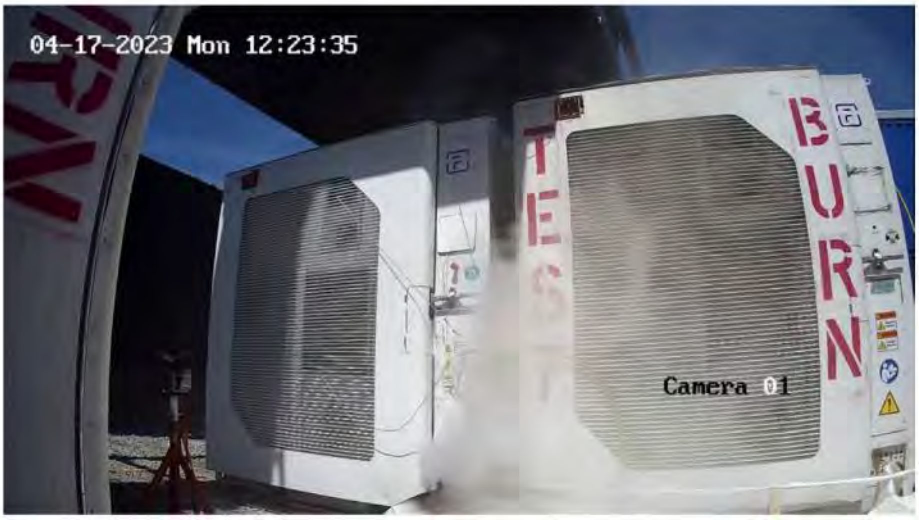

Figure 22. A screen capture showing timeline event 9 (2:01).

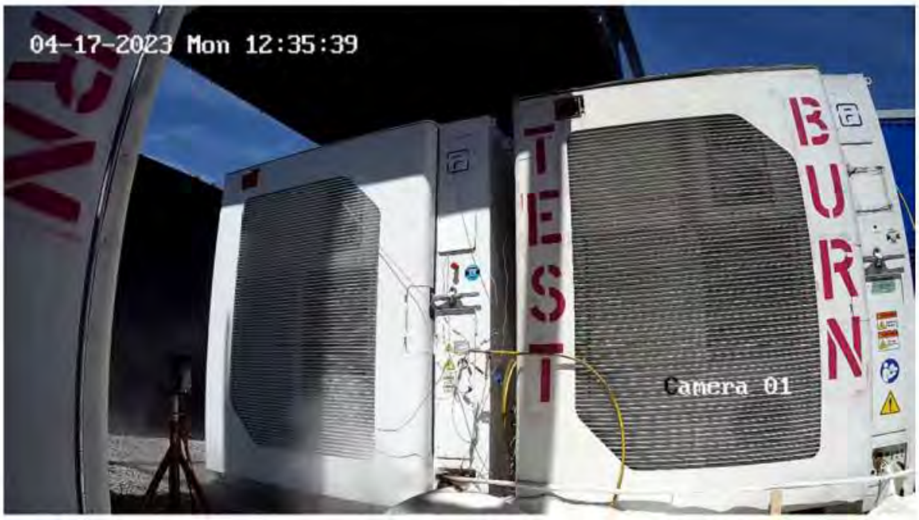

Figure 23. A screen capture showing timeline event 10 (2:13).

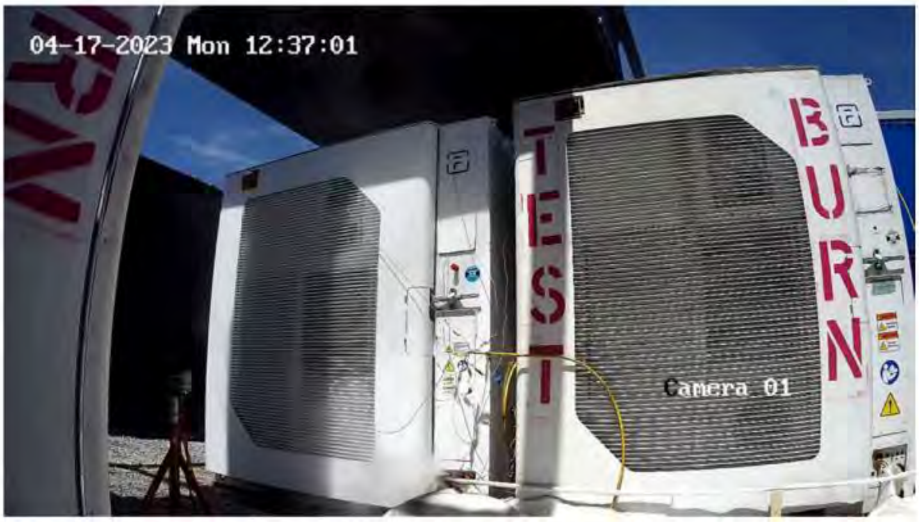

Figure 24. A screen capture showing timeline event 11 (2:15).

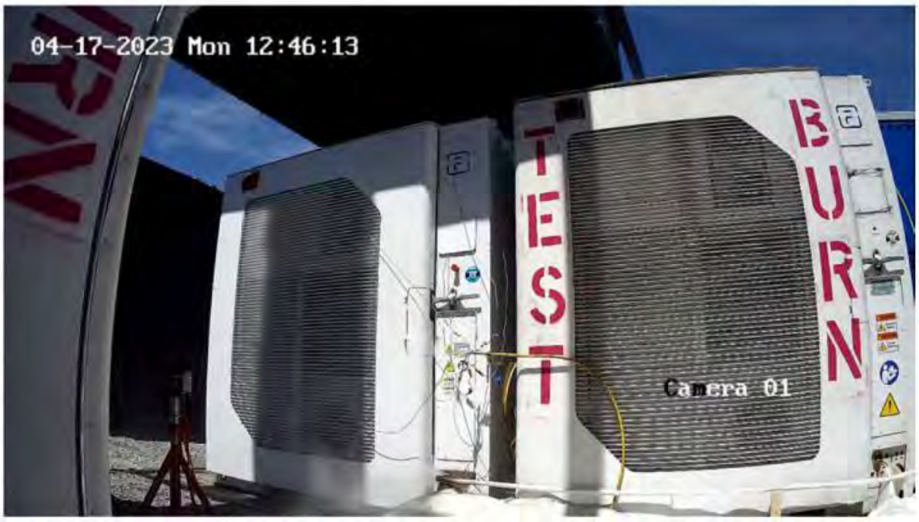

Figure 25. A screen capture showing timeline event 12 (2:24).

Figure 26. A screen capture showing timeline event 13 (2:31).

Figure 27. A screen capture showing timeline event 14 (2:34).

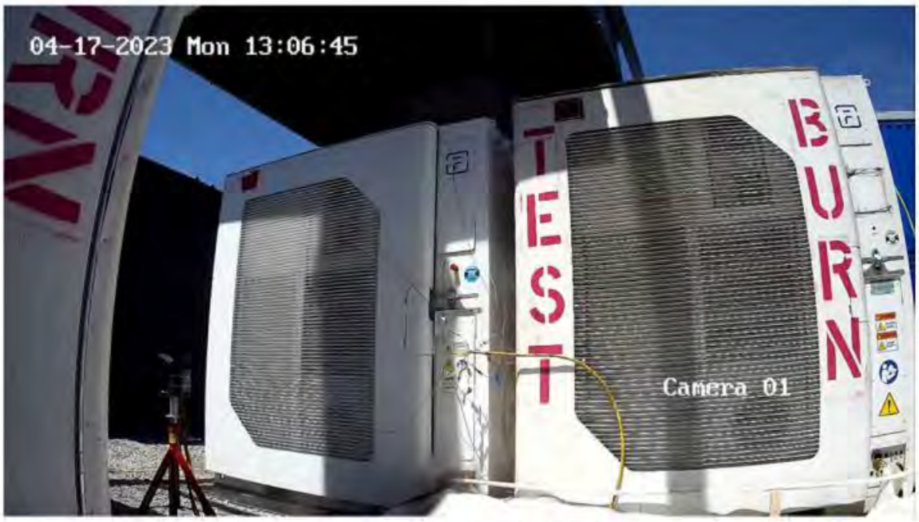

Figure 28. A screen capture showing timeline event 15 (2:44).

C. Thermocouples

Temperature data was captured for 24 hours after the start of the test, but all temperatures continue cooling trends after the first few hours. No subsequent thermal events occurred after the first 6 hours of the test.

Figure 29 shows the temperature data from the thermocouples that were used to control the ramp rate of the heaters. The 60Hz AC heater current data is also shown in this figure. Due to the scale of the time axis, the PWM waveforms cannot be seen. The heaters are not energized 100% of the time as it may appear in the figure. The heater current was controlled to maintain the 4 degrees C per minute ramp rate.

Figure 30 shows the temperature data from the other two heater thermocouples, shown in Figure 15. The data from all 4 of the heater thermocouples was logged even after the heaters were turned off.

Figure 31 shows the temperature data from the other thermocouples inside the initiating module. All thermocouples showed temperatures consistent with thermal runaway over a period of approximately one hour.

Figure 32 shows all initiating unit temperatures, except those internal to the initiating module. The thermocouples acquiring this data were located outside the modules, in the center of each module lid.

Figure 33 shows initiating and surrounding module temperature data. These thermocouples were also located on the outside of the modules. The location of the thermocouple on module 1-7 (rack 1 module 7) was centrally located directly between the metal top of module 1-7 and the bottom cooling plate of module 1-6 (initiating module). Module 1-5 experienced the longest and most severe thermal impact of any adjacent module. The thermocouple was located on the top plate of module 1-5, so the bottom of module 1-5 was experiencing temperatures between 200-300 C for approximately 3 hours. None of the cells in module 1-5 experienced thermal runaway, though. Modules in the adjacent rack did not experience temperatures above 100 C except for briefly during the initial flames.

Figure 34 through Figure 36 shows the temperature data of the target units. None of these temperatures rose above 30 degrees C. The rise in temperature in the target units was likely influenced by ambient environmental conditions more than the events inside the initiating unit.

Figure 37 shows the target wall temperature data. This data was also more influenced by the ambient environmental conditions than it was by the events inside the initiating unit.

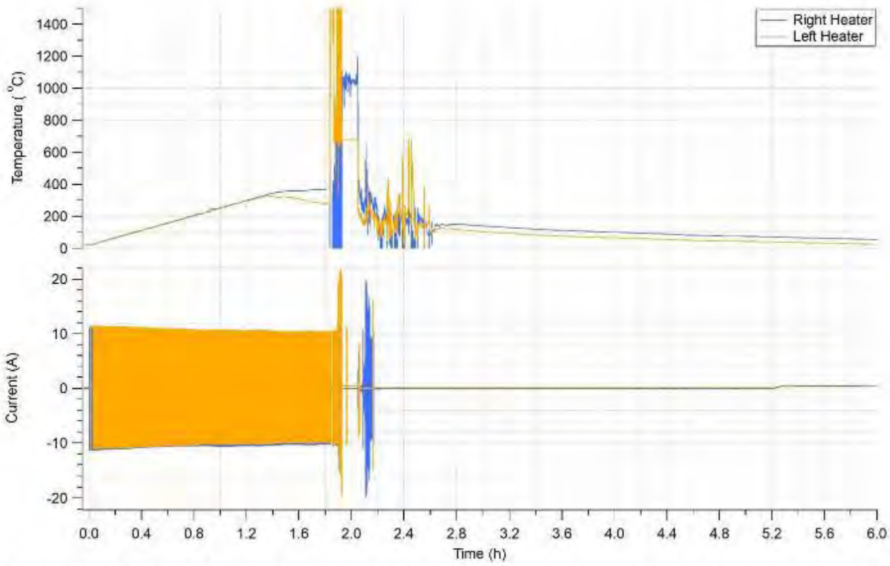

Figure 29. Initiating heater temperature from the thermocouples used for control (top) and initiating heater current (bottom).

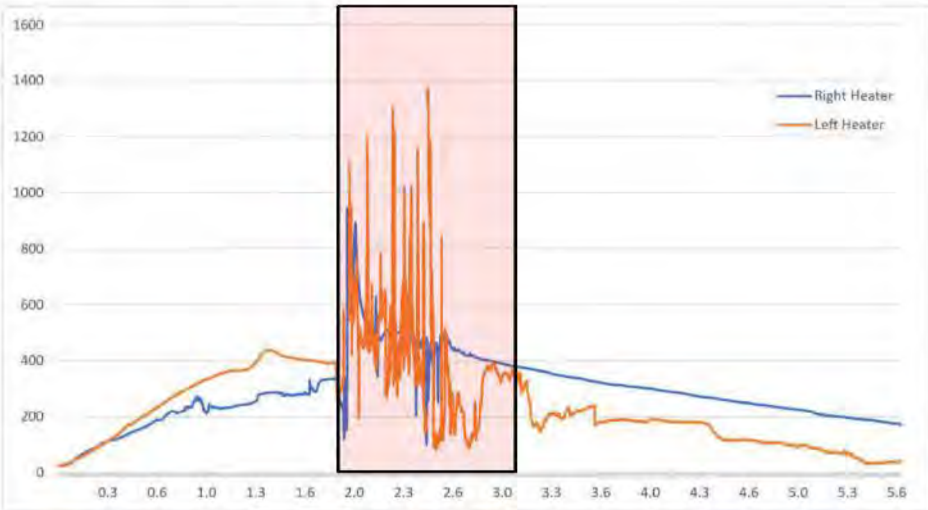

Figure 30: Heater thermocouple data (ºC) vs. time (h) from the two thermocouples that were not used for control.

Notes: Red box shows the same period gasses were being observed outside of the cube

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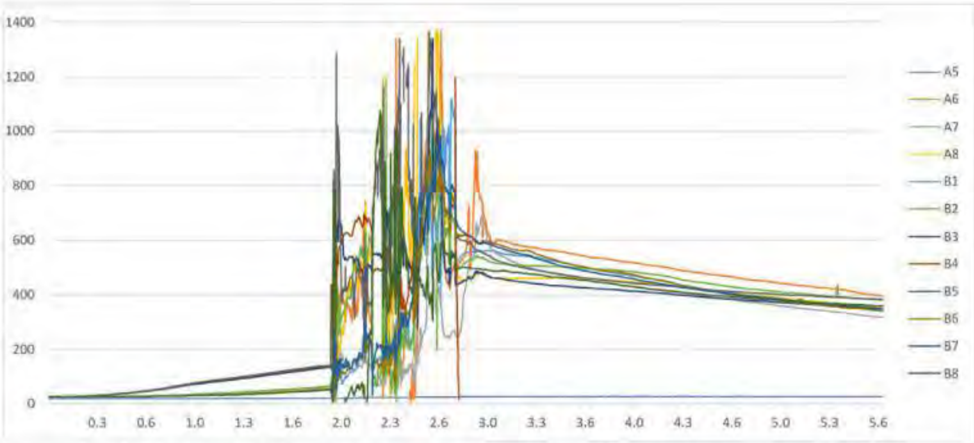

Figure 31: Initiating module temperatures (ºC) vs. time (h) all thermocouples shown in Figure 9.

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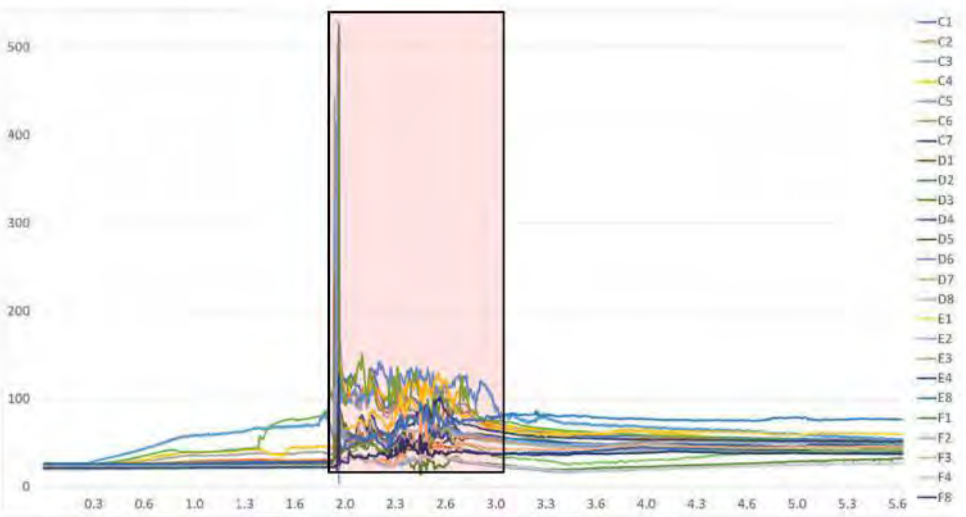

Figure 32: Temperatures of internal initiating unit (°C) vs. time (h).

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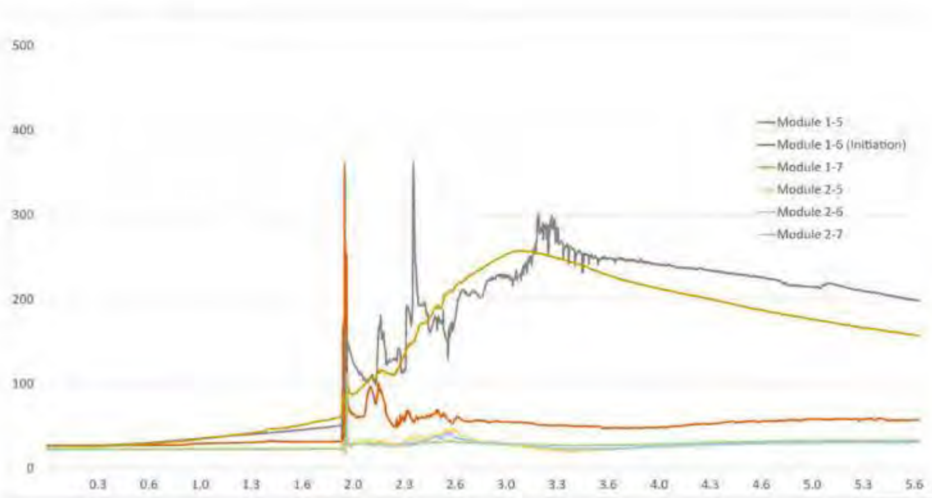

Figure 33: Temperatures of modules surrounding initiating module (ºC) vs. time (h).

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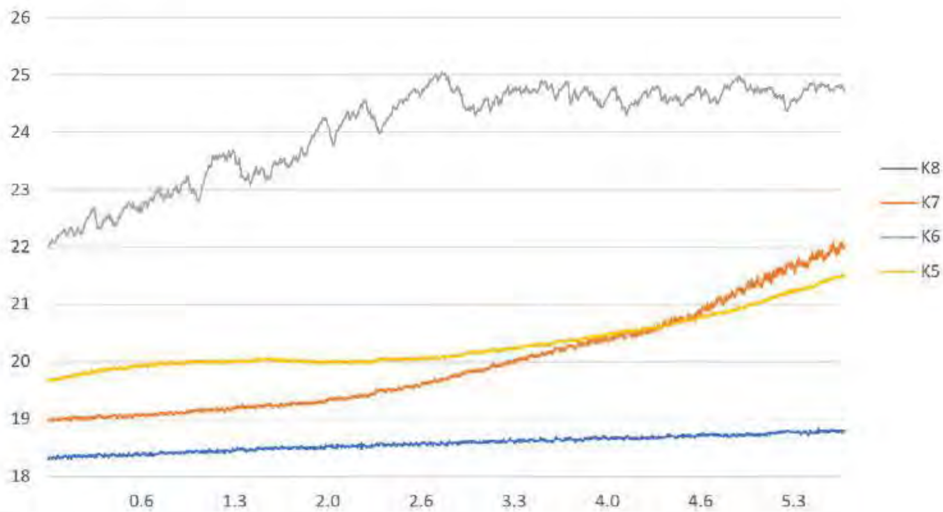

Figure 34: Temperatures inside target 1 (°C) vs. time (h).

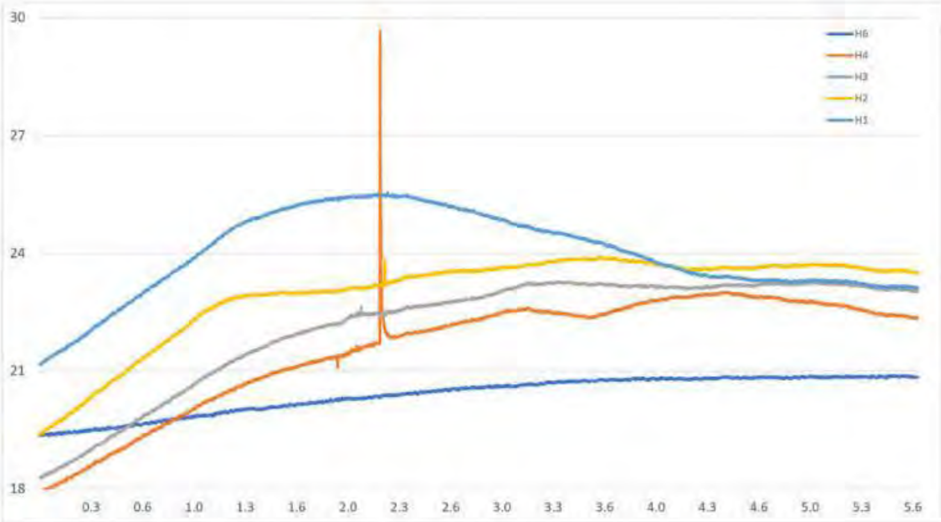

Figure 35: Temperatures inside target 2 (°C) vs. time (h).

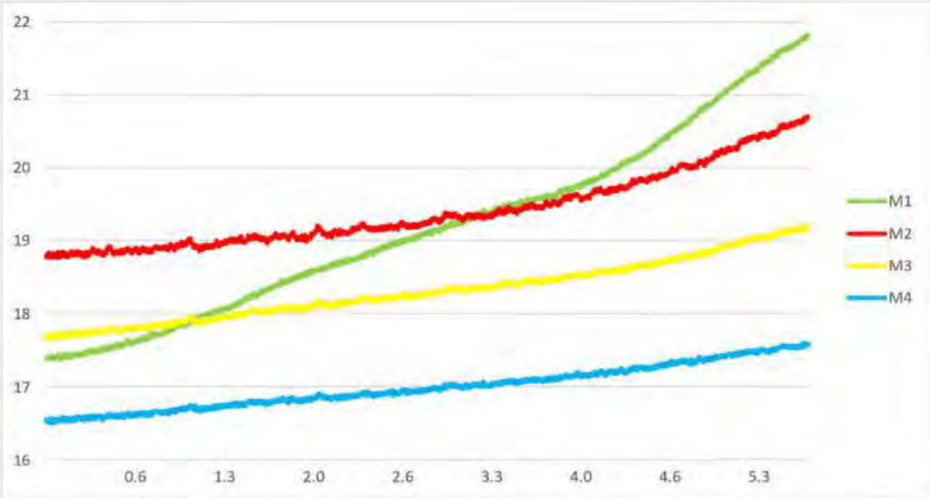

Figure 36: Temperatures inside target 3 (ºC) vs. time (h).

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Figure 37: Temperatures of all target wall thermocouples (ºC) vs. time (h).

D. Heat Flux

Heat flux from the four water cooled transducers is shown in Figure 38. This heat flux data was affected more by the sunlight than the events taking place in the initiating unit. The wall heat flux transducer was exposed to direct sunlight for a portion of the test. Except for the elevated levels due to direct sunlight and the heat flux transducer on target 1, the water-cooled heat flux transducers did not indicate any other elevated heat flux levels.

The heat flux transducer on target 1 indicated two brief rises in heat flux around the same time visible flames were observed in the initiating unit. The magnitude was only about 0.225 kW/m^2 higher than the heat flux due to direct sunlight. This brief increase was not seen on any of the other heat flux transducers.

The data from the heat flux transducers in the target cubes was as expected, showing no elevated heat flux due to the events in the initiating unit.

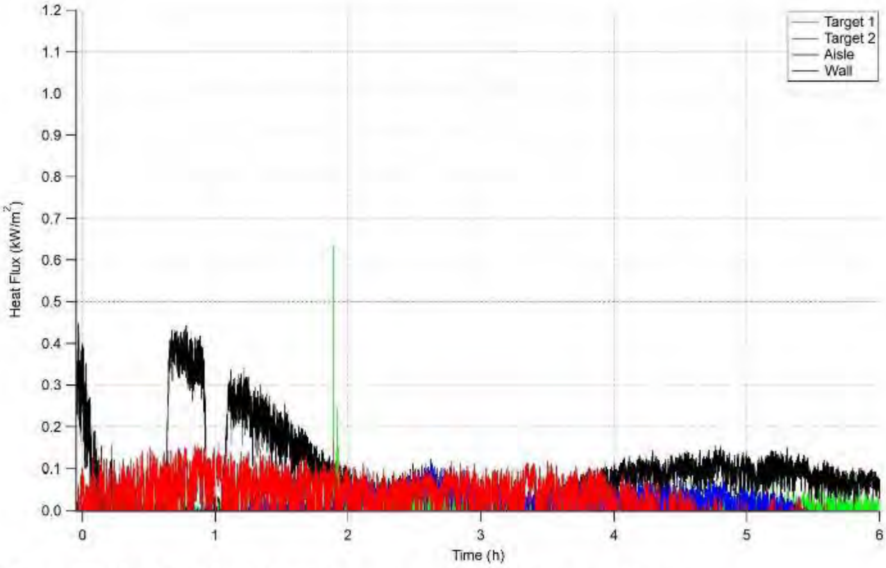

Figure 38. Heat flux data from the water-cooled heat flux transducers.

E. CEMS

In both the UL 9540A unit level test and the BDBT, alkyl carbonates were the first gases detected. Electrolytes used in lithium-ion batteries often contain alkyl carbonates and their detection was attributed to cell venting. Alkyl carbonates were detected prior to thermal runaway and before fire developed.

For the UL 9540A unit level testing, temperature related degradation of various materials including, but not limited to, those used for module and cell construction, cathode materials, and anode materials, caused gases to evolve. These gases included hydrofluoric (HF), hydrochloric (HCl), hydrogen (H_2), carbon monoxide (CO), and ethylene, among others (Figure 40 and Figure 41).

As shown in Figure 40 and Figure 41, the amount of gas generated increased rapidly once thermal runaway occurred, but this was only detected inside the cube. In contrast, no significant levels were detected within the duct (Figure 42). Monitoring in the duct continued for over an hour during UL 9540A unit level testing, at which point the monitoring was returned to the cube. No visible flames were noted during this test and 24 hours after testing began. The gas analysis ended at this point. For gases inside the cube, the levels decreased slowly and steadily over that period, as shown in Figure 50 and Figure 44.

Two days after the UL 9540A unit level test, the BDBT was performed and, once again, alkyl carbonate gases were the first gases detected. This was detected just before the first cells audibly vented. Approximately five minutes after that, flames ignited, and oxygen levels rapidly dropped to 5% (Figure 45). The flames were brief and self-extinguished in less than one minute. Following visible flames, the amounts of various gases detected were notably higher than those detected during the UL 9540A unit level testing (Figure 45).

The location for gas analysis was switched to the duct and the following gases were detected within the duct: carbon monoxide, alkyl carbonates, ethylene, methane, and hydrogen (Figure 55). As much as 40 ppm of carbon monoxide was detected but this same amount of carbon monoxide was detected within the duct prior to the test when blank samples were collected. Except for hydrogen, the others were present at 20 ppm or less. As shown in Figure 55, ~ ½-hour after flames, hydrogen was present at 70 ppm. After another ½-hour, the amount of gas had decreased to negligible amounts except for hydrogen. Instead, hydrogen had increased to 116 ppm. At this point monitoring returned to the cube (Figure 47) where levels of several gases remained high. An hour after ignition, hydrogen inside the cube remained above 13%.

The location for sampling was switched again and, in the hour since the previous measurement, hydrogen within the duct had more than tripled to 385 ppm (Figure 48). While noteworthy, it was still low compared to the amount within the cube. Furthermore, the amount of hydrogen within the duct began to decrease and remained below 385 ppm in the duct for the remainder of sampling.

Gas analysis switched to the cube and continued through the end of the day and into the following morning, as shown in Figure 49 and Figure 50. Once again, gases inside the cube decreased slowly over time. At 3:00am, FTIR analysis was stopped but hydrogen monitoring continued. This hydrogen monitoring changed between the duct and cube on hourly intervals. Within the duct, hydrogen remained below 150 ppm until 10:00am, at which point no further monitoring of the duct was performed. Within the cube, hydrogen levels remained above 4% until after 11:00am, almost 23 hours after visible flames (Figure 51.).

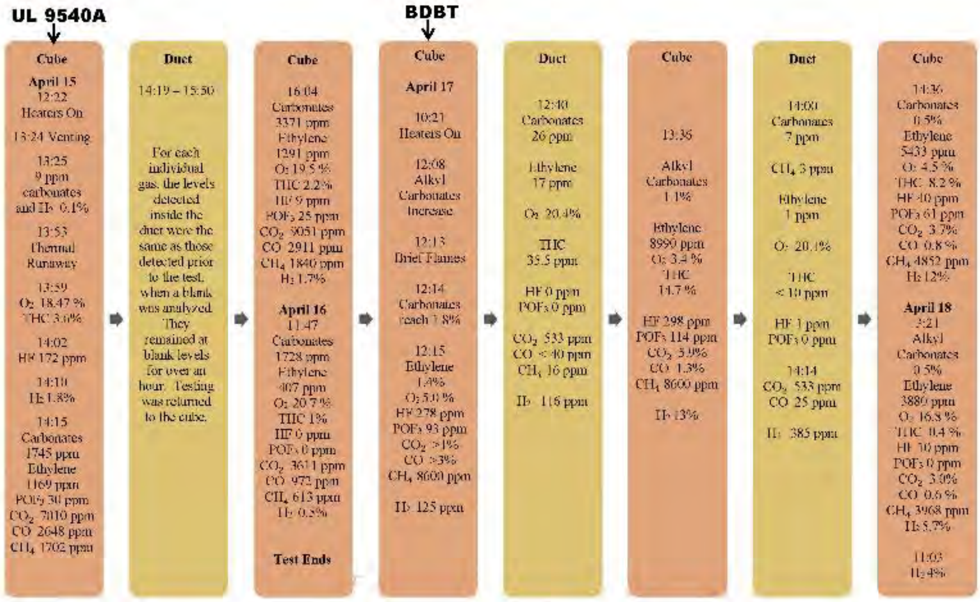

Figure 39. Overall summary of gas testing results for UL 9540A unit level testing and BDBT.

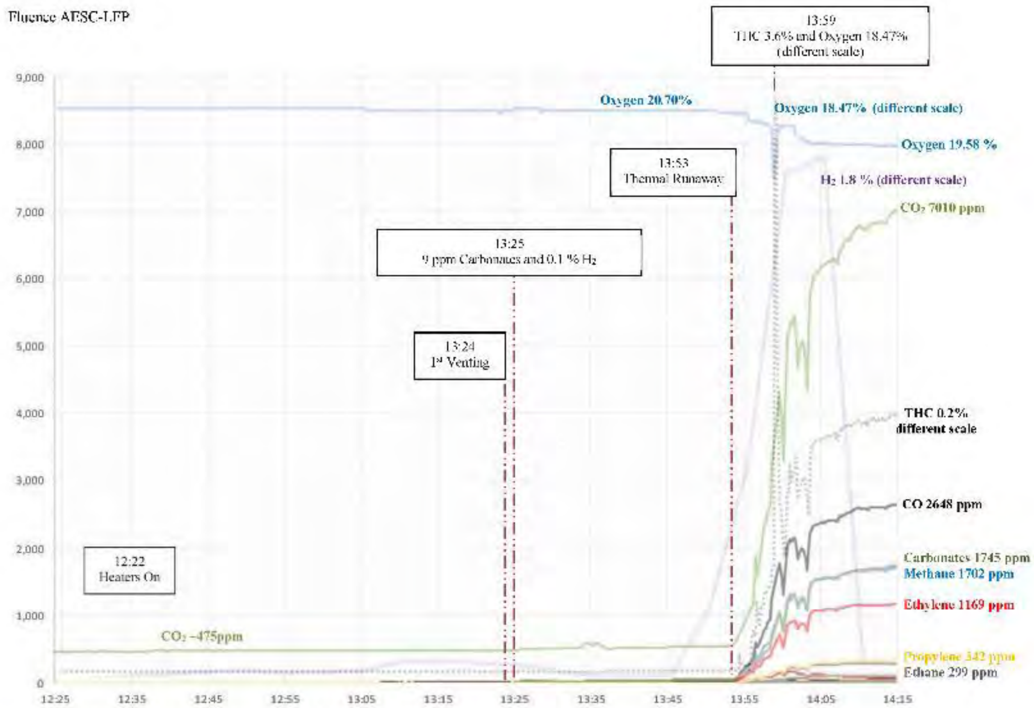

Figure 40. UL 9540A unit level testing within cube.

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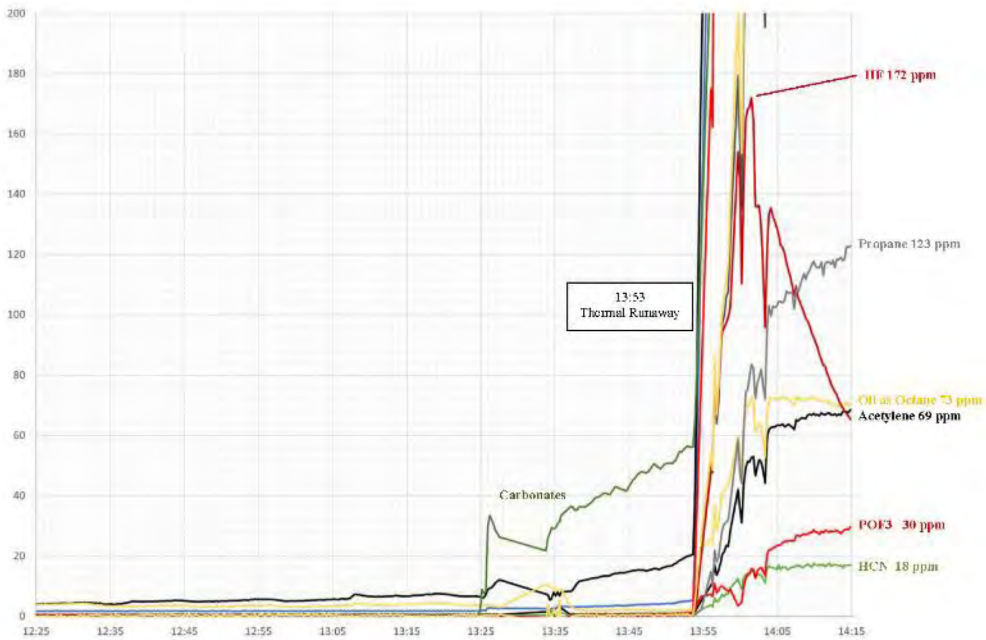

Figure 41. UL 9540A unit level testing within cube – magnified view.

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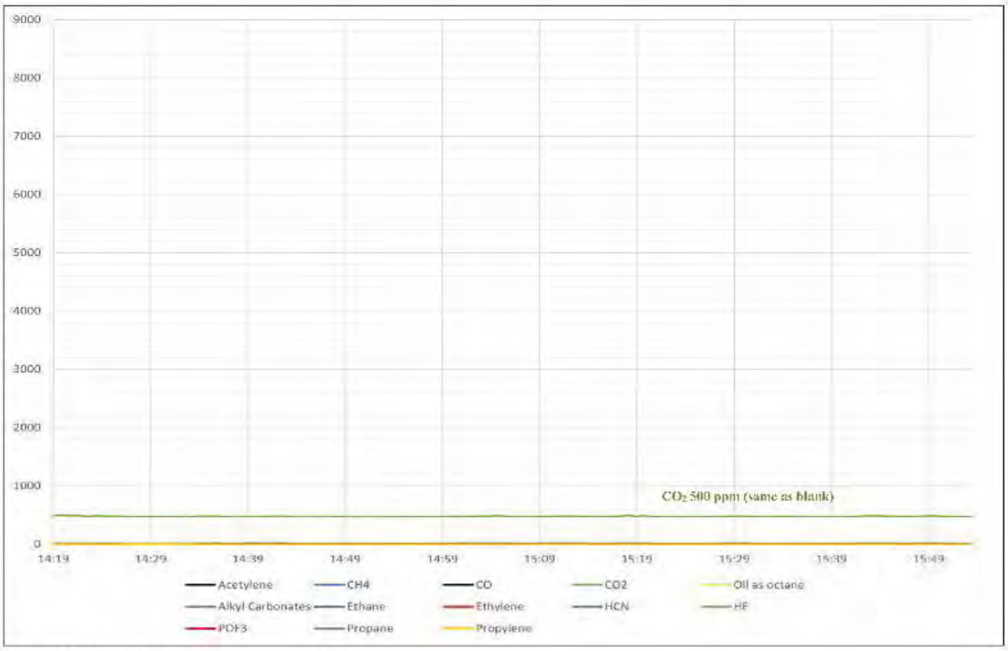

Figure 42. UL 9540A unit level testing within duct.

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The following levels were noted at 16:04: Propane 98 ppm Oil as Octane 95 ppm **Acetylene 72 ppm** **POF3 25 ppm** **HCN 14 ppm** **HF 9 ppm**

Figure 43. UL 9540A unit level testing within cube.

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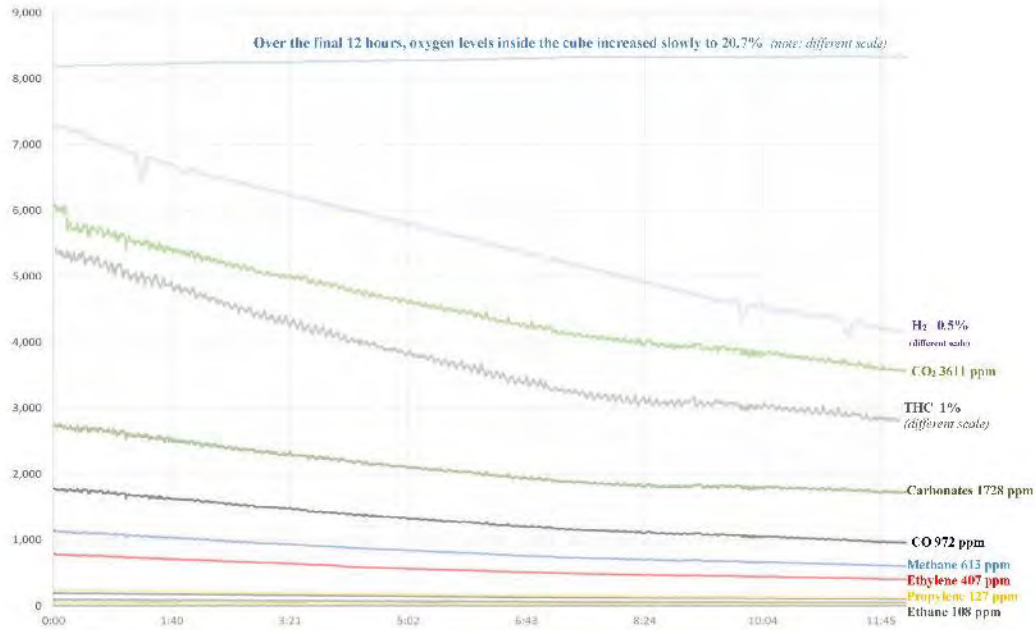

Figure 44. UL 9540A unit level testing within cube.

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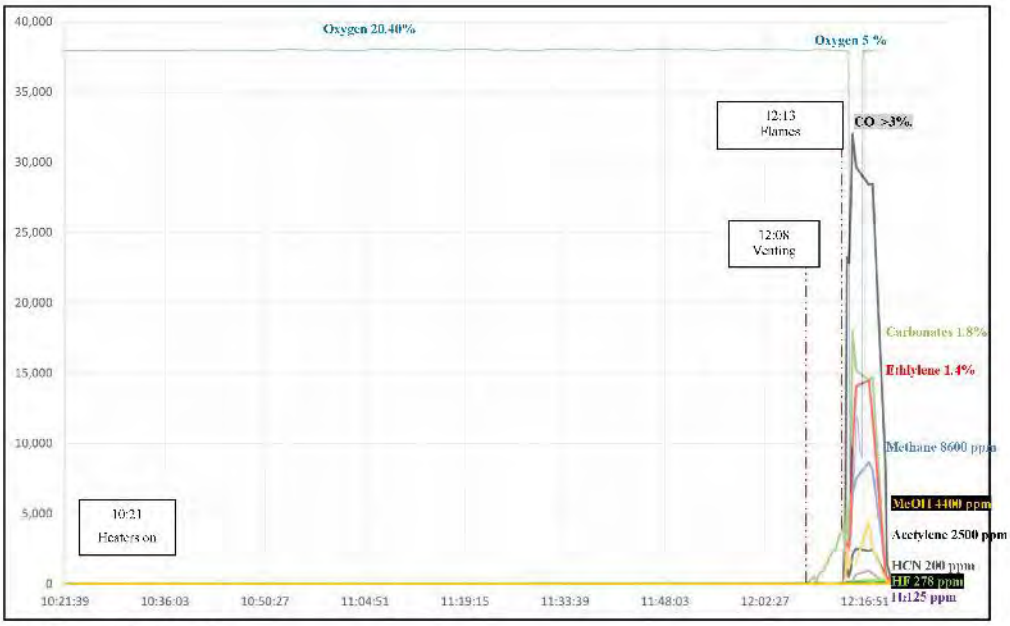

Figure 45. BDBT within cube.

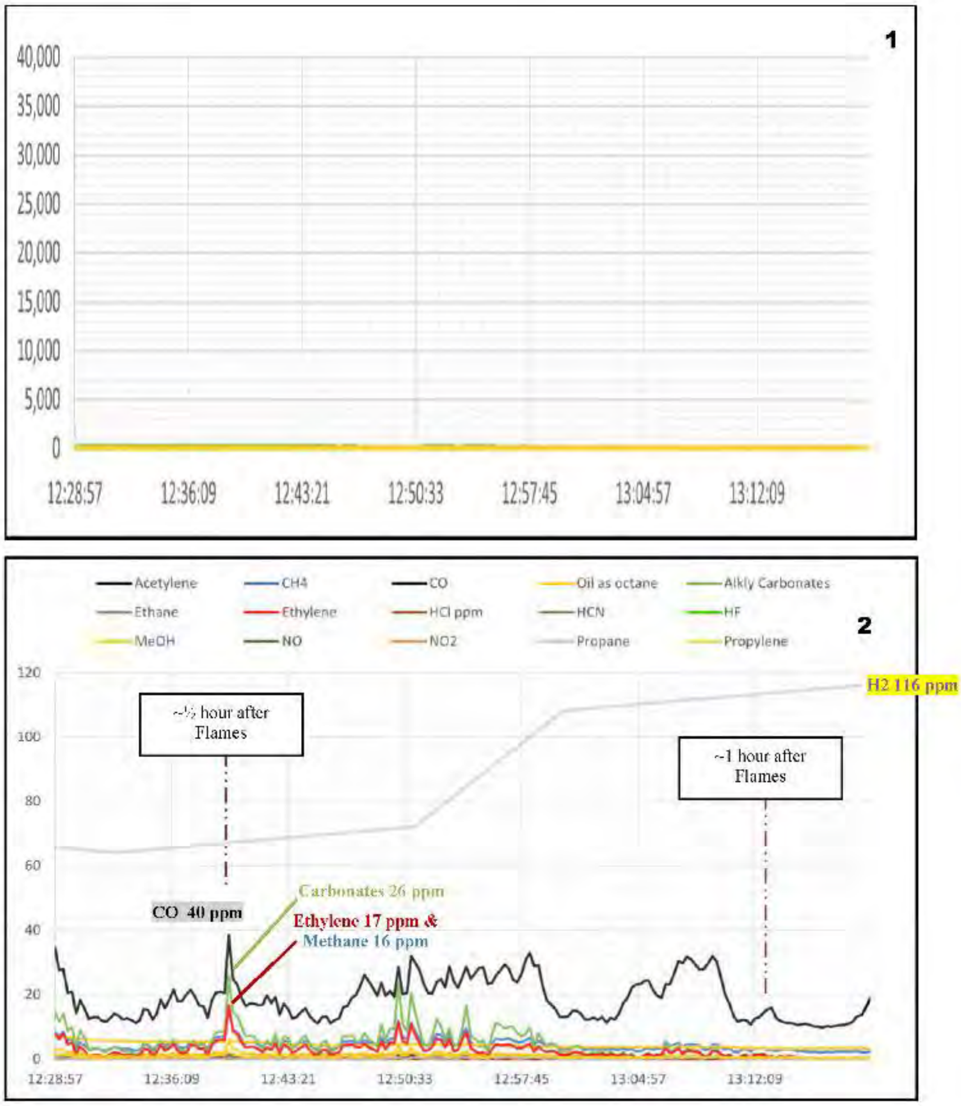

Figure 46. BDBT within duct.

Notes:

1. Showing results obtained inside the duct at the same scale as previous graph.
2. Showing the same results at magnified scale.

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Figure 47. BDBT within cube.

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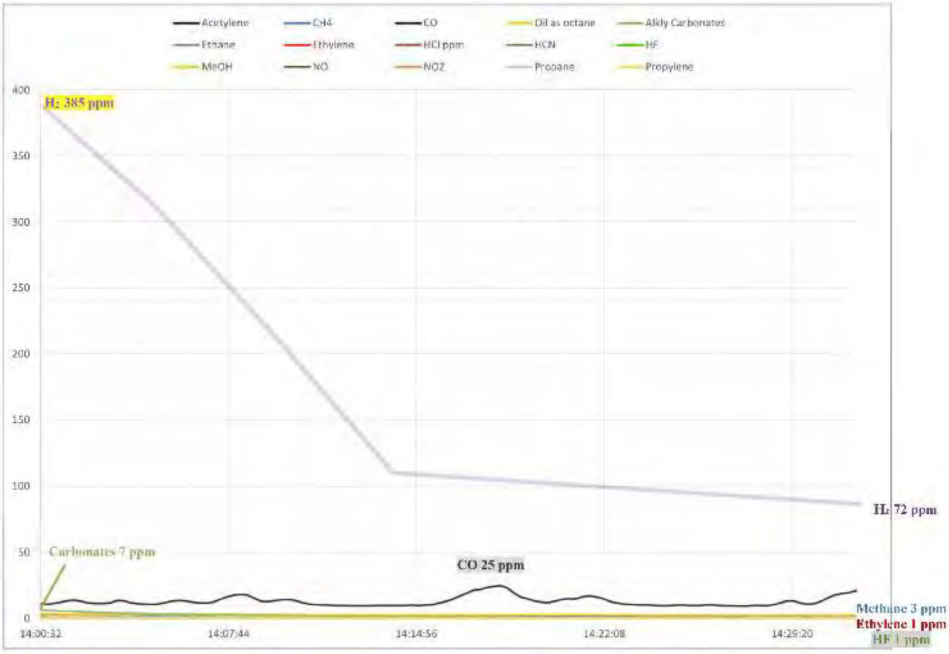

Figure 48. BDBT within duct.

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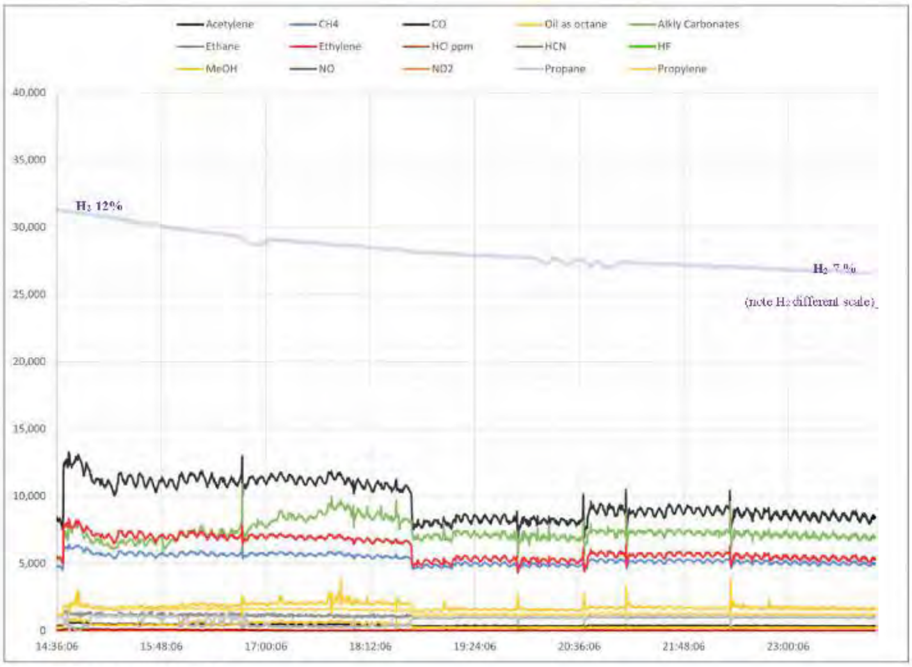

Figure 49. BDBT within cube.

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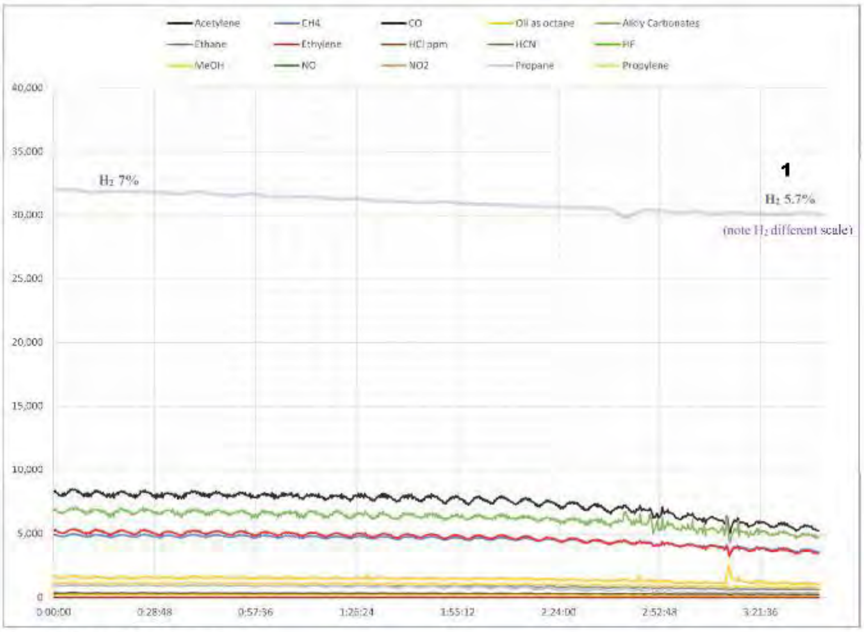

Figure 50. BDBT within cube.

Note:

1. FTIR analysis was stopped but hydrogen monitoring continued and, at 11:03:00, hydrogen levels dropped to 4%.

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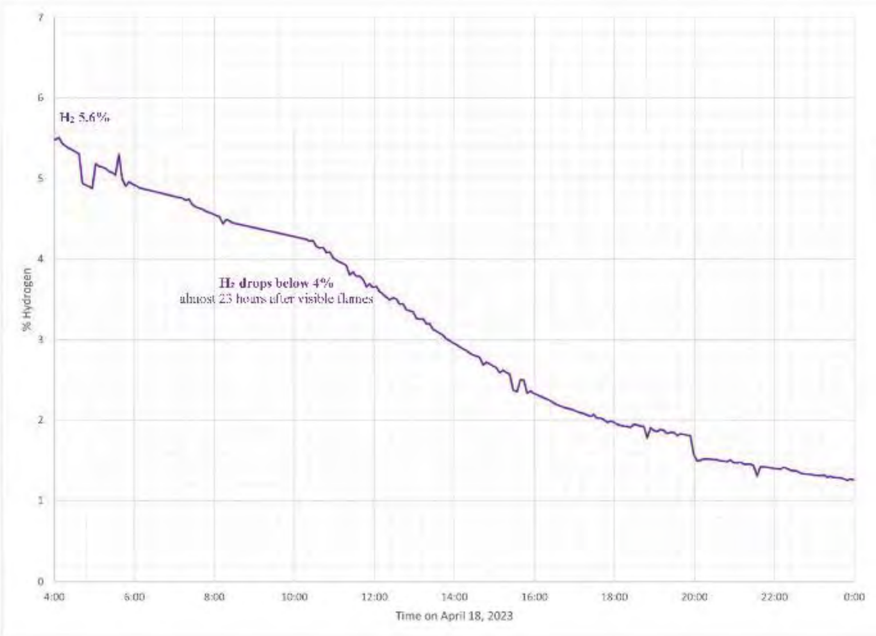

Figure 51. BDBT- monitoring hydrogen within cube.

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VI. TEST RESULTS

Due to the combination of electrical energy and elevated hydrogen and hydrocarbons measured within the initiating unit, it was allowed to sit undisturbed for 8 days until April 25, 2023. On that day, a rope was tied around the handle and the unit was opened from a distance as a precaution. The unit was then allowed to ventilate for several hours. No thermal or electrical events occurred while opening the door or after the door was open.

The BDBT test did not cause significant damage to the outside of the initiating or target cubes, as shown in Figure 52 and Figure 53. From the outside, appearance before the test was similar to appearance after the test. The most notable exception was the soot staining on the fire blanket in front of the initiating unit. This occurred as smoke and gases vented from the initiating unit through the cable penetrations.

Inside the initiating unit, the damage was more noticeable and was much greater than UL 9540A unit level testing. There was heat and smoke damage throughout the cube. The damage was greatest at and near the initiating module, as shown in Figure 54 through Figure 59. Even in this area, module housings remained mostly intact. The module with the greatest visible damage was the initiating module, which suffered far more damage during the BDBT than the UL 9540A unit level test. Figure 60 shows a comparison between the UL 9540A initiating module and the BDBT initiating module after each test.

After the initiating unit door was opened, the module voltages were recorded. The results are shown in Table 4. All but the initiating module still had near 100% SOC open circuit voltages. The initiating module voltage was zero. The cells in all modules except module 1-5 were still isolated from the equipment ground.

Module 1-5, the module directly above the initiating module, was approximately 2 volts less post-test than pre-test. This is likely due to thermal damage and loss of isolation inside the module. The potential from the module positive terminal to equipment ground was 59.3 VDC and 113.2 VDC from the module negative terminal to equipment ground. Despite the loss of isolation, none of the cells in this module experienced thermal runaway.

On the other hand, all 52 cells within the initiating module experienced thermal runaway. There was no evidence of module-to-module propagation within the initiating unit. There was also no evidence of deflagration or detonation within the initiating unit.

Figure 52. A photograph of the initiating and target cubes after the test.

Notes:

1. Target 1 cube
2. Target 2 cube
3. Target 3 cube
4. Initiating unit
5. Soot staining on fire blanket

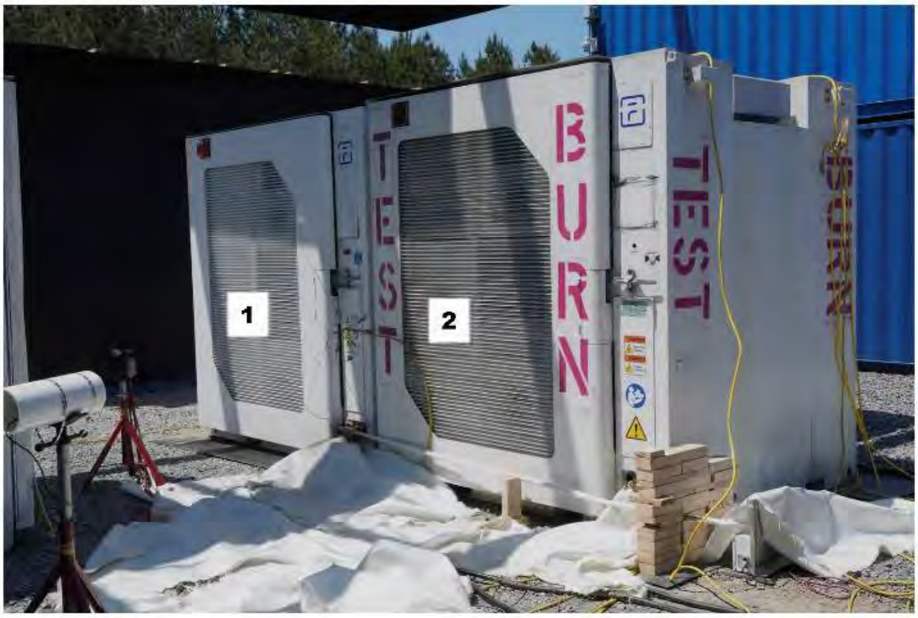

Figure 53. Another photograph of the initiating and target cubes after the test.

Notes:

1. Initiating unit
2. Target 2 cube

Figure 54. Initiating unit after the BDBT.

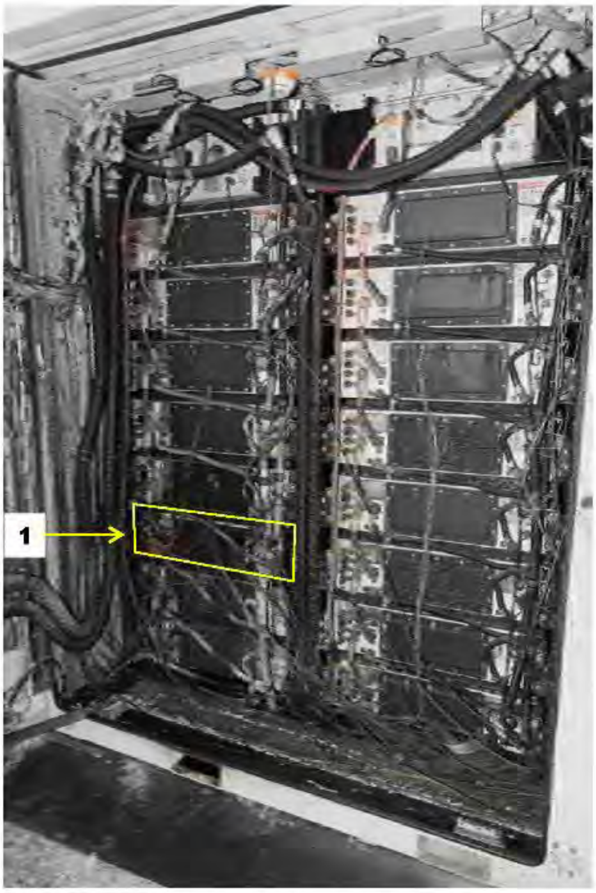

Figure 55. A photograph inside the initiating unit after the BDBT.

Note

1. Initiating module

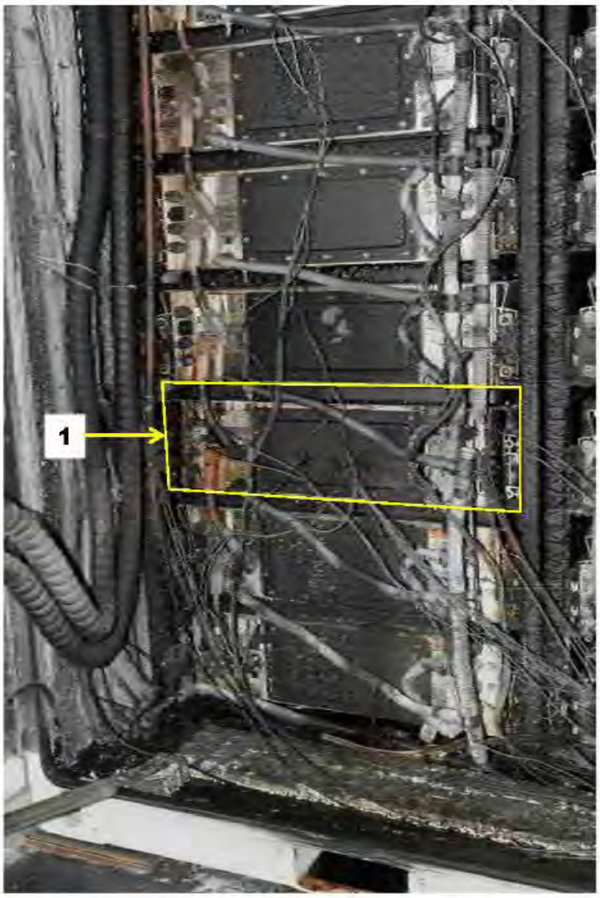

Figure 56. Another photograph inside the initiating unit after the BDBT.

Notes

1. Initiating module

Figure 57. A photograph of the initiating module as it's being removed from the initiating unit.

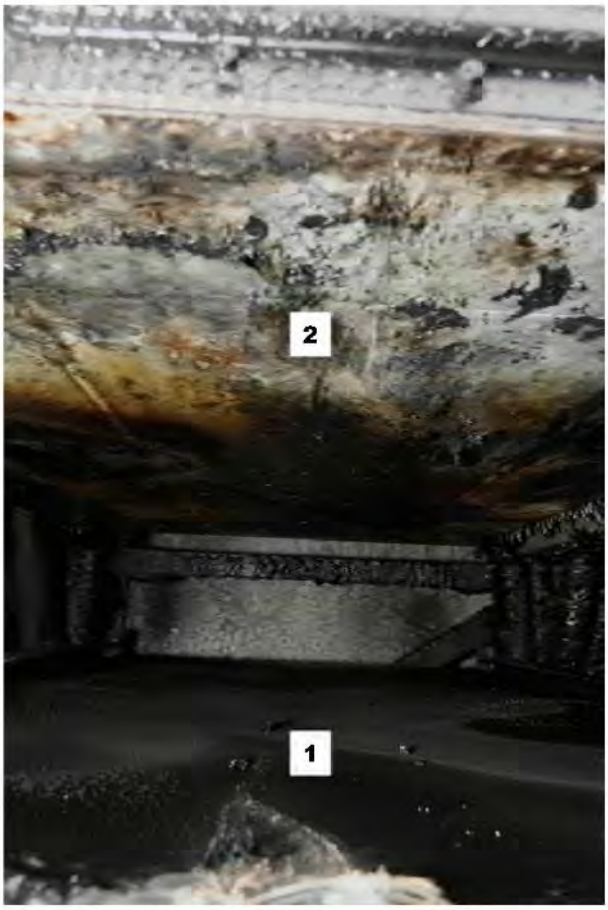

Figure 58. A photograph inside the rack after the initiating module was removed.
Notes
1. Top of Module 1-7
2. Heat damage to the bottom of Module 1-5

Figure 59. A photograph inside the initiating module as the lid is being removed.

Notes:

1. Holes in lid (yellow circles)

Figure 60. A comparison between the UL 9540A initiating module (top) and the BDBT initiating module (bottom).

Table 4 Open circuit voltages before and after test.

Rack 1 Module	Pre Test Voltage	Post Test Voltage (V)	Rack 2 Module	Pre Test Voltage	Post Test Voltage (V)
Module 1-1	175.6	175.6	Module 2-1	175.2	175.2
Module 1-2	174.5	174.5	Module 2-2	174.6	174.6
Module 1-3	175.1	175.1	Module 2-3	174.6	174.6
Module 1-4	174.9	174.9	Module 2-4	174.7	174.7
Module 1-5	175.2	173.2	Module 2-5	175.0	175.0
Module 1-6	175.1	0	Module 2-6	174.8	174.8
Module 1-7	175.1	175.1	Module 2-7	174.8	174.8
Module 1-8	175.6	175.6	Module 2-8	174.9	174.9

Appendix D – Response to FRNSW feedback

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
1.	-	General Comment	FRNSW notes the following sections are not included, as required under HIPAP2: • Codes and References - Section 3.15 of Hazardous Industry Planning Advisory Papers No.2 (HIPAP2) requires that standards and codes used throughout the report be referenced at the end of the report. • Glossary and Abbreviations – Section 3.4 of HIPAP2 requires the addition of glossary and abbreviations section.	Codes and references used in the report have been added to the rear of the document (after conclusion). Glossary and abbreviations have been added after the executive summary.	Noted	Closed
2.	1- Introduction	-	Section 3.3 of HIPAP2 requires the Summary of Main Findings and Recommendations to provide details on the implementation program agreed to by the proponent company or the owner or operator, as required by Section 3.3 of HIPAP2. If any recommendations are not	Executive summary, including summary of main findings and recommendations has been added to the front of the report.	Noted. However, FRNSW notes that Table 2 mentions that the recommendations have been accepted by Fluence. The acceptance should be provided by the operator.	Fluence is engaged under a Long Term Services Agreement with Ampyr Energy as the operator of the facility. Both Ampyr Energy and Fluence have accepted the recommendations, and this has been indicated within the FSS. This reference has been

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			to be proceeded with, supporting reasons should be provided. In addition, as per HIPAP2's requirements, the summary should "briefly outline the nature of the proposed or existing facility, the scope of the report and the matters addressed. It should present in point form the main findings and, where appropriate, recommendations for action."			added to the revision to the FSS for closure

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
3.	2.1 Site Development	• Switch room and control room • An operations and maintenance building • Workshop and storeroom	FRNSW considers that insufficient information is provided and provides the following recommendations/comments, which are required by Section 3.6 of HIPAP2: • Details of the brief process description in each building (e.g. activities that are performed within each building) to be provided within this section. Current information is considered insufficient. • Site location sketch be provided for review, clearly delineating between the existing and proposed facilities. (Site drawing provided isn't clear and doesn't highlight what is existing and what will be built as part of the BESS	Building descriptions, distance to surrounding landmarks (including sensitive receptors), and typical occupational profile have been added.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			installation.) • Building description of all buildings within the site (i.e. switch room and control room, operations and maintenance building and workshop and storeroom), including floor area limitations, fire resistance, means of egress, firefighting services and appliances, type of construction, and special provisions. • A brief description of adjacent/surrounding land uses, including distances to the nearest occupiable buildings (such as dwelling, offices, school and etc.). • Number of people typically on the site and hours of operation			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			• Location of firefighting infrastructures be clearly indicated on floor plan, e.g. firewater storage tank, fire hydrants, fire hydrant booster, sprinkler booster, fire control room/centre, hardstands, fire indicator panels and mimic panels.			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
4.	Section 2.2.3 Off gassing and smoke	Firefighters will likely respond with air sensing equipment or be able to source the equipment to monitor the gases resulting from the thermal runaway event. Firefighters will be familiar with the site and attended site familiarisation opportunities. They will also have received training from their fire agency on the response to large scale BESS incidents.	FRNSW recommends developing an Emergency Plan to ensure responding firefighters are made aware of potential toxic gases resulting from thermal runaway events. Refer to note 16, outlining Emergency Plan and Emergency Services Information Package recommendations.	The emergency plan requirements have been incorporated into Section 8.	Noted	Closed
5.	3.3.2 Chemical Hazards	The main chemical hazards include: • Lithium ion within the batteries. • Refrigerant • Oils contained within the transformers and	FRNSW requires further details on the chemical composition of the hazards onsite, presented in a tabular format as per Section 3.7 of the HIPAP2. FRNSW recommends assessing the impact of chemical components or by-products	Provided safety data sheets and product information sheets have been used to source chemical hazards. This has been put together into a table.	As per Section 3.7 of HIPAP2, Table 7 should also include the class of the materials, average and maximum quantities onsite, physical state of	Table 7 updated with this requested information.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
		other equipment • Toxic gas as a result of a thermal runaway event. Apart from the toxic gas release, the other chemical hazards are all contained within equipment and cannot come into contact with people apart from maintenance periods. Even during maintenance periods, the likelihood of chemicals coming into contact is limited.	released during an incident, as per Clause 5.1.4 of the FRNSW Fire Safety Guideline – Large-Scale External Lithium-ion battery energy storage system – Fire safety study consideration (referred as 'the FRNSW BESS Guideline' herein).		substances and a reference to the location on the site layout that they are present. Refer to Table 2 of HIPAP2 for further guidance. The toxic gas release assessment for the worst-case fire involving the BESS unit has not been conducted. However, based on the site's distance from sensitive receivers and FRNSW's previous experience with toxic gas release assessments involving the Fluence BESS unit, the comment regarding toxic gas release is considered closed.	Note that the comment regarding toxic gas release is closed.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
6.	4 Fire Consequences	This consequence analysis has been undertaken using a qualitative approach.	FRNSW does not support the use of qualitative risk assessment methodology and provides the following comments: • Large-scale external lithium-ion BESS have limited records or historical incidents to analyse, meaning the data is scarce to provide any statistically meaningful information. This absence makes it difficult to predict potential failures or negative outcomes, which are crucial for defining the probability of an incident. • Rapid evolution of the technology involving different battery types further limits the	See section 5.3. Details have been sourced from the large scale fire test.	As per Section 5.6.5 of the FRNSW BESS Guideline, the impacts of environmental conditions (e.g., wind effects) must also be assessed. This should include assessment of flame tilt, etc. This has not been included in the assessment.	Assessment has been updated to outline the impacts of environmental conditions. At this stage wind effects have been identified as the key environmental conditions requiring assessment. No other environmental conditions have been identified as needing assessment.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			applicability of data from historical incidents. • The risk assessment methodology does not comply with the requirements of Section 2.3 of HIPAP2, which *states "Once the hazards have been identified, the consequences of incidents can be estimated. The consequence analysis should address both the direct impacts of incidents and the potential for propagation and secondary incidents. The analysis should relate selected targets such as people, equipment or buildings to specific time related exposures (heat flux, explosion overpressure, toxic concentrations and so*			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			on).” • Therefore, FRNSW does not consider the qualitative assessment documented in Section 4 complies with the requirements of HIPAP2. • If a non-intervention strategy is selected, then FRNSW recommends complete elimination of the risk, demonstrated by large-scale testing.			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
7.	4.2.2 Fires involving equipment	Fires can involve the other equipment at the Project site including inverters and transformers. Usually fires that involve these items involves the oils that are normally enclosed within the equipment. The most common cause of fires within this type of equipment is poor maintenance activities. Items including oil quality and other regular maintenance items are critical to ensure the equipment operates effectively and safely.	FRNSW recommends quantitative analysis of the fire involving the transformers be conducted, incorporating the following HIPAP2 requirements: • Section 2.3 of HIPAP2 "*The analysis should relate selected targets such as people, equipment or buildings to specific time related exposures (heat flux, explosion overpressure, toxic concentrations and so on).*" • Section 2.3 of HIPAP2 *"Justification must be given for the selection of targets, exposures and models used in the consequence calculation."* • Section 2.3 of HIPAP2 *"All models and assumptions used to*	A quantitative analysis is not considered a requirement due to the separation between the infrastructure and the types of oils that are being utilised. Transformer and inverter fires are treated as burnout scenarios with controlled exposure risk.	FRNSW considers that this comment has not been addressed and maintains the comment. It is noted in the report that *"exposure protection to nearby infrastructure will be provided, if required, by firefighter intervention, separation distance, and hardstand buffers"*. FRNSW recommends conducting quantitative analysis, as per the previous comment, to demonstrate that the separation distance between the transformers and the	This comment has been satisfied by inclusion of the table outlining separation distances, and corresponding compliance to Australian Standards requirements.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			estimate consequences should be justified." • Section 3.6 of HIPAP2 *"Where applicable, diagrams showing worst case scenario heat flux distances, explosion overpressures and toxicity effects must be included. Such information should be time related where applicable. Consequence and risk contours used in the PHA/FHA (see Figure 1) must be included."* • Section 3.6 of HIPAP2 *"The potential for fire propagation without fire protection measures should be detailed."* • When assessing fire spread to the adjacent BESS units, the radiation threshold should be the		nearby infrastructure is adequate in preventing fire spread. Without this analysis, the adequacy of separation distance cannot be demonstrated. Therefore, FRNSW considers this comment has not been addressed. Consideration will be given for less combustible liquid-insulated transformers (i.e. insulating liquid with a fire point greater than 300°C). FRNSW accepts the separation distance provided in AS2067, to be adequate without consequence analysis, given their inherent	

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			radiant heat flux that can initiate a thermal runaway in a battery cell/module, verified by a large-scale testing that represents the credible incident as described in the FRNSW BESS Guideline.		thermochemical properties.	

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
8.	4 Fire Consequences and 2.2.3 Off gassing and smoke	The products generated from a thermal runaway event are considered dangerous to humans and consideration is required to ensure staff, contractors and firefighters are able to evacuate or approach the location of the thermal runaway event safely.	Table 3 and Section 2.2.3 of the FSS detail the composition of gases produced in a thermal runaway event and mention that they are *"dangerous to humans"*. As such, FRNSW recommends assessing the impacts of the toxic by-products in the worst-case fire scenario, as per Clauses 5.1.4 and 5.8.2 of the FRNSW BESS Guideline. The worst-case fire scenario is as per Clause 5.1.3 of the FRNSW BESS Guideline. FRNSW recommends including a diagram showing the worst-case toxicity effect, as per Section 3.8 of HIPAP2. Any test results used must be representative of the worst credible scenario, outlined in the FRNSW BESS Guideline. FRNSW does not consider the testing conditions under UL9540A to represent a credible	The information provided from the large scale fire test along with the increased separation distances has resulted in an acceptable outcome. The separation between BESS Units and the outcomes of the large scale fire test report clearly articulates the level of safety and limited ability for fires to spread between Units or to other infrastructure.	The toxic gas release assessment for the worst-case fire involving the BESS unit has not been conducted. However, based on the site's distance from sensitive receivers and FRNSW's previous experience with toxic gas release assessments involving the Fluence BESS unit, the comment regarding toxic gas release is considered closed.	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			fire scenario as required by the FRNSW BESS Guideline. Therefore, any results derived solely from UL9540A testing regarding toxic gas emissions cannot be supported.			
9.	4.2.3 General fires	The likely fire within the Control Room will start small and due to the fire safety systems installed within the enclosure including smoke detection systems will ensure that any detection of smoke will activate the fire alarm quickly.	With regards to the ancillary building, FRNSW recommends providing details on the following: • FRNSW require clarification on whether the water storage onsite has been sized based on any requirements for use on any buildings. • If static water supply is provided, FRNSW	The report now outlines that a AS2419.1 open yard compliant fire hydrant system is being provided. This includes static water, pumps and booster assembly and fire hydrants located throughout the site.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			recommends conducting firefighting water supply and demand analysis to determine the necessary volume of the water required to be stored on site.			
10.	Section 5 Fire Safety Strategy	Table 7 – Overview of the fire safety strategy	It is noted in Section 6.1 that "*Due to the high likelihood of the fire being contained to the Unit of origin and the surrounding separation distances preventing fire spread, firefighters are not likely to have to undertake any activities*." FRNSW recommends detailing the separation distances within the recommendations in Section 1, Table 7 and Section 8, if the physical separation forms a key part of mitigating fire spread.	This has been included in Table 7 of Section 8.	FRNSW note that there is no table in Section 8 and that Table 7 is the table identifying the chemical hazards likely to be onsite. This comment has not been addressed and maintains the previous recommendation. It is expected that the separation distances between BESS units, transformers, buildings, hydrants and other firefighting	Table has been included in Section 8 detailing the separation distances within the recommendations in Section 1.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
					infrastructures should be detailed as per previous comment.	
11.	Section 5.3.4 & Table 2	Most importantly and as described previously, the site is monitored 24/7 remotely and any alert or alarm activation will be identified quickly. The monitoring centre will have in place a procedure on how to respond to the various alerts and alarms. If the smoke and heat detectors are triggered, both alarms will activate, and corresponding alarms will be sent to the Monitoring Centre through the SCADA system.	FRNSW recommends providing provision for monitoring of the Alarm Signalling Equipment (ASE) where a fire detection is provided as part of the fire safety system, as per Clause 5.5.7 of the FRNSW BESS Guideline.	This has been included in Section 6.3.4 and the mitigation treatments table.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
12.	Section 5.4.2 Fire water containme nt Section 6.2	Activities occurring at the flow of 30 l/s will allow for firefighting activities to occur for a period of nearly 2.5 hours before consideration will need to be given to the disposal of fire water The provision of 100,000 litres of static water supply will enable firefighters to deliver 20l/s (1,200 l/m) for approximately 1.5 hours. At 10l/s (600l/m) it is likely to provide nearly three hours of fire water running constantly	FRNSW recommends reassessment of the firewater containment upon incorporating comments in item 14.	Fire water containment that exceeds the static water supply quantity is being provided.	FRNSW notes that Section 6.4.2 and Appendix F identify that the firewater containment for the site will have a capacity of 515,000L, however Section 7.4 mentions the provision of 251,000L firewater containment. Further clarification is required.	Within the Fire Safety Study, Section 6.4.2 and Appendix F is correct. Section 7.4 has been updated to reflect Section 6.4.2.
13.	Section 5.4.2 Fire water containme nt	The site is required to provide the ability to contain fire water until it has been tested and an appropriate disposal mechanism has been determined.	FRNSW recommend providing further clarification as to whether the containment system is connected to a reticulated stormwater system. Refer to Clause 5.8.5 of the FRNSW BESS Guideline and FRNSW	Additional clarifications have been added to 6.4.2. No automatic or uncontrolled release of firewater will occur. The reference to releasing	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			recommends providing details of measures to comply with the requirement. In addition, Section 5.4.2 mentions *"It is expected that the fire water can be released during the firefighting stage if it extends beyond the 2.5-hour period."* FRNSW seeks clarification and supporting justification regarding the rationale for allowing fire water to be released after 2.5 hours.	firewater after 2.5 hours has been withdrawn from the strategy.		
14.	Section 6 Fire water	-	FRNSW recommends providing further details on the hydrant system proposed to be installed on site. FRNSW requests detailed drawings of fire services layout capturing the requirements of Section 3.11 of HIPAP2 to be provided for review and comment. Drawings of adequate scale to clearly indicate relevant details.	7.2 - The horizontal separation between the Transformers and any surrounding exposures (grassland or buildings) 15m or more and consists of hardstand. It is unlikely that a fire from a substation of this size is capable of travelling more than 20m, and as such, modelling has not been completed.	The horizontal separation distance between nearby infrastructures such as BESS units, inverters, hydrants and other firefighting infrastructures should be considered. In addition, a substation fire should be considered for	Table with horizontal separation distances has been included, with referenced Australian Standard separation distances to be included. Site layout of hydrant system, showing location of hydrant booster and hydrants (and firewater

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			It is understood that the proposed strategy is to let the BESS unit burn out. It's uncertain the same strategy applies to the transformers. In order to demonstrate adequacy of the proposed strategy, it must be demonstrated that there will be no fire spread under any fire scenario, including a fire involving transformer under the worst-case wind condition. In addition, FRNSW recommends providing details about the specific actions and resources anticipated to facilitate effective firefighting operations under these conditions.	An AS2419.1 fire hydrant system is being installed.	adequate separation distances. FRNSW notes that a hydrant system will be installed onsite and that the site layout identifies the firewater tanks and pumps. However, the locations of a hydrant booster and hydrants (if exists) cannot be identified. FRNSW recommends providing detailed drawings of fire services layout capturing the requirements of Section 3.11 of HIPAP2.	containment tanks) has been included in updated Fire Safety Study.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
15.	Section 6.2 Fire water demand	The provision of 100,000 litres of static water supply will enable firefighters to deliver 20l/s (1,200 l/m) for approximately 1.5 hours. At 10l/s (600l/m) it is likely to provide nearly three hours of fire water running constantly.	Section 2.7 of HIPAP2 states that *"the demand calculation is based on the worst-case scenario."* It also states that *"the demand will depend on the duration and intensity of potential fire(s), the prevention measures including facility design and the protection systems selected. Demand will be particularly influenced by choice of firefighting media and facility layout (especially in relation to cooling water)."* FRNSW recommends conducting quantitative fire water demand calculation to demonstrate that the static water supply of 100,000 L is adequate in cooling down the exposure from the worst-case fire scenario, as per Section 2.7 of HIPAP2. For exposure protection, the analysis shall consider the radiant heat exposure, area of exposure and the flow rate required. In	An AS2419.1 fire hydrant system is being provided that is based on 30l/s flow for four hours.	FRNSW considers that the firewater demand calculations have not been carried out as per the requirements of Section 2.7 of HIPAP2. It is understood that 432,000L of static water supply will be provided. However, there is conflicting information provided in the report to make determination of the proposed static water supply. FRNSW recommends confirming the proposed static	Reference to static water quantities to be updated to 515,000L for all references to clear ambiguity. Details of calculations for quantity of static water is provided within updated Fire Safety Study. Section 9 has been updated to reflect the proposed static water supply volume.

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			addition, FRNSW recommends conducting quantitative fire water demand calculation for all ancillary buildings within the site.		water supply and then updating the Executive Summary and Section 9 to reflect the proposed static water supply volume.	

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
16.	Section 7 Emergency Managemen t		FRNSW recommends the development of an Emergency Plan for the site in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No.1 and preparation of an Emergency Services Information Package (ESIP) in accordance with FRNSW fire safety guideline – Emergency services information package and tactical fire plans. In addition to the points identified in Section 7, FRNSW recommends ensuring that the following will also be addressed in the Emergency Response Plan for the site: g) Details on how the owner / operator is alerted to abnormal operation, fault	This additional detail has been included in section 8.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			or hazard in a BESS. h) Details on how fire services are notified of an incident. This should be described as part of the fire safety strategy. Upon detection of a fire in a BESS or on the site via an automatic detection system, notification of the fire services should be automatic. i) Detail effective communication strategy with remote operator representative for incident duration. j) Suitable arrangements for attendance on site by an appropriately qualified			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			representative during any incident. k) Details on how battery status and information is relayed to emergency services, including items such as deployment of deflagration panels, etc. Firefighting strategy proposed for the site and intended use of the firefighting system onsite (e.g. intention for it is to provide cooling water to surrounding equipment at a certain point in a fire or for a particular fire).			
17	Section 8 Summary of mitigation measures	First Aid Fire Protection: Ensure fire extinguishers are available throughout the site. Train personnel in basic firefighting and evacuation procedures.	FRNSW recommends providing further details for the following items in accordance with Section 2.9 of HIPAP2: • Fire extinguishers – size, type,	These aspects have been included into Section 8.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			medium, number, location, testing and maintenance. • Hose reels - number, location, type, testing and maintenance • Warning signs (including exit signs, placarding and first aid firefighting equipment use instruction signs), location, type, size. Refer to 5.3.3 of the FRNSW BESS Guideline for further details on recommended signage for the facility entrances. • Training of operators/staff - knowledge of plant, materials, emergency action/shut down procedures.			

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
			FRNSW Access – As per FRNSW Fire Safety Guideline – Access for fire brigade vehicles and firefighters, FRNSW recommends providing further details (such as road width, gradients, ramps, hardstand and etc.) demonstrating compliance with the relevant requirements.			
18.	Codes and References	-	Section 3.15 of Hazardous Industry Planning Advisory Papers No.2 (HIPAP2) requires that standards and codes used throughout the report be referenced at the end of the report. FRNSW recommends adding a section at the end of the report to identify codes and standards referenced throughout the report.	This has been provided at the rear of the report.	Noted	Closed

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
19.	Appendices	-	FRNSW recommends providing the following documents: • building plans; (indicate fire rated walls, doors and escape routes) • drainage systems drawings; • proposed fire protection layouts; • fire protection/fighting equipment. type, design and specifications;	These plans have been incorporated into the report.	Refer to Item 14.	Refer to Item 14.
20	Additional item					Fire Safety Study will remove reference to gas suppression system being provided to switchrooms and control rooms. Automatic smoke detection and Portable fire extinguishers will be provided within these

No.	Section	Fire Safety Study Comment	FRNSW Comment	Response to FRNSW comment	FRNSW Comment (September 2025 V2.2)	Fluence / FRC comment
						buildings.

Response to email dated – 14/10/2025

No.	FRNSW comment	Response
5	Item 5 – No average/maximum quantity of the dangerous goods have been provided. FRNSW's expectation is that the average/maximum quantity for each dangerous good being listed in a tabular format as per HIPAP2. Example is provided below, which is an extract from HIPAP2 that should be used as a guidance.	Additional information has been provided in Section 2.3.
6	Item 6 – Insufficient detail provided for the flame tilt assessment. Section 2.3 of HIPAP2 states "*All models and assumptions used to estimate consequences should be justified*." The limited details do not provide transparency on the calculations conducted. The following comments for Section 5.2.1 should be addressed: o Provide details on the methodology used to calculate the radiant heat exposure – all assumptions, equations used.	Additional information has been included in Section 5.2.2 and Appendix G. The information has been assessed against the LSFT again and we can confirm that this is aligned.

No.	FRNSW comment	Response
	- Provide details of all calculations carried out, as it is stated that a "hand-based analysis" was conducted. - Has the analysis considered flame tilting towards all sides (including back and sides) of the cube? The cubes are positioned back-to-back, side-to-side. - Flame length factor of k=1.2H is used. Provide justification, does this match with observed flame height in the large-scale fire testing? - Flame temperature T=973K (≈ 700 °C). Provide justification. Does this match with flame temperature measured in the large-scale fire testing? - What is the radiation heat limit that the BESS unit can withstand without going under thermal runaway? The limit should be used for assessing whether or not a fire spread will occur or not in flame-tilt scenarios (environmental impact) - It is stated "Design separation of 3.5 m continues to provide effective separation between the BESS Units". If the separation distance is 3.5 m, then it should be stated in the Executive Summary.	
7	Item 7 – It is noted in Executive Summary that the recommendations for separation distance states "*Separation distances in accordance with manufacturers recommendations*.". FRNSW recommends specifying exact separation distances required – actual distances (side, back, front and etc).	Additional information has been included within the Executive Summary to address these matters.

Appendix E – Response to FRNSW Guideline

Fire Safety Study Consideration	Compliance	Comments
The development of a FSS for a facility containing the large-scale LiBESS should be undertaken in accordance with the Hazardous Industry Planning Advisory Paper No 2 (HIPAP No. 2) Fire Safety Study Guidelines (Department of Planning, Industry and Environment 2011). This guideline assists persons developing the FSS in undertaking a case-specific hazard-based approach to the design to ensure that the fire safety system is adequate to meet the extent of potential fires for the site and effective in minimising the potential for propagation and escalation of an incident. It is noted that there are many different battery chemistries. The FSS should be based on the particular batteries proposed to be used on the site.	✓	The FSS has been developed in accordance with HIPAP No. 2 and aligns with FRNSW's BESS Guideline. FSS is specific to LFP chemistry, with UL9540A and large scale fire test results referenced throughout the report.
Section 5.1 – Assessment of potential consequences of credible incidents		
A fundamental objective of a FSS is that the hazard potential of a plant and/or operation is defined by a process of hazard identification and subsequent estimation of the potential consequences of credible incidents. Underestimation of the potential consequence of a credible incident is likely to result in failure of the fire safety system and subsequent propagation and escalation of an incident.	✓	Addressed in Section 4 (Hazard Analysis) and Section 5 (Fire Consequences), including thermal runaway, chemical hazards, and arc flash. Mitigation measures have been detailed throughout the document and summarised in Section 9 (Summary of mitigation treatments). These are sufficient to mitigate the potential risk on site for a BESS of this nature and size.

Fire Safety Study Consideration	Compliance	Comments
A failure event involving LiBESS may eventuate from a number of internal and external mechanisms including mechanical-, thermal- and electrical abuse or failure, and may result in the expulsion of chemical components, propagation of chemical vapours and/or a thermal runaway event and fire and/or explosion.	✓	The Fire Safety Study recognises that failure events involving LiBESS can be triggered by a range of internal and external mechanisms, including mechanical damage, thermal stress, or electrical faults. Section 4.2 identifies these failure modes as credible initiating events, which can lead to the release of chemical components, the accumulation of flammable or toxic vapours, and potentially a thermal runaway event. Section 5.2.1 further details the consequences of such failures, including fire, gas release, and the potential for deflagration or explosion. The fire safety strategy incorporates detection, containment, and isolation systems specifically designed to manage these risks and prevent escalation, in accordance with HIPAP No. 2 and FRNSW expectations.
FRNSW consider a credible incident to be one in which a fire propagates within a LiBESS system or unit, with active fire safety systems disabled, and involves the full BESS unit / container.	✓	Section 5.2.1 considers full cube involvement. Testing confirms fire self-containment with minimal risk of propagation.
When undertaking consequence analysis of an incident, both the direct impacts of an incident and the potential for propagation and secondary incidents should be addressed. This includes management of chemical components or by-products released during an incident and the environmental impacts of toxic water-run off that may be used to mitigate an incident.	✓	The FSS addresses both direct and secondary consequences of incidents in Sections 5.2 and 6.4. Fires involving BESS Cubes, transformers and general infrastructure are analysed, including worst-case thermal runaway and radiant heat exposure. UL9540A and large-scale fire test data demonstrate limited potential for propagation. Gas by-products and smoke composition are detailed in Section 3.2.3, with hydrogen, carbon monoxide and methane identified as key emissions. Environmental impacts from contaminated firewater are addressed in Section 6.4.2. A 251,000 L firewater containment system is included to prevent runoff entering local waterways. Automatic isolation valves are also installed to separate the stormwater system during a fire event. This containment and treatment approach is designed to manage toxic by-products and ensure environmental protection.
Where a hazard analysis study (i.e., preliminary hazard analysis, final hazard analysis, or a hazard and	✓	The Preliminary Hazard Analysis (PHA) was completed by EMM Consulting in September 2022 for the Wellington South BESS. This study identified key fire and chemical hazards

Fire Safety Study Consideration	Compliance	Comments
operability study) has been undertaken for the site in question, this should be used to inform the FSS.		associated with the site. The findings of the PHA have been used to inform the FSS, particularly in Sections 4 (Hazard Analysis) and 5 (Fire Consequences).
Whilst the emphasis of this section is the assessment of consequences of a failure event involving LiBESS and the potential for propagation and secondary incidents, the FSS must still consider the broader potential for all credible incident scenarios at the facility	✓	The FSS considers a broad range of credible incident scenarios beyond just BESS failure events. Section 4 outlines fire, chemical, electrical, and physical hazards, including transformer fires, general building fires, and arc flash. Section 5 addresses consequence analysis for each, including thermal runaway, radiant heat, bushfire exposure, and toxic gas release. Section 6 incorporates these into the fire safety strategy, ensuring that prevention, detection, and response measures apply across all likely incident types on site. This approach aligns with HIPAP2 and FRNSW expectations for comprehensive risk coverage.
Section 5.2 – Defining the fire safety strategy		
Within the context of a FSS, the fire safety strategy relates to the strategy and approach that will be adopted to achieve the required level of safety and performance. An effective fire safety strategy aims to minimise the likelihood, severity, and extent of an incident.	✓	The FSS defines a clear fire safety strategy in Section 6. It incorporates prevention, preparedness, and response measures designed to reduce the likelihood, severity, and extent of incidents. Key elements include a Battery Management System (BMS), emergency stop and shutdown functions, fire and gas detection systems, 24/7 remote monitoring, and separation between BESS units and infrastructure. These controls are supported by site-specific emergency planning and water containment systems.
Special consideration should be given to developing a fire safety strategy that is effective in minimising potential for propagation and escalation of an incident with reference to the credible incidents outlined in *Section 5.1 Assessment of potential consequences of credible incidents.* An example of an element of a fire safety strategy that may be adopted is the separation of BESS containers or racks by way of either appropriately fire-rated physical barriers or distance.	✓	The fire safety strategy outlined in Section 6 of the Fire Safety Study prioritises prevention of incident propagation using higher-order controls. The primary mitigation adopted is spatial separation of BESS Cubes, with fluence's specifications for clearance between units. Large-scale fire testing confirmed this distance is effective in preventing fire spread (Section 3.2.2 and Appendix C). The strategy avoids reliance on administrative or manual intervention and instead uses engineered systems such as automatic shutdowns, integrated detection and suppression systems, and a BMS. These controls are designed to isolate faults early and contain thermal events, addressing the credible incidents identified in Section 5.1.

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Where possible, preference should be given to the implementation of strategies that are supported by higher-order risk controls (i.e., elimination and/or engineering controls, etc.).		
Supporting analysis and/or evidence should be provided within the FSS to justify the selection, appropriateness, and efficacy of the selected fire safety strategy. This should include all calculations and analyses and contain justification of all inputs and methods used. Where testing is relied upon, detailed test reports need to be provided which detail who undertook the tests, the test methodology and results obtained. Testing should be witnessed and verified by parties who are independent from the battery manufacturer / supplier.	✓	The FSS includes supporting evidence to justify the selected fire safety strategy. Section 3.2.2 details large-scale fire testing conducted on the Fluence BESS Cube, including full thermal runaway scenarios. Results showed no fire propagation between Cubes with 177.8 mm spacing, supporting the adopted separation strategy. Additional analysis in Sections 5 and 6 outlines the selection of controls such as BMS, automated shutdown, gas detection, and passive containment. The firewater demand assessment in Section 7.3 outlines the implementation of an AS2419.1 fire hydrant system based on open yard requirements. Test reports are included in Appendices B and C.
The fire safety strategy should consider the likelihood of occupants being present within the BESS unit / container.	✓	The FSS considers site occupancy and the likelihood of personnel being present during an incident. Section 3.1.1 notes that the Wellington BESS site operates with minimal daily staffing, typically two personnel during normal operations, with higher numbers only during maintenance. The BESS Cubes themselves are not occupiable spaces. The fire safety strategy reflects this low occupancy risk. Visual and audible alarms are installed on all Cubes and can alert personnel in a thermal runaway event (Section 6.4.5). Emergency response procedures and site inductions also ensure that workers are aware of evacuation protocols.
FRNSW does not support the adoption of fire safety strategies that are either partially or wholly reliant on fire brigade intervention to achieve an acceptable level of safety, given that:		

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• Intervention of a fire brigade at an incident is considered to constitute application of a low-order administrative type risk control and is not in line with the so far as is reasonably practicable principle in managing risk, given higher-order controls are available and may be implemented in a reasonably practicable manner	✓	The FSS adopts a fire safety strategy based on higher-order controls and does not rely on fire brigade intervention to achieve an acceptable level of safety. Section 6 outlines engineered and passive systems, including automatic detection, BMS triggered shutdowns, separation distances, gas monitoring, and remote 24/7 monitoring. These systems are designed to detect and contain incidents without the need for manual intervention. Fire brigade response is treated as a last resort, with clear instructions that will be provided in the EMP that attending firefighters should not intervene with burning Cubes and instead allow controlled burnout where appropriate.
• Large-scale LiBESS including supporting infrastructure may constitute a chemical or electrical hazard such that intervention activities and/or firefighting operations may pose unacceptable risks to the safety of attending firefighters	✓	Section 4.3 outlines the electrical and toxic gas hazards, including stranded energy and off-gassing during thermal runaway. To protect emergency responders, the strategy includes engineered controls such as automatic shutdown, BMS isolation, remote monitoring, and fixed gas detection systems (Sections 3.2 and 6).
• The rapid intervention of a permanent full-time fire brigade cannot be relied upon as it is subject to resource availability and proximity to the incident.	✓	The site is unlikely to have rapid intervention from a fire brigade and measures have been formulated around this. Sections 6 and 7 outline engineered and passive controls, including automatic detection systems, BMS triggered shutdowns, separation between units, and 24/7 remote monitoring. These measures are designed to contain and manage incidents without requiring immediate external intervention. The EMP will also provide clear instructions that the preferred response to a BESS fire is controlled non-intervention, allowing the affected unit to burn out while protecting nearby assets. This approach aligns with FRNSW’s position and eliminates dependence on variable brigade response times.
• Potential for significant variation in the weight of response, capability, equipment, and level or training of attending fire brigade resources.	✓	Sections 3.2, 6 and 8 describe the use of higher-order controls, including automatic fire detection, gas monitoring, emergency shutdown via the BMS, and physical separation of BESS Cubes to prevent propagation.

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Section 5.3 – *Electrical hazards posed to firefighters*		
Large-scale LiBESS including supporting infrastructure are considered to constitute an electrical hazard when involved in an incident, given that:		
• It may not be possible to determine the state of charge of an affected unit.	✓	Section 4.3 identifies this as a key electrical hazard, noting that BESS units must be treated as live at all times, regardless of shutdown status. The EMP will reinforce this by using a 'burn out' technique. Regular liaison will be made with local crews to ensure they are aware of this hazard. It will also be detailed in the EMP and Emergency Services Information Package.
• High voltages may still be present, even at low states of charge.	✓	As above. The primary mechanism will be to let the fire burn out.
• There is potential for energy to be stranded within an affected unit.	✓	As above. The primary mechanism will be to let the fire burn out.
• FRNSW currently does not have the equipment or capability to be able to detect live direct current (DC) power.	✓	As above. The primary mechanism will be to let the fire burn out.
• It may not be possible to isolate the input to- or output from an affected unit, particularly where isolation controls (automated or otherwise) have been adversely affected by exposure to radiant heat.	✓	As above. The primary mechanism will be to let the fire burn out.
• The affected and surrounding units may experience a degradation of the ingress	✓	As above. The primary mechanism will be to let the fire burn out.

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protection (IP) rating as a result of exposure to radiant heat.		The surrounding units will be separated with the Large Scale Fire Test results in mind.
A FRNSW incident commander may determine that no intervention activities or firefighting operations will be undertaken where it is considered that there is unacceptable risk posed to the safety of firefighters.	✓	The FSS fully supports FRNSW's position that incident commanders may choose not to undertake intervention or firefighting operations where firefighter safety cannot be assured. Section 8 of the FSS outlines that the preferred strategy during a BESS fire is controlled non-intervention, allowing the affected unit to burn out while maintaining safe separation and exposure protection. The EMP includes clear guidance for responders, recognising the risks posed by high voltage, toxic gases, and limited accessibility.
Signage should be provided at appropriate locations (based upon a site assessment), including but not limited to all entrances to the facility and the main control room, warning of the potential electrical and chemical hazards present. Whilst the scope of AS 5139 is limited to a battery with a maximum capacity of 200 kWh, Section 7 of the standard contains useful guidance that can be used for labels and safety signage.	✓	Section 8.1.3 confirms that warning signage will be installed at all key entry points, including the facility entrance, control room, and near BESS Cubes. Signage will identify the presence of high voltage equipment, potential toxic gas release, and other relevant risks. Placards will also be provided on transformer bunds and hazardous goods storage areas. This signage strategy ensures responders and site personnel are clearly warned of hazards before entry, supporting safe emergency response and compliance with industry best practice.
Section 5.4 – *Fire Brigade Intervention*		
Section 5A *General functions of Commissioner* of the *Fire and Rescue NSW Act 1989* imposes specific statutory functions on the Commissioner of FRNSW, specifically that: 1) It is the duty of the Commissioner to take all practicable measures for preventing and extinguishing fires and protecting and saving life and property in case of fire in any fire	✓	The FSS acknowledges FRNSW's statutory obligations under Section 5A of the Fire and Rescue NSW Act 1989. In recognition of FRNSW's duty to respond to fire and hazardous material incidents, the FSS places strong emphasis on ensuring first responder safety. Section 8 outlines site-specific emergency procedures, including controlled non-intervention for BESS Cube fires, access restrictions, and the requirement for technician confirmation before entry. Site familiarisation, signage, and the provision of an Emergency Services Information Package ensure that responders are adequately informed and equipped to carry out their duties without being exposed to unacceptable risk.

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district. (and) 2) It is the duty of the Commissioner to take all practicable measures— a) for protecting and saving life and property endangered by hazardous material incidents, and b) for confining or ending such an incident, and c) for rendering the site of such an incident safe. In the event of a fire or hazardous material incident involving large-scale LiBESS, FRNSW may be required to undertake intervention activities and firefighting operations in order to fulfil statutory obligations, as such, consideration to the safety of first responders conducting intervention activities must be considered.		
A potential incident at a BESS facility may be deemed a “hazardous material incident” in accordance with Section 3 of the *Fire and Rescue NSW Act 1989*. Substantial Hazardous Material response resources may be required to determine an appropriate intervention and mitigation strategy in the event of an incident.	✓	Section 4.3 and Section 5.2.1 of the FSS detail the presence of hazardous substances, including toxic and flammable gases released during thermal runaway. In response, the EMP (Section 8) will incorporate procedures for notifying FRNSW, isolating the site, and providing immediate access to hazard information via the ESIP. These measures support an informed and safe response by specialised HAZMAT crews, should they be required.
Intervention activities and firefighting operations at an incident involving large-scale LiBESS will be undertaken in a manner similar to that for large-scale	✓	Section 8 of the FSS will ensure the EMP will clearly state that first responders are not to enter the BESS compound during an incident unless accompanied by a qualified technician who can confirm that it is safe. Site technicians will be made available to provide technical

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electrical infrastructure (e.g., substations, electrical switchyards, etc.). FRNSW personnel may not enter the affected BESS compound or compartment until an electrical company representative is in attendance on site and has confirmed power is isolated. The electrical company representative may also be required to provide safety and technical advice to a FRNSW incident commander to assist in determining what intervention activities and firefighting operations can be safely undertaken.		support and safety confirmation. This procedure ensures that any intervention or firefighting activity is based on accurate system status and aligns with best practice for managing electrical hazards during emergency response.
As previously noted, a FRNSW incident commander may determine that no intervention activities or firefighting operations will be undertaken where it is considered that there is unacceptable risk posed to the safety of firefighters.	✓	As previously mentioned, the primary response technique will be to let the fire burn out. The surrounding units will be separated with the Large Scale Fire Test results in mind.
An Emergency Plan is to be developed for the site in accordance with *Hazardous Industry Planning Advisory Paper No 1* (HIPAP No. 1) *Emergency Planning*. The findings of the FSS should inform the development and content of the Emergency Plan. This should include, but not be limited to: a. Details on how the owner / operator is alerted to abnormal operation, fault or hazard in a BESS. b. Details on how fire services are notified of an incident. This should be described as part of the fire safety strategy. Upon detection of a fire in a BESS or on the site	✓	An EMP will be developed in accordance with HIPAP No. 1 and informed directly by the findings of the FSS, as detailed in Section 8. The plan will include: a. Automated alerts from the BMS and SCADA platform notify the operator of any abnormal operation, faults, or fire-related conditions in the BESS (Section 3.2 and 6.2). b. Upon detection of smoke, gas, or fire, the fire detection system triggers automatic notification to Fire and Rescue NSW through the Alarm Signalling Equipment (or through manual methods) (Section 6.4.5). c. The plan includes protocols for real-time communication between the remote operations centre and FRNSW, ensuring consistent updates throughout an incident (Section 8).

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via an automatic detection system, notification of the fire services should be automatic. c. Detail effective communication strategy with remote operator representative for incident duration. d. Suitable arrangements for attendance on site by an appropriately qualified representative during any incident. e. Details on how battery status and information is relayed to emergency services, including items such as deployment of deflagration panels, etc..		d. Qualified technical representatives are required to attend the site during any emergency to provide status confirmation, isolate systems, and support FRNSW personnel with technical advice (Section 8). e. Information such as battery information, hazard zones, firewater containment, and deflagration risk is included in the Emergency Services Information Package (ESIP), accessible on site via the Emergency Information Container. Batteries will always be assumed to be electrically charged equipment, unless a technician confirms otherwise (Section 6.4.4 and 8). These measures ensure the Emergency Plan is fully aligned with HIPAP No. 1 and supports a coordinated and safe response
Detail the required level of personal protective equipment (PPE) including any breathing apparatus (BA) requirements for emergency services.	✓	RFS and FRNSW personnel are expected to follow their own operational guidelines and wear full structural firefighting PPE or splash suits/fully encapsulated suits (if required), and a self-contained breathing apparatus (BA). This is due to the potential release of toxic and flammable gases such as hydrogen, carbon monoxide, and methane (Section 3.2.3 and 5.2.1). It will be clearly stated within the EMP and ESIP that gas is a hazard on site and responding firefighters are to wear appropriate PPE as detailed above.
The following FRNSW guidelines should also be utilised as part of the fire safety strategy and documentation requirements for the site: a. FRNSW Fire safety guideline – Hazardous chemicals manifest b. FRNSW Fire safety guideline – Emergency services information package and tactical fire plans	✓	Section 6.4.4 and Section 8 confirm that the site will comply with: a. The FRNSW Fire Safety Guideline – *Hazardous Chemicals Manifest*, through the inclusion of a detailed inventory of hazardous substances stored on site, such as lithium-ion components, transformer oils, and refrigerants. This information will be made available to FRNSW via the ESIP. b. The FRNSW Fire Safety Guideline – *Emergency Services Information Package and Tactical Fire Plans*, by preparing and maintaining an ESIP that includes site layout maps, hazard zones, contact details, shutdown procedures, and tactical response checklists.

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The most recent versions can be found on the FRNSW website.		The Emergency Information Container will house this material at the site entrance for immediate access during incidents.
Section 5.5 – *Implemented fire safety systems*		
The implementation of fire detection and protection measures may be required to ensure that the necessary level of safety and performance has been achieved for a site.	✓	Section 6.4.3 outlines the fire detection systems within each BESS Cube, including smoke and gas detectors connected to the site's SCADA system for real-time monitoring and alerting. These systems trigger automatic alarms, visual indicators, and shutdown protocols via the BMS.
The analysis of requirements for fire detection and protection measures should be informed by the assessment of potential consequences of credible incidents for the site. This should also align with the objectives of the fire safety strategy for the site, particularly those relating to the management and mitigation of the severity of an incident, and prevention of propagation and escalation of an incident, including the potential off-site and environmental impacts.	✓	The FSS bases the fire detection and protection requirements on the assessment of credible incident consequences outlined in Section 5. These include thermal runaway within BESS Cubes, transformer oil fires, and toxic gas release. The detection and protection systems are designed to align with the fire safety strategy's objectives by enabling early identification of faults and triggering automatic shutdown and alerts. These systems minimise incident severity and reduce the likelihood of fire propagation. Firewater containment infrastructure (Section 6.4.2) further supports the strategy by preventing environmental contamination from runoff, ensuring both on-site and off-site impacts are controlled.
Supporting analysis and evidence is required to be provided within the FSS to justify the suitability and efficacy of proposed fire detection and protection measures for the site. This evidence is required to demonstrate that the specified performance of individual measures and the collective system is adequate to satisfy the objectives of the fire safety strategy.	✓	Section 3.2 and Section 6.4.3 describe the design and function of the BESS Cube systems, including integrated smoke and gas detectors, automated alarm activation, and remote monitoring via SCADA. These systems are directly linked to the Battery Management System (BMS), which initiates shutdown procedures to prevent incident escalation. The performance of these measures is supported by UL9540A testing and large-scale fire test results (Appendices B and C), which confirm that fires are contained within individual Cubes and do not propagate to adjacent units. The combined system of early detection, automated response, and passive containment meets the objectives of the fire safety

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		strategy by preventing fire spread, reducing environmental impact, and ensuring personnel and responder safety.
All fire detection and protection measures that are relied upon to satisfy the objectives of the fire safety strategy should be automatic in nature (i.e., not require manual operation by an operator or attending emergency service). Supporting evidence is required to be provided within the FSS to demonstrate that individual measures and the collective system have sufficient capacity to operate at the required level of performance for the full duration of an incident.	✓	Section 3.2 outlines the integration of smoke and gas detectors, audible and visual alarms, and automated shutdown via the BMS. These systems activate independently upon detection of abnormal conditions. Section 6.4.3 further describes that these systems are supported by an uninterruptible power supply. Large-scale fire testing (Appendix C) supports their performance, confirming that the measures effectively contain incidents without external intervention, consistent with FRNSW and HIPAP2 expectations.
Adequate redundancy should be provided to all fire detection and protection measures that are relied upon to satisfy the objectives of the fire safety strategy. Emergency power supply to essential systems is one key consideration.	✓	Section 3.2 confirms that key systems, including smoke and gas detectors, alarms, the Battery Management System (BMS), and SCADA communications—are connected to an uninterruptible power supply
Where the fire safety strategy does not rely on direct fire attack on a LiBESS system or unit, a fire hydrant system should still be provided for the purpose of addressing other credible fire scenarios (e.g. within auxiliary buildings and infrastructure) and protection of LiBESS units from all potential fire sources. The specific requirements of the fire hydrant system, in terms of locations of hydrants, water supply, etc., should be based on the level of risk of the facility. Coverage by street hydrants is not considered adequate for such a facility.	✓	Section 7.4 outlines the provision of an AS2419.1 fire hydrant system. The system includes compliant hydrant outlets, suction connections, and a hardstand for appliance access. This setup supports suppression efforts for ancillary structures such as the control room, switch rooms, and transformers, and also enables firefighters to apply water for exposure protection if required.

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Provision should be made for monitoring of the Alarm Signalling Equipment (ASE) where a fire detection system is provided as part of the fire safety system for a site and a readily available response from a permanent fire brigade is available.	✓	Section 6.4.5 states that the ASE is linked to automatic fire detection within the BESS Cubes and site buildings, ensuring immediate alert to Fire and Rescue NSW upon activation.
Section 5.6 – *BESS unit separation*		
As identified in Section 5.2 *Defining the fire safety strategy*, the separation of large-scale LiBESS containers or racks by way of either appropriately fire-rated physical barriers or distance may be adopted as a fire safety strategy for a site.	✓	As outlined in Section 9, the minimum separation distance will be in accordance with fluence's specifications for clearance and as per the manufacturer's recommendations, which is supported by large-scale fire testing (Section 3.2.2 and Appendix C). The test results confirm that this spacing effectively prevents flame spread and limits radiant heat transfer.
Where such a strategy is adopted, the FSS is required to contain supporting analyses or evidence to demonstrate that the objectives of the fire safety strategy have been satisfied, namely that the provided separation is adequate to prevent propagation and escalation of an incident. Where active and/or passive measures are provided to support the implementation of this strategy, evidence is required to be provided in the FSS that demonstrates their ability to maintain the required level of performance for the full duration of an incident.	✓	Section 3.2.2 references large-scale fire testing conducted with Cubes placed 177.8 mm apart. This is consistent with the separation located at this site. The test results confirmed no flame spread or significant radiant heat transfer to adjacent units, with temperatures in neighbouring Cubes remaining below 30°C. These outcomes validate that the chosen separation distance, combined with the Cube's internal fire-resistant design, satisfies the objectives of the fire safety strategy and performs effectively for the duration of a thermal event.
Where separation is provided by way of a physical barrier that is constructed of a material with a fire resistance level as determined in accordance with AS	✓	This requirement is not applicable to the Wellington BESS site, as the fire safety strategy does not rely on physical fire-rated barriers for separation.

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1530.4:2014 *Methods for fire tests on building materials, components and structures - Fire-resistance tests for elements of construction*, an assessment is required to be undertaken to demonstrate that the fire severity associated with the design fire of the worst credible incident (i.e., the design fire severity) does not exceed that associated with the 'standard time versus temperature curve' as prescribed within Section 2.11 of AS 1530.4:2014*.* Failure to accurately quantify the design fire severity such that it is underestimated or exceeds that associated with the standard fire curve may result in the fire resistance performance of materials relied upon for separation being exceeded and subsequent failure of the fire safety system.		
Where separation is provided by way of distance, an assessment is required to be undertaken to demonstrate that propagation of the incident will not occur to adjacent and surrounding racks, containers, and/or associated infrastructure. The assessment is required to consider the combined effects of exposure to convective and radiant heat on a receiving body from the worst credible fire for the full duration of an incident.	✓	Section 3.2.2 and Appendix C detail testing where Cubes were placed 177.8 mm apart which is consistent with the separation adopted at the Wellington site. The test involved a full thermal runaway event and measured both convective and radiant heat impacts. Results showed minimal radiant heat exposure, and no significant temperature rise in adjacent units (remaining below 30°C). These outcomes confirm that the adopted separation is sufficient to prevent fire spread under worst-case conditions for the full duration of an incident.
The impacts of environmental conditions (e.g., wind effects) must also be assessed. This should include assessment of flame tilt, etc.	✓	While the large-scale fire test (Section 3.2.2 and Appendix C) was conducted under controlled conditions, the FSS applies conservative assumptions regarding wind direction and speed in its fire water and exposure protection planning (Sections 6.4.2 and 7.3).

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		The EMP will also instruct responders to assess weather conditions before approaching an incident. The site layout, including hardstand areas and separation distances, is designed to minimise the influence of wind-driven fire spread. These considerations ensure that the risk of flame tilt impacting adjacent infrastructure remains low under worst-case conditions, particularly given that BESS Units will be separated by more than what was tested in the large scale fire test.
Section 5.7 – BESS unit ventilation and flammable and toxic gases:		
A LiBESS may produce large volumes of flammable, corrosive and toxic vapours and gases when involved in a thermal event as a result of: thermal decomposition of battery components and electrolytes, pyrolysis of combustible materials, and incomplete combustion of volatiles within smoke. Flammable vapours and gases when confined within a compartment or a container are deemed to have the potential to result in a hazardous atmosphere. Any person exposed to these vapours or gases is considered to be at risk of harm.	✓	Section 3.2.3 and Section 5.2.1 detail the composition of gases released during thermal runaway, including hydrogen, carbon monoxide, and methane, each posing inhalation and ignition risks. The risk of hazardous atmosphere formation within confined compartments is recognised, and the EMP (Section 8) will include protocols for evacuation, use of PPE (breathing apparatus), and restricted access until gas levels are confirmed safe.
Ignition of the flammable gases produced during a thermal runaway event may result in a deflagration or explosion. This is noted to have caused or contributed to injury and death to attending emergency services at past incidents.	✓	Section 5.2.1 discusses the potential for gas accumulation within confined spaces and the associated hazard of sudden ignition. While large-scale fire testing (Appendix C) did not result in deflagration, the FSS adopts a conservative approach by assuming this risk exists. As a result, BESS units will be separated in accordance with fluences specifications. Additionally, the EMP (Section 8) will include strict exclusion protocols, mandate the use of breathing apparatus, and prohibit entry into affected areas until clearance is provided by a site technician.

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The design of the fire safety system for any facility containing large-scale LiBESS is required to demonstrate that consideration has been given to the management of flammable, corrosive and toxic vapours and gases that may be produced during a thermal runaway event.	✓	Section 3.2.3 outlines the gas detection systems installed in each BESS Cube, which monitor for early signs of gas release. Upon detection, the system activates alarms and initiates automatic shutdown through the BMS. Section 5.2.1 further details the types of gases expected, referencing UL9540A testing, and notes that the BESS Cubes are designed to contain off-gassing without external release. The EMP will include procedures for site evacuation, restricted access, and firefighter use of PPE and breathing apparatus, ensuring safe management of vapour-related hazards.
Where a large-scale LiBESS is proposed to be located within a an enclosing container or compartment, a FSS must assume that there is potential for a hazardous atmosphere to be generated unless suitable evidence is provided that demonstrates otherwise. A subsequent analysis of potential consequences is required to be undertaken to inform the analysis of requirements for detection and protection such that suitable measures can be selected for implementation.	✓	Section 3.2.3 acknowledges the potential for accumulation of flammable and toxic gases inside the container, including hydrogen and carbon monoxide. Section 5.2.1 provides a consequence analysis based on UL9540A testing, which identifies gas types and quantities released during thermal runaway. Based on this analysis, the fire safety system includes gas detection, automatic alarms, and BMS triggered shutdowns.
Where a large-scale LiBESS is proposed to be located within a an enclosing container or compartment and it is determined that there is potential for a flammable atmosphere to be generated from a thermal runaway incident, the consequence assessment is required to consider how an ignition of the atmosphere resulting in a deflagration or explosion will impact on surrounding racks or units, supporting infrastructure, and any other surrounding elements or structures.	✓	Section 5.2.1 refers to large-scale fire testing and UL9540A results, which found no external flame jetting, structural failure, or propagation to adjacent units. The assessment confirms that, even in the event of internal ignition, the containerised design of the BESS limits the effects to within the unit. Adjacent BESS Cubes and infrastructure remained unaffected in testing, and separation distances and site layout further reduce any external impact.

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Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment that is occupiable by a person, signage should be provided at appropriate locations including but not limited to the entrance to the respective compartment or container, warning that in the event of an incident involving the LiBESS there is potential for a hazardous atmosphere to be present.	✓	While the BESS Cubes at the Wellington site are not designed for routine occupation, signage is still provided in accordance with FRNSW guidance. Section 8.1.3 confirms that warning signs will be installed at all access points to the BESS Cubes and relevant enclosures, advising of the potential presence of a hazardous atmosphere during an incident. These signs will clearly indicate risks associated with toxic and flammable gases and will comply with the guidance outlined in AS5139 Section 7. This ensures personnel and emergency responders are appropriately warned before entry.
Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment that is occupiable by a person, a visual warning device should be provided at the entrance to the compartment or container that is to activate upon the activation of any provided detection or protection measures, with associated signage provided stating that a fire safety measure has activated and warning that there is potential for a hazardous atmosphere to be present.	✓	Although the Cubes are not routinely occupied, they are treated as occupiable for safety purposes. Section 3.2 and Section 6.4.3 confirm that each BESS Cube is fitted with external strobes and audible alarms that activate upon detection of smoke, gas, or thermal events. These indicators alert personnel to the activation of a fire safety system and the potential presence of a hazardous atmosphere. In addition, signage is provided at all entrances to clearly state that an alarm has been triggered, and entry is restricted due to potential exposure risks.
Section 5.8 – Environmental impacts		
A LiBESS involved in a thermal runaway incident may produce by-products that are hazardous to the environment.	✓	The site includes a 251,000 L firewater retention system with isolation valves to prevent discharge into the stormwater system (Section 6.4.2). This containment system ensures that any contaminated water used during firefighting is captured and safely managed. The EMP also includes procedures for safe disposal of waste materials and firewater following an incident, aligning with environmental protection requirements.
When undertaking any consequence assessment relating to a thermal runaway incident, consideration must be given to the potential for the generation of a	✓	Section 5.2.1 outlines the expected composition of smoke and gas emissions, including carbon monoxide, hydrogen fluoride, and other toxic by-products. The assessment

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toxic smoke plume and its subsequent impact on the surrounding environment and communities. This should include demonstrating that toxic gas emissions during such a fire will not impact neighbours, first responders or passers-by, under worst-case weather conditions specific to the site.		assumes a worst-case thermal event and references UL9540A and large-scale test data to characterise emission volumes. While the study does not include a full atmospheric dispersion model, conservative assumptions are made regarding plume behaviour and prevailing site-specific weather conditions. The site's remote location, prevailing wind direction, and separation from public areas reduce the likelihood of exposure to neighbouring properties or public spaces. The EMP includes procedures for isolating the site, restricting access, and notifying emergency services in the event of a toxic gas release, ensuring the safety of first responders and the broader community under worst-case conditions.
Any Emergency Plan for the site should detail the required level of personal protective equipment (PPE) including any breathing apparatus (BA) requirements for emergency services.	✓	The EMP will specify the required level of personal protective equipment (PPE) for emergency services responding to an incident at the site. Due to the risk of toxic and flammable gases during a thermal runaway event, attending FRNSW personnel are required to wear full structural firefighting PPE, including self-contained breathing apparatus (BA). These requirements are based on the expected gas composition identified in Section 5.2.1 and reflect the elevated risk of exposure to hazardous atmospheres. The plan ensures responders are adequately protected when operating in or near the BESS compound during an incident. This will be detailed in the ESIP as well.
Where a fire safety strategy is adopted that relies on the application of water (or water- based agents) to suppress a fire, provision must be made for the containment of all contaminated firefighting water for the entire expected duration of the incident. Any provided containment system must ensure that contaminated firefighting water is not able to enter local waterways or groundwater.	✓	Although the fire safety strategy does not rely on active suppression of BESS fires, water application may be used to protect adjacent infrastructure or address fires in auxiliary areas. Section 6.4.2 details the inclusion of a 251,000L firewater retention system, designed to contain the full volume of expected runoff for the duration of an incident. The system includes bunding, isolation valves, and hardstand drainage to prevent release into stormwater systems, local waterways, or groundwater.

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Where a containment system is proposed to be connected to a reticulated stormwater system, provision must be made for the isolation of the system by way of automatically operated valves that close upon activation of an associated fire safety measure.	✓	Section 6.4.2 states that isolation valves are installed within the drainage network and are programmed to automatically close upon activation of a fire safety system, such as gas or smoke detection. This prevents contaminated firefighting water from entering the stormwater system and ensures all runoff is directed to the 251,000 L on-site retention system.
Whilst not a requirement of a FSS, it is recommended that any Emergency Plan developed for the site identify local catchment areas and drainage pathways such that appropriate measures may be implemented in the event that the capacity of the provided containment system is exceeded.	✓	The EMP will outline the fire water runoff arrangements.
Appropriate consideration should also be given to *Planning for Bushfire Protection (2019).*	✓	Section 6.3 outlines the site's compliance with bushfire protection principles, including asset protection zones (APZs), vegetation management, and defensible space around key infrastructure.
Section 5.9 – Post-incident clean-up and disposal		
Whilst not a requirement of a FSS, it is recommended that supporting management and procedures documentation for the site provide details of the following:		
• Following an incident, how LiBESS will be handled and removed (including transportation) from site. It is noted that this is the responsibility of the facility owner and/or operator and that FRNSW is not responsible for aiding or facilitating such actions.	✓	While not a formal requirement of the Fire Safety Study, it is acknowledged that the site's supporting management and procedures documentation will, at a later stage, identify the process for handling, removing, and transporting damaged LiBESS units following an incident. This will likely be identified in the EMP.

Fire Safety Study Consideration	Compliance	Comments
• A procedure for the removal and disposal of contaminated firefighting water.	✓	As detailed within Section 8, this will be identified within the EMP.
Section 5.9 – Reference standards and codes		
HIPAP No.2 states "The principle of a fire safety study is that the fire safety 'system' should be based on specific analysis of hazards and consequences and that the elements of the proposed or existing system should be tested against that analysis. This should always produce a better outcome than the application of generalised codes and standards alone" (DPIE 2011).	✓	The Fire Safety Study aligns with the principle outlined in HIPAP No. 2, which states that the fire safety system should be based on specific analysis of hazards and consequences, rather than relying solely on generalised codes and standards. As referenced in Section 1.3 of the FSS, the strategy has been developed using site-specific hazard identification (Section 4), consequence analysis (Section 5), and large-scale test data (Appendices B and C). Each element of the fire safety system, including detection, containment, separation, and emergency response, has been selected and justified against this analysis.
The provisions within applicable codes and standards may be adopted where it can be demonstrated that the requirements of HIPAP No.2 have been adequately satisfied.	✓	Section 1.3 notes that while standards such as AS2419.1, AS 5139, and AS/NZS 3000 have been referenced, their application is not prescriptive. Instead, these standards are used to support system design elements only where the hazard and consequence analysis (Sections 4 and 5) confirms they are appropriate.

Appendix F – Analysis against contaminated water guidelines

Risk Assessment Matrix and Process – Contaminated Water Retention and Treatment Systems

This analysis is designed to align with the NSW Government *Best Practice Guidelines for Contaminated Water Retention and Treatment Systems* (July 1994). It incorporates hazard analysis, quantitative/qualitative risk assessment, and environmental risk criteria from HIPAP No. 4.

Risk Assessment Matrix

The following risk assessment matrix has been adapted from the Guidelines.

Likelihood Scale

Rating	Descriptor	Example Frequency Reference
1	Rare	≤ 1 in 10,000 years
2	Unlikely	1 in 1,000 – 1 in 10,000 years
3	Possible	1 in 100 – 1 in 1,000 years
4	Likely	1 in 10 – 1 in 100 years
5	Almost Certain	≥ 1 in 10 years

Consequence Scale

Rating	Descriptor	Environmental/Health Impact
A	Insignificant	No measurable impact; below AWRC criteria; no injury
B	Minor	Short-term minor exceedance; recoverable localised impact
C	Moderate	Localised but significant ecological effect; short-term human health risk
D	Major	Widespread or long-term ecological damage; significant human health impact
E	Catastrophic	Irreversible ecosystem collapse; major injury/fatality; long-term contamination

Risk Matrix

Likelihood / Consequence	A	B	C	D	E
1 Rare	Low	Low	Low	Medium	Medium
2 Unlikely	Low	Low	Medium	Medium	High
3 Possible	Low	Medium	Medium	High	High
4 Likely	Medium	Medium	High	High	Extreme
5 Almost Certain	Medium	High	High	Extreme	Extreme

Risk Assessment Process

Step 1 – Hazard Identification

As outlined within the Fire Safety Study, the identification of materials with potential to harm the environment, in normal state or due to combustion/reaction has been identified. This is also listed within the UL9540A and large scale fire test reports. The likely mechanism for fire water containment to be required is in relation to water being delivered directly onto the lithium ion.

Step 2 – Assessment of Receiving Waters

The site is fitted with both a fire water containment system and a stormwater management system. The operation of a valve will isolate the stormwater system and ensure the fire water is contained within the culvert system. When the culvert commences filling, a pump will automatically activate and commence filling a 100,000 litre water tank that is dedicated to containing fire water.

The culvert has been designed to contain 415,000 litres of fire water. In total the site will be able to store 515,000 litres of fire water runoff.

The stormwater isolation process ensures that fire water does not impact on the surrounding environment or leave the site until it has been tested and confirmed that it is not contaminated.

Step 3 – Estimate Potential Volumes & Contaminant Loads

The supply of firefighting water is deemed to be highly conservative and is highly unlikely to be utilised in the quantities that are supplied. The analysis contained within this Fire Safety Study outlines that BESS Unit and other infrastructure fires should not be suppressed using fire water. The site is designed to allow any of the infrastructure to burn out. If required, asset protection firefighting streams can be deployed. This water is considered clean until it is directed towards flame.

Step 4 – Consequence Analysis

The design of the fire water containment system ensures the valve will be activated prior to any firefighting activities being undertaken. Therefore the consequence is limited to when the fire water being used exceeds the capacity of the fire water containment system. The fire water being supplied is 432,000 litres as the site has been deemed to require 30 l/s as per the open yard requirements of AS2419.1.

The provision of 515,000 litres of fire water containment well exceeds the availability of fire water.

Step 5 – Frequency/Probability Analysis

As outlined in this Fire Safety Study, fires within BESS sites is considered rare and a low risk. Whilst two fires have been recorded within Australia in recent years, these are considered low occurrence events. The design of these sites ensures that data is collected 24/7 and is then interpreted through systems and monitoring to detect any issues early.

Step 6 – Determine System & Component Capacities

Fire hydrant system capacity – 432,000 litres

Fire water containment capacity – 515,00 litres.

Step 7 – Estimate Residual Risk

The key acceptance principles for fire water containment are listed in Table 11.

Table 14 - Fire water containment - key acceptance criteria and residual risk

Key acceptance principles	Criteria	Discussion	Residual risk
Human health criteria:	Individual fatality risk should generally be less than 1 in a million per year (1×10^{-6}) for residential areas. Higher tolerances may apply for industrial land uses (up to 1×10^{-5}).	The site is located away from residential and industrial areas. Therefore, the risk of impacting on huma health from offsite communities is considered rare. Onsite staff and emergency service personnel are at a greater risk however due to the availability of PPE, PPC and the fire water containment system, this is also considered to be rare.	**Low** (Unlikely Minor)
Environmental/ ecological criteria:	Any event that could result in irreversible ecosystem collapse, extinction of species, or major long-term contamination is unacceptable. More minor discharges are assessed against AWRC (Australian Water Resources Council) water quality criteria for drinking water and aquatic ecosystem protection	The implementation of the isolation valve will prevent any offsite passage of water that is suspected to be contaminated due to firefighting activities. There is also limited areas that can be affected by fire water runoff int eh surrounding landscape.	**Low** (Rare Insignificant)
Social/economic considerations:	Impacts on community assets (e.g., drinking water sources, fisheries, recreation areas) must be factored into acceptability.	There is no drinking water supplies or other community assets within the local area.	**Low** (Rare Insignificant)

Step 8 – Review & Integrate with Site Safety Management System

Based on the outcome of the assessment the following actions will be implemented:

1. Fire water containment system consisting of 415,000 storages within the culverts and a 100,000 litre water tank.
2. Isolation valve installed to close the stormwater runoff system and to contain fire water.
3. Isolation controls to be outlined within the Emergency Management Plan.
4. Fire water testing and removal process to be within the Emergency Management Plan.
5. The isolation valves and culvert will be checked annually to ensure it is in working order.

Appendix G – Flame tilt calculations

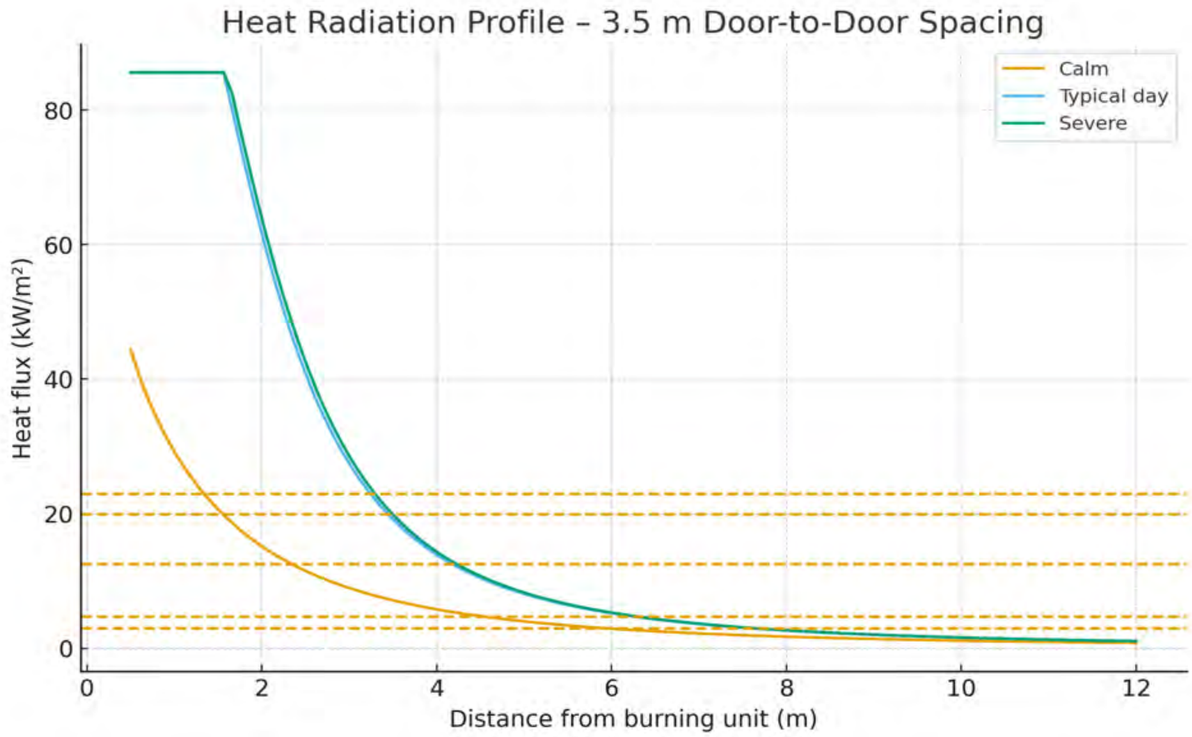

Figure 9 - Heat radiation profile.

Table 15 - Input assumptions

Item	Value
Project	Wellington BESS – Flame Tilt Appendix G (Simplified)
Unit height H (m)	2.6
Unit width/depth W (m)	2.6
Front separation (m)	3.5
Back/side clearance (m)	0.15
Flame length factor k (-)	1.2
Flame emissivity ε (-)	0.9
Flame temperature T (K)	973
Characteristic plume velocity Uc (m/s)	3
Observation height (m)	1.5
Wind bins (m/s)	0.0, 8.33, 11.11
Acceptance thresholds (kW/m²)	3, 4.7, 12.5, 20, 23
Notes	Back/side treated as shared-wall; governing case is front (aisle).

Table 16 - Results

Wind (m/s)	Scenario	Tilt angle θ (deg)	Effective separation S_eff (m)	Peak flux at aisle (kW/m²)	Comment
0	Calm	0	3.5	7.1	Door-to-door
8.33	Typical day	70.2	2.03	19.2	Door-to-door
11.11	Severe	74.9	1.99	19.9	Door-to-door

Table 17 - Radiation profile

Distance (m)	Flux Calm (kW/m²)	Flux Typical day (kW/m²)	Flux Severe (kW/m²)
0.5	44.31863349	85.51937399	85.60782862
0.596638655	40.5163494	85.51937399	85.60782862
0.693277311	37.25642441	85.51937399	85.60782862
0.789915966	34.40323153	85.51937399	85.60782862
0.886554622	31.87176703	85.51937399	85.60782862
0.983193277	29.60490152	85.51937399	85.60782862
1.079831933	27.56170256	85.51937399	85.60782862
1.176470588	25.71119692	85.51937399	85.60782862
1.273109244	24.02890252	85.51937399	85.60782862
1.369747899	22.49481854	85.51937399	85.60782862
1.466386555	21.09220712	85.51937399	85.60782862
1.56302521	19.80681805	85.51937399	85.60782862
1.659663866	18.62636933	80.11084451	82.48628642
1.756302521	17.54018108	74.56095914	76.94894781
1.852941176	16.53890499	69.2118671	71.57950664
1.949579832	15.61431654	64.11124707	66.4283774
2.046218487	14.75914996	59.29362108	61.53443376
2.142857143	13.96696413	54.78056206	56.924536
2.239495798	13.23203161	50.58198629	52.61416654
2.336134454	12.54924551	46.69808501	48.60883292
2.432773109	11.9140408	43.12148911	44.90587696
2.529411765	11.32232714	39.83936579	41.49638464
2.62605042	10.77043139	36.83526491	38.36698159
2.722689076	10.25504805	34.09063355	35.50139021
2.819327731	9.773196551	31.58598806	32.8816981
2.915966387	9.322184131	29.30177417	30.48933776
3.012605042	8.899573626	27.2189649	28.30580629
3.109243697	8.503155369	25.31945028	26.31316706
3.205882353	8.130922616	23.58626912	24.49437741
3.302521008	7.781050013	22.00372548	22.83348367
3.399159664	7.451874675	20.55742417	21.31571829
3.495798319	7.141879514	19.23425157	19.9275276
3.592436975	6.849678516	18.02232156	18.65655221
3.68907563	6.574003721	16.91090051	17.49157681

Distance (m)	Flux Calm (kW/m²)	Flux Typical day (kW/m²)	Flux Severe (kW/m²)
3.785714286	6.31369366	15.89032159	16.42246131
3.882352941	6.067683092	14.95189506	15.44006231
3.978991597	5.834993855	14.0878191	14.5361508
4.075630252	5.614726705	13.29109415	13.70333014
4.172268908	5.40605402	12.55544229	12.93495699
4.268907563	5.208213265	11.87523273	12.22506678
4.365546218	5.020501134	11.24541358	11.5683045
4.462184874	4.84226828	10.66145004	10.9598613
4.558823529	4.672914579	10.11926867	10.39541677
4.655462185	4.511884858	9.615207479	9.871086938
4.75210084	4.358665042	9.145971229	9.383377403
4.848739496	4.212778671	8.708591719	8.929141497
4.945378151	4.073783749	8.300392385	8.505542878
5.042016807	3.941269887	7.918956887	8.110022222
5.138655462	3.814855717	7.562101214	7.740267594
5.235294118	3.694186538	7.227848955	7.394188116
5.331932773	3.578932179	6.914409346	7.069890583
5.428571429	3.468785052	6.620157811	6.765658688
5.525210084	3.363458383	6.343618682	6.479934587
5.621848739	3.26268459	6.083449872	6.211302514
5.718487395	3.166213813	5.838429241	5.95847423
5.81512605	3.073812562	5.607442496	5.720276082
5.911764706	2.985262483	5.389472408	5.495637489
6.008403361	2.900359233	5.183589221	5.283580693
6.105042017	2.81891144	4.988942098	5.083211625
6.201680672	2.740739761	4.804751485	4.89371176
6.298319328	2.665676005	4.630302299	4.714330842
6.394957983	2.593562334	4.464937832	4.544380382
6.491596639	2.524250534	4.308054292	4.383227846
6.588235294	2.457601327	4.159095915	4.230291443
6.68487395	2.39348376	4.017550577	4.085035457
6.781512605	2.331774621	3.882945855	3.946966057
6.878151261	2.272357914	3.754845484	3.815627524
6.974789916	2.215124371	3.632846165	3.690598873
7.071428571	2.159970996	3.516574694	3.57149079
7.168067227	2.106800653	3.405685364	3.45794289
7.264705882	2.055521676	3.299857627	3.349621227
7.361344538	2.006047513	3.19879397	3.246216054
7.457983193	1.958296397	3.102218001	3.14743979
7.554621849	1.912191033	3.009872711	3.053025183
7.651260504	1.867658323	2.921518893	2.962723644
7.74789916	1.824629093	2.836933713	2.876303731
7.844537815	1.783037851	2.755909407	2.793549778

Distance (m)	Flux Calm (kW/m²)	Flux Typical day (kW/m²)	Flux Severe (kW/m²)
7.941176471	1.742822562	2.678252096	2.714260643
8.037815126	1.703924432	2.603780704	2.638248568
8.134453782	1.666287711	2.532325977	2.565338148
8.231092437	1.629859511	2.463729579	2.495365376
8.327731092	1.594589635	2.397843275	2.428176786
8.424369748	1.560430416	2.334528176	2.36362866
8.521008403	1.52733657	2.273654054	2.301586304
8.617647059	1.495265054	2.215098707	2.24192339
8.714285714	1.464174941	2.158747386	2.184521345
8.81092437	1.434027294	2.104492258	2.129268794
8.907563025	1.404785056	2.052231925	2.076061054
9.004201681	1.376412944	2.001870967	2.024799657
9.100840336	1.348877347	1.953319534	1.975391922
9.197478992	1.322146237	1.906492966	1.927750555
9.294117647	1.296189078	1.861311438	1.881793284
9.390756303	1.270976747	1.817699639	1.837442515
9.487394958	1.246481459	1.775586469	1.794625028
9.584033613	1.22267669	1.734904769	1.753271681
9.680672269	1.199537116	1.695591058	1.713317144
9.777310924	1.177038544	1.6575853	1.674699658
9.87394958	1.155157856	1.620830686	1.637360798
9.970588235	1.133872953	1.585273423	1.601245266
10.06722689	1.113162701	1.550862555	1.566300694
10.16386555	1.093006881	1.517549781	1.53247746
10.2605042	1.073386145	1.485289293	1.49972852
10.35714286	1.05428197	1.454037628	1.468009248
10.45378151	1.035676618	1.423753521	1.437277293
10.55042017	1.017553094	1.394397779	1.407492441
10.64705882	0.999895114	1.365933158	1.378616485
10.74369748	0.982687066	1.338324246	1.350613114
10.84033613	0.96591398	1.311537358	1.323447795
10.93697479	0.949561495	1.285540439	1.297087674
11.03361345	0.933615832	1.260302969	1.271501479
11.1302521	0.918063765	1.235795874	1.24665943
11.22689076	0.902892594	1.21199145	1.222533157
11.32352941	0.888090122	1.188863285	1.199095617
11.42016807	0.873644631	1.166386185	1.176321025
11.51680672	0.859544859	1.144536113	1.154184782
11.61344538	0.845779981	1.123290121	1.132663411
11.71008403	0.832339588	1.102626296	1.111734501
11.80672269	0.819213666	1.082523701	1.091376641
11.90336134	0.806392582	1.062962327	1.071569376
12	0.793867066	1.043923044	1.052293152

Appendix H – FRNSW correspondence

OFFICIAL

NSW GOVERNMENT | FIRE + RESCUE

File Ref. No: FRN21/2654 BFS25/7204 8000045767
TRIM Doc. No: D25/125860
Contact: Station Officer Chris Naisby

23 October 2025

ANTHONY YEATES
AMPYR Australia Pty Ltd
L17 167 Macquarie Street
SYDNEY NSW 2000

Dear Anthony,

Re: Review of Fire Safety Study (FSS) – WELLINGTON SOUTH BESS – 6773 GOOLMA ROAD WUULUMAN NSW 2820
Fire and Rescue NSW (FRNSW) acknowledge correspondence received on the 14 October 2025 requesting review of the submitted FSS for WELLINGTON SOUTH BESS – 6773 GOOLMA ROAD WUULUMAN NSW 2820. FRNSW note the FSS was to be developed to the satisfaction of FRNSW and in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2[i].

FRNSW acknowledge previous correspondence regarding this matter. FRNSW have reviewed the updated FSS prepared by Fire Risk Consultants. The current version of the FSS (V2.5) has been **prepared to the satisfaction of FRNSW.**

Additionally:

1. All relevant stakeholders, including as a minimum the owner, operator and insurers, need to be made aware of the following:
   a. In the event of a significant fire involving a BESS unit, FRNSW may be unable to intervene given the hazards associated with the BESS, including potential electricity risks, explosion potential, toxic gases, etc.
   b. In the event FRNSW are required to respond to an incident, there is the potential that incidents involving BESS units can be protracted.
2. FRNSW note that a potential incident at a BESS facility may be deemed a “hazardous material incident” in accordance with Section 3 of the Fire and Rescue NSW Act 1989 No 192.

For further information please contact the Fire Safety Liaison Unit, referencing FRNSW file number BFS25/7204. Please ensure that all correspondence in relation to this matter is submitted electronically to firesafety@fire.nsw.gov.au.

Yours sincerely,

Superintendent James O’Carroll
Manager
Fire Safety Liaison Unit

Cc: anthony.yeates@ampyrenergy.com

[i] https://www.planning.nsw.gov.au/sites/default/files/2023-03/hazardous-and-offensive-planning-advisory-paper-no-2-fire-safety-study-guidelines.pdf

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