Technical Appendix 1.3: Proposed Battery Energy Storage System

Introduction

1.1 This Technical Appendix has been prepared to provide more detailed information on the battery energy storage system (BESS) element of the Proposed Development.

What is Energy Storage?

1.2 Battery Energy storage systems (BESS) have been identified as an effective method for storing energy in moments of oversupply and releasing energy back into the grid during times of high demand. As well as this energy storage systems are used to maintain grid frequency within normal operating limits. In Northern Ireland, existing Battery Energy Storage Systems (BESS) such as Castlereagh Storage Unit, Kells Battery Storage and Kilroot Battery already enhance the grid significantly. However, more battery installations are required as part of grid modernization efforts.

1.3 The Proposed Development includes 20 no. energy storage containers The battery enclosures will be one of two types depending on the final choice of supplier, maximum dimensions of which are outlined in **Figure 1.9.** The first type are simply modified ISO -style shipping containers set on concrete foundations, with typical dimensions of 6.1m long, 2.4m wide and 2.9m high. Heating Ventilation & Air Conditioning (HVAC) units are located at each end of each container. The enclosures are generally finished in a shade of white or grey. The second type are modular battery enclosures, also set on concrete foundations, which are 'packed' together to form similar dimensions to that of the enclosure mentioned above. These modular battery storage enclosures typically have a white or grey finish.

1.4 Accompanying the battery storage containers are 4 Power Conversion Systems and 4 Transformers which require a typical combine dimension of 10.3m long, 6m wide and 2.5m high. These would also be set on concrete block foundations and would be finished in a shade of white or grey.

1.5 A small substation building/Control Room would be required, with maximum dimensions measuring 10.5m long, 6m wide and 6m high, as shown in **Figure 1.9.**

1.6 Various other associated equipment would include:

- harmonic filter
- A pre insertion resistor

- capacitor bank
- Spares Container
- Security fencing
- Lighting/CCTV columns

1.7 According to SONI statistics, the electricity demand in Northern Ireland varies significantly day to day, for instance during 2018 the lowest demand ranged from as low as 437MW to as high as 1648 MW. Therefore, power generation and the grid must deal with large transitions between lows and highs, not only over the course of a day or week but second by second. One of the basic roles of energy storage is to act as a power reserve for when electricity generation drops below demand. Its importance then is linked to its ability to ensure a constant supply of electrical energy to our homes and business. That improves efficiency and reduces prices for consumers.

1.8 Battery energy storage can absorb energy at times of high generation and low demand, and release energy at times of peak demand. Customers offering Energy Storage Services (ESS) therefore have the potential of deferring network reinforcement and accommodating the connection of further demand or generation which would otherwise be constrained by thermal capacity. BESS can also play in the System Services market helping to balance demand and generation.

The Need for Energy Storage – Why is it Important?

1.9 The Proposed Development is intended to be used to provide cost effective flexible services to the electricity network, such as adding electricity to, or removing electricity from the system, when this is useful to the operation of the system. SONI, the System Operator in charge of ensuring stable secure power for the island's homes and businesses, procures such services from grid connected energy systems and the flexibility they provide is critical to achieving national decarbonisation targets and a stable supply of electricity at least cost to consumers.

1.10 According to SONI statistics, the electricity demand in Northern Ireland varies significantly day to day, for instance during 2018 the lowest demand ranged from as low as 437MW to as high as 1648 MW. Therefore, power generation and the grid must deal with large transitions between lows and highs, not only over the course of a day or week but second by second. One of the basic roles of energy storage is to act as a power reserve for when electricity generation drops below demand. Its importance then is linked to its ability to ensure a constant supply of electrical energy to our homes and business. That improves efficiency and reduces prices for consumers.

RG9 - Reduce our carbon footprint and facilitate mitigation and adaptation to climate change whilst improving air quality "Climate change is increasingly seen as one of the most serious problems facing the world. Air pollution from particulate matter is currently estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months, it is important that Northern Ireland plays its part by reducing air pollution and greenhouse gas emissions and preparing for the impacts of climate change. These include the effects on species and habitats and on health as a result of warmer temperatures, storms, floods and coastal erosion."

1.11 Energy provision in Northern Ireland is undergoing a transition from one designed primarily around a number of large thermal power stations such as Kilroot, Ballylumford and Coolkeeragh, to one which now includes a number of renewable generators such as wind farms. Renewable generation is now supplying over 40% of the total annual electrical requirement in Northern Ireland. With the recent announcement by the Department for the Economy (DfE) that the Renewable Energy target for Northern Ireland will be 70% by 2030, this transition will be even more important.

1.12 There are, however, technical constraints on the transmission network which are limiting the amount of renewable energy which can be delivered from these renewable generators to the main demand centres in the east of the province.

1.13 Energy Storage is an innovative solution, which is being deployed across the world, to facilitate the shift from traditional thermal generation to low/zero carbon generation. The energy storage containers will help match generation produced from intermittent renewable generation with the peaks and troughs in electricity demand.

In SONI's "Shaping Our Electricity Future Roadmap Version 1.1" key message 3 reads "The scale of the challenge is without precedent. Whilst EirGrid and SONI have an important role to play, the entire electricity ecosystem also needs to deliver." Following this statement the report outlines a non-exhaustive list of deliverables, one of which reads the following: "Delivery of enabling solutions such as sources of system flexibility, demand side management, long duration storage, low carbon technologies amongst others". Key message 10 of the report also gives mention to the need for energy storage on the network: "The Roadmap recognises the strategic deployment of energy storage technologies in constrained regions of the network." The report also predicts a scenario where 625MW of energy storage is required on the network by the year 2030. Systems such as this proposal help in reaching these quantities of energy storage on the system.

1.14 The proposal provides an opportunity to support innovative technology, contribute towards renewable energy targets, ensure a secure electricity supply to its population and play its part in reducing electricity costs for consumers.

1.15 In particular, the Proposed Development will deliver frequency response service to enable the necessary balancing of the emerging low carbon electricity system. The need for battery energy storage systems has been identified by SONI under their DS3 programme. The frequency at which the electricity system operates is an indication of the balance between supply and demand and a failure to maintain this frequency within strict boundaries would lead to catastrophic system failure and blackouts. Normally, the system runs at a frequency of 50Hz. If there is not enough supply to meet demand the frequency drops below 50Hz. If there is too much supply for the current demand, the frequency rises above 50Hz. The Proposed Development will be able to respond within a fraction of a second to frequency deviations away from 50Hz (by increasing supply or demand as appropriate) to help keep the system in balance.

1.16 The energy storage element of the Proposed Development would also provide distribution, reinforcement and deferral services. These enable existing electrical network assets such as substations and overhead lines to have their capacity increased without the need for building new infrastructure. All of these uses of the Proposed Development involve charging the battery system with electricity, storing electricity for a period, or discharging electricity. The Proposed Development will make a valuable contribution to Ireland’s secure, low carbon and affordable electricity system.

Scope of Assessment

1.17 This Technical Appendix should be read in conjunction with Volume 1 to Volume 4 of the Mullaghclogher Environmental Statement. The assessment of the Proposed Development is based mainly on a study area within the site boundary.

1.18 The aim of the EIA is to describe and assess the potential effects upon various receptors within the site and the wider environment as applicable.

1.19 Identification and evaluation of the likely significance of effect associated with the BESS element of the Proposed Development during Construction, Operation and Decommissioning phases and the recommendation of appropriate mitigation measures to avoid and or reduce the predicted adverse effects of the Proposed BESS.

Assessment Methodology

1.20 The study methodology includes both desktop and field survey methods in order to assess the potential impact of the proposed BESS on the receiving environment. Volume 2 of the Environmental Statement outlines in detail how the Proposed Development including the BESS development avoids all areas of interest where possible.

Key Terminology and Assessment Criteria

1.21 The following terms and assessment criteria form the basis for the assessment and are summarised below for ease of reference.

Significance of effects

1.22 The importance or value for appraisal of level of importance is set out in Table 1 below, in order to inform this process.

Table 1: Criteria for appraisal of level of importance

Importance / value	Description
Very High	The receptor has a high quality and has no capacity to accommodate change. The receptor is of very high importance and is international in scale.
High	The receptor has a high quality and limited capacity to accommodate change. The receptor has key characteristics which contribute to the character and is of high importance that is international in scale.
Medium	The receptor has limited capacity to accommodate change. The receptor has characteristics which contribute to the character and is of medium importance that is international in scale.
Low	The receptor has moderate capacity to accommodate change. The receptor has characteristics which are locally distinctive and are of low to medium importance. They can be potentially substituted or replaced.
No importance	The receptor is generally tolerant of and can accommodate change. The receptor has characteristics do not make a significant contribution to local character and are of very low importance, they are easily substituted and replaced

Assessment of effects

1.23 To ensure the planning balance is appropriately informed, where an adverse effect is identified, it will be categorised as either Major Adverse, Moderate Adverse, Minor Adverse or Slight Adverse. Where effects would not be adverse these will be categorised as either Negligible or as resulting in no change. This spectrum of effects is summarised in Tables 2 & 3, below, along with brief descriptions of the terms used.

1.24 Assessments of the level of effect on the significance is based upon the extent to which factors that contribute to the significance of the proposed development. This process is not quantitative but relies upon professional judgement at each step. However, the factors considered in informing these judgments and in arriving at the various rankings of value and magnitudes of impacts are observable facts.

Table 2: Significance of impacts	
Level of effect	Description
Major Adverse	Loss of resource and or integrity of the resource, severe damage to key characteristics, features or elements. Permanent or irreplaceable change which is certain to occur.
Moderate Adverse	Loss of resource but not affecting the integrity of the resources, partial loss of or damage to key characteristics, features or elements. Permanent or irreplaceable change which is likely to occur.
Minor Adverse	Minor loss of, or alteration to the site. Long term though reversible change which is likely to occur.
Slight Adverse	Very Minor loss of, or alteration to the site. Short to medium term though reversible change may possibly occur.
Negligible	Temporary or intermittent, very minor loss of or alteration to the site, short term impact which is unlikely to occur.
No Impact	No change

1.25 The categories of significance of effect are not meant to be prescriptive but are rather meant to allow the professional judgement of the assessor to be articulated clearly and consistently across different types of effects. In recognition of this, where there are two options within a category of significance of effect, the assessor will provide evidence for one or the other of the options. Ultimately, the most appropriate categorisation of the significance of effect must be chosen, using professional judgement which is informed by a thorough understanding of the significance and the nature of the effect.

1.26 Where the significance of effect is assessed as being Moderate or higher, this is considered to be a significant effect as referred to in the Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 2017.

Table 3: Criteria for determining significance of effect					
Level of Importance	Degree of adverse effect				
	Major	Moderate	Minor	Slight	Negligible
Very High	Very Large	Large	Moderate / Large	Minor	Negligible
High	Large	Moderate / Large	Moderate/ Minor	Minor	Negligible
Medium	Moderate / Large	Moderate/ Minor	Minor	Slight	Negligible
Low	Moderate/ Minor	Minor	Slight	Negligible	Negligible

The Proposed BESS

1.27 The proposed design of the battery containers is a low-key containerised scheme involving lithium-ion battery technology which has already been deployed on multiple projects across the UK & Ireland. The containerised energy storage element of the proposed development consists of 20 no. battery containers (up to 100 megawatt hours (MWh) provided), with a maximum export capacity (MEC) of 30 megawatts (MW), with ancillary heating, ventilation and air conditioning (HVAC) units, corresponding power conversion systems (PCS), spares container and auxiliary transformer. These are all housed on an area of hardstanding and enclosed within a compound by appropriate fencing. The containers will be connected by an underground cable to the Mullaghclogher substation contained within the Proposed Development.

1.28 Lithium batteries are required to store the electricity. The table below outlines the typical quantities for the battery storage.

Table 4: Typical quantities for the battery storage

Chemical Composition of Typical Battery Storage		**Approx. per Module (%)**	**Approx. Weight per Module (Kgs)**	**Approx. Weight per Container (Kgs)**
Steel		30	40	6,000
Cell	Lithium Iron Phosphate	23	31	4,650
	Carbon as Graphite	10	13	1,950
	Aluminium as Metal	9	12	1,800
	Copper Metal	9	12	1,800
Separator	Polyolefin	1	1.5	225
Electrolyte	Ethylene Carbonate	15	20	3,000
	Dimethyl Carbonate			
	Ethyl ethyl carbonate			
	Lithium Hexafluorophate			
Connectors	Copper	2	3	450
Screw	Iron (III) Oxide Dihydrate	1	1.5	225
Total Weight				20,100

The type and quantities of chemicals used for the batteries do not fall within the Schedule listed within the Planning (Hazardous Substances) Regulations (NI) 2015 and therefore do not require Hazardous Substance Consent.

1.29 The Control of Major Accident Hazards Regulations 2015 (COMAH) apply to dangerous substances as classified by the Classification, Labelling and Packaging Regulations 2008. Lithium-ion batteries are considered to be articles, rather than substances, and are therefore outside of the scope of the COMAH Regulations.

Construction Phase

1.30 The construction phase will be aligned and incorporated into the general construction of the wind farm. The BESS container area will be constructed at the later part of the overall construction programme as the containers and their compound will be located within an area which will be used as the temporary construction compound for the wind farm.

1.31 The lithium ion batteries will be manufactured off site and will be delivered to site as fully sealed modules. The batteries will be tested to all the required standards including the UL9540A standard (Appendix A).

1.32 The lithium ion batteries will be enclosed in steel ISO shipping containers, designed and manufactured to a bespoke design for lithium-ion batteries. The enclosures will be mounted on concrete foundations with dc cables connecting the batteries to the power conversion systems (changes the electricity from dc to ac) then ac cables connecting the power conversion systems to the substation.

1.33 The compound area would be constructed by laying stone over a geotextile membrane. During the construction phase temporary drainage measures will be installed to control sediment run-off in line with the SUDS measures outlined in Vol 4 Technical Appendix 10 of the ES.

Operational Phase

1.34 The batteries will operate on average for up to 24 hours per day to support the grid network, times of operation will depend on the grid parameters and requirements. There shall be no emissions from the site with the exception of noise from cooling fans and PCS units. All noise associated with the BESS has been assessed in Vol 2 Chapter 11 of the ES with the full technical details supplied in Vol 4 Technical Appendix 11.

Power Conversion Systems and transformer units

1.35 One or more of the battery containers are connected to a PCS and transformer unit, these may be separate pieces of equipment or one combined PCS and transformer. The PCSs are inverters which convert the Direct Current (DC) from the batteries to Alternating Current (AC) when the batteries are exporting electricity into the grid. The system works in reverse when the batteries are being charged or importing electricity from the grid. Power transformers will step up the PCS AC voltage from a low voltage to a higher voltage as required by the electricity grid connection.

Decommissioning

1.36 At the end of life, the battery enclosures, power conversion systems, substation, foundations and cables will be removed from site and appropriately disposed of and recycled where possible.

1.37 The battery modules will be removed from the site fully intact (they are sealed units) and sent for recycling. As part of the battery supply agreement the manufacturer shall have an obligation to take the battery enclosures back to their factory for onward recycling at an approved facility. The battery enclosures, PCS's and cables will be recycled more locally at an authorised metal recycling centre.

Assessment of Effects

1.38 Detailed assessment of effects has been covered in Volume 2 of the Environmental Statement. Climate Change is covered within Chapter 2 (Planning Policy); Biodiversity is covered under Chapters 6 (Vegetation & Peatland),7 (Terrestrial Fauna), 8 (Ornithology), 9 (Fisheries) & 10 (Geology & Water Environment); Human Health is covered under Chapter 11 (Noise). A summary of effects and mitigation is described in Chapter 15.

Human Health

1.39 Human Health is covered under Chapter 11 (Noise Assessment) of the ES which assesses the Cumulative effects of the Proposed Development as a whole.

1.40 The nearest residential dwelling to the BESS is 645m mitigating any risk to local properties or their occupiers.

1.41 The following table provides some details with regards to the potential effects associated with the battery storage along with details of the mitigation measures that will be employed to further reduce the significance of the potential impact:

Table 5: Summary of Effects of the Proposed BESS

Description	Level of importance	Impact Significance without mitigation	Response/Mitigation	Impact Significance with Mitigation
Transportation of harmful substances Will the Project involve use, storage, transport, handling or production of substances or materials which could be harmful to human health or the environment or raise concerns about actual or perceived risks to human health?	Low	Moderate	All battery cells and modules will be manufactured off site and the system will be designed in accordance with IEC 62485-5:2020 (Safety requirements for secondary batteries and battery installations - Part 5: Safe operation of stationary lithium ion batteries). The batteries will be delivered to site as fully sealed modules. Should any battery fail during the lifetime of the project it will not be repaired on site but will be replaced with a new sealed module. The faulty module will be returned to the manufacturer for inspection/ repair or disposed of at an authorised disposal facility.	Negligible
Waste Will the Project produce solid wastes during construction or operation or decommissioning	Low	Moderate/ Minor	No waste will be produced by the batteries during construction or operation or decommissioning apart from the overall battery itself at the end of life, which will be disposed of at an authorised disposal facility. In the event of a fire all wastes will be dealt with appropriately through the procedures agreed within the site specific Fire Management Plan.	Negligible
Air Pollution Will the Project release pollutants or any hazardous, toxic	Low	Moderate	Should an individual cell seriously fail during the lifetime of the project (e.g. go into Thermal Runaway), gases will be	Minor

or noxious substances to air?			released from this cell into the battery container. The battery container has a gas detection and forced fan ventilation system that will vent these vented gases to atmosphere (such as hydrogen, CO_2 and carbon monoxide – all of which are present in the atmosphere). Any of the gases that are released (whether Hydrogens etc will be minimal).	
Designated Sites/ Watercourses Will the Project lead to risks of contamination of land or water from releases of pollutants onto the ground or into surface waters, groundwater, coastal wasters or the sea?	Low	Moderate	The batteries are sealed units. The UL9540A test show that a cell thermal runaway will not propagate beyond the initiating unit or rack, and therefore the amount of potential pollutants will be restricted, limiting any potential impact of contamination of land. In the event of a fire all wastes will be dealt with appropriately through the procedures agreed within the site specific Fire Management Plan.	Minor
Human Health Will there be any risk of accidents during construction or operation of the Project which could affect human health or the environment?	Low	Moderate	The batteries are sealed units which are rigorously tested to withstand external damage (e.g. dropping them). There is only external access to the battery containers, i.e. a person will not be exposed to any potential gases in an enclosed space.	Negligible
Fire Potential for harm to the environment including smoke and toxic gases. Battery fires can potentially give off	Low	Moderate	The batteries are sealed units. The risk of fire spreading to an adjacent battery pack is low as the battery cells will be housed and contained appropriately to mitigate for this. The UL9540A test show that a cell thermal runaway will not propagate	Minor

harmful chemicals or combustion products which may be irritating, corrosive and or toxic and may be harmful to surrounding populations. It is understood that large amounts of hydrogen fluoride (HF) may be generated, ranging between 20 and 200 mg/Wh of nominal battery energy capacity.			beyond the initiating unit or rack, and therefore the amount of potential pollutants will be restricted, limiting any potential impact of contamination of land The BESS will be fitted with a fire detection system comprising of heat and smoke sensors, an extinguishing system. The battery enclosure itself has a fire rating of a minimum of 90 minutes. The fire control panel will have visual and audible alarms which can be seen and heard from outside of the enclosure. The system will be monitored 24 hours a day, 365 days a year from a remote monitoring facility. A fire management response plan will be prepared in conjunction with the battery supplier post consent and the local Fire Service for both the construction and the operational phases, this will outline appropriate measures required to deal with remote monitoring, first response, air quality, firefighting operations, water application and the disposal of any post fire waste reducing the potential environmental hazards. It is acknowledged that there is no clear consensus on the exact quantities of gases such as HF that could be released by a battery fire. Typically, HF is of a concern in enclosed spaces due to toxicity, RES sites are designed as unmanned with external access enclosures meaning it is	

			very unlikely that personnel outside the enclosure would be exposed to HF concentrations high enough to be of concern. The closest property is at a distance of 645 m which further mitigates the potential risk.	
Post Fire Waste	Low	Minor	Cells will be segregated and the burnt cells will be removed from site by a licenced carrier and disposed of in line with the battery manufacturers procedures. All cells will be checked for any residual heat using thermal imagery in order to avoid any further risk of thermal runaway. A fire management response plan will be prepared in conjunction with the battery supplier prior to construction and the local Fire Service for both the construction and the operational phases, this will outline containment measures for firewater and methods which will be implemented to mitigate risk of contamination into groundwater.	Negligible
Receptors Are there existing land uses on or around the location e.g. homes, gardens, other private property, industry, commerce, recreation, public open space, community facilities, agriculture, forestry, tourism, mining or quarrying which	Low	Minor	The nearest residential dwelling to the BESS at Mullaghclogher is 645m mitigating any risk to local properties or their occupiers.	Negligible

could be affected by the project?				
Receptors Are there any areas on or around the location which are occupied by sensitive land uses e.g. hospitals, schools, places of worship, community facilities, which could be affected by the project?	Low	Minor	As stated the nearest residential dwelling to the BESS at Mullaghclogher is approx. 645 mitigating any risk to local properties or their occupiers.	Negligible

Mitigation

1.42 In addition to Table 5 above please also refer to Vol 2 of the ES Chapter 15 which outlines all mitigation measures associated with the Proposed Development.

1.43 The below measures summarise the Fire suppression system which will also be installed as a precautionary measure.

Fire suppression system

1.44 Each battery container is fitted with a fire suppression system, the design of which is based on project specific battery technology and enclosure specifications and will meet industry standards and best practice. In general fire suppression systems are composed of:

i) 2 stage detection system consisting of heat and smoke alarms.

ii) Sequencer or control panel

iii) Sounders and/or alarm bells

iv) Suppressant/extinguishant generator

1.45 The energy storage facility will be continually monitored and controlled via a 24hour offsite control centre.

1.46 The facility will be unmanned during normal operations and the battery container enclosures are externally accessed, therefore no personnel entry is required

Risk

1.47 Thermal Runaway would be the main reason for fires in battery storage projects. The batteries selected for the Mullaghclogher project will be tested in accordance with UL9540A (Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems) and the system will be designed in accordance with IEC 62485-5:2020 (Safety requirements for secondary batteries and battery installations - Part 5: Safe operation of stationary lithium ion batteries), there are multiple mitigation measures in place to prevent thermal runaway on a RES designed BESS. The UL9540A is a widely accepted test standard for evaluating thermal runway for propagation in battery energy storage systems.

Mitigation measures to be employed:

1.48 Critical failure of a battery energy storage system component will result in a shutdown from the network, further to this our BESS have a UPS (Uninterruptable Power Supply) or back up battery in each enclosure ensuring safe shut down of the Batteries and their Battery Management System and the associated PCS even on loss of auxiliary power to the enclosure.

1.49 Should a HVAC system fail on an enclosure the battery system will also include 'Over Temperature Protection' that will enact at a threshold cell temperature well below the Thermal Runaway temperature of the Lithium-ion cells.

1.50 If a cell still reaches a temperature high enough to cause Thermal Runaway despite these multiple layers of protection the system will have been tested to UL9540A standard to show that a battery rack can withstand a forced cell thermal runaway in a way that:

- Explosion hazards are not observed, including deflagration, detonation or accumulation
- No flaming beyond outer dimensions of the initiating Battery Rack, i.e. a fire will be contained within the Rack that has been forced into thermal runaway
- The surface temperature along instrumented wall surfaces around the Battery Rack does not exceed 97 °C above ambient

1.51 The UL9540A test report of our preferred battery supplier (see Appendix A) of the UL9540A shows that all these requirements are passed and in addition a forced thermal runaway of one cell does not cause a thermal propagation to any other cell. This means that the amount of vented gases will be limited to one cell and the fire will be contained within the affected Rack preventing a major fire incident of the entire BESS.

1.52 In the event of a cell failure there may be a minimal amount of gas expelled from the module this would be an airborne gas discharged to atmosphere and no pollution risk to the local area. Any liquid escaping from a cell would again be a very minimal amount and would be contained within the sealed battery unit.

1.53 All RES designed BESS systems utilise battery enclosures with external access only, therefore eliminating the risk of personnel inside the battery enclosure all maintenance is done externally as would any firefighting.

1.54 In addition, our batteries do also comply to the IEC 62619 (Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications) which also contains tests regarding thermal propagation and does not allow any external fire outside of the initiating Battery Rack based on a single cell thermal runaway.

1.55 The nearest residential dwelling to the BESS at Mullaghclogher is 645m mitigating any risk to local properties or their occupiers.

1.56 The IEC 62933-5-2 Standard (Electrical energy storage (EES) systems – Part 5-2: Safety requirements for grid-integrated EES systems – Electrochemical-based systems) safety standard will also typically apply. This IEC 62933-5-2 is a European standard which references the UL9540A for large-scale fire testing on BESS.

1.57 Adherence of all of these Standards will ensure that the appropriate mitigation measures will be in place in order to reduce any unlikely significant impacts resulting from the proposed BESS Development. As previously stated a fire management response plan will be prepared in conjunction with the battery supplier post consent and the local Fire Service.

Conclusion

1.58 In conclusion, the potential effects of the proposed BESS have been assessed, and it has been found that, with the benefit of minimal mitigation measures, the proposed BESS will result in no adverse impacts on the receiving environment.

1.59 The importance of battery energy storage is key to integrating higher levels of renewable energy generation into the grid assisting Northern Ireland in meeting its 2030 renewable energy targets. Energy storage is also a critical in a secure and sustainable supply of energy to homes and businesses. Energy storage projects are part and parcel of a resilient electricity grid. A secure and sustainable grid is of local, regional and national importance.

Appendix A: UL9540A Test Report

Test Report

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

Report Reference No. ....:	200801760SHA-002	
Tested by (name + signature)..........:	Albert Zhou	Albert Zhou ....
Approved by (name + signature)......:	Will Wang	Will Wang ....
Date of issue ....:	2020-10-17	
Total number of pages ....:	50	
Testing Laboratory.........................:	Intertek Testing Services Shanghai	
Address ....:	Building No.86, 1198 Qinzhou Road (North), Shanghai 200233, China	
Applicant's name ....:	Zhejiang Narada ESS Integration& Operation Co., Ltd	
Address ....:	Room 503, Building 1, No.223 Yile Road, Hangzhou, Zhejiang, 310000, P. R. China	
Test specification:		
Standard/or Rule ....:	ANSI/CAN/UL 9540A:2019, Fourth Edition	
Test procedure ....:	Testing	
Non-standard test method…………..:	N/A	
Test Report Form No. ....:	UL9540AA	
TRF Originator ....:	Intertek Shanghai	
Master TRF ....:	Dated 2019-12	

Test item description......................:	Battery cell, module and unit
Trade Mark ....:	NARADA
Manufacturer.....................................:	Hangzhou Narada Motive Power Science&Technology Co., Ltd No.120 Hongda Road, Yuhang Economic Develpment Zone of Yuhang District, Hangzhou, Zhejiang 311100, P.R.China
Model/Type reference.......................:	Cell: FE105A Module: 76.8NESP200 Unit: 76.8NESP200*15pcs
Rating…………………………………..:	Cell: 3.2V, 105Ah Module: 76.8V, 200Ah Unit: 768V, 200Ah (for 76.8NESP200*15pcs) Up to 1500V, 200Ah, Up to 261kWh (for Unit Configuration)

Copy of label

Cell:

Polarity: + Polarity: -

Secondary (Rechargeable) Li-ion Cell

IFpP36/130/240 (FE105A)

3.2VDC, 105Ah, 336Wh

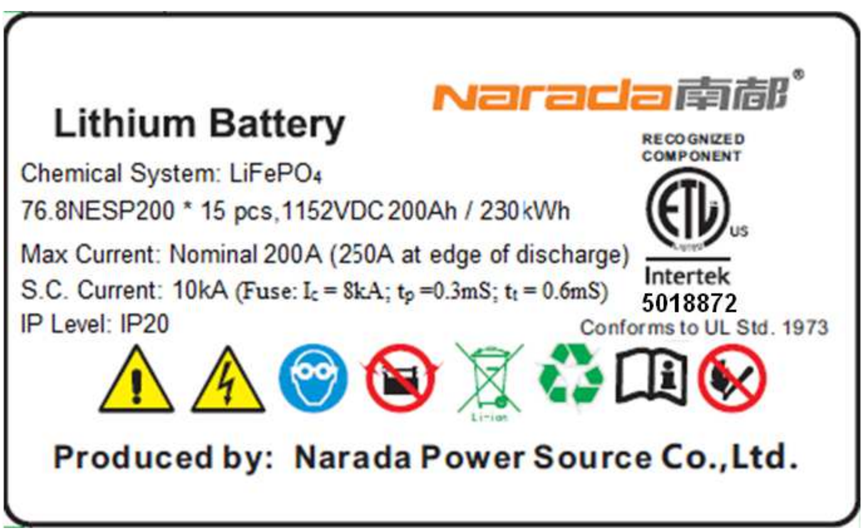
Data of Manufacture: 14th August 2020

Module:

Polarity: + Polarity: -

- Secondary (Rechargeable) Li-ion Battery
- Battery Designation: 76.8NESP200 (24IFpP36/130/240-2)
- Data of Manufacture: dd mm yyyy
- Rated Capacity: 200Ah, 10,240Wh
- Nominal Voltage: 76.8VDC

Unit：



Possible test case verdicts:

- test case does not apply to the test object................: N/A
- test object does meet the requirement......................: P (Pass)
- test object does not meet the requirement................: F (Fail)

Testing ....:

Date of receipt of test item ....: 2020-05-29

Date (s) of performance of tests ....: 2020-05-29 to 2020-09-29

General remarks:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.
Throughout this report a point is used as the decimal separator.

Determination of the test conclusion is based on IEC Guide 115 in consideration of measurement uncertainty.

“Peak smoke release rate and total smoke release data” is achieved by calculation, since Light transmission signal is not accurate when total smoke volume is small.

For Gas Characteristic Test, it is with accordance of ASTM E681 as per requirement of V3 UL9540A, instead of ASTM E918 according to V4 UL9540A, since when apply UL9540A test, Version 4.0 was just released and ASTM E918 test lab is not available.

For Gas Characteristic Test, the result is refer to report < 200101346SHA-003>

For Cell Level Test, the result is refer to report < 200101346SHA-003>

Test results:

Cell Test:

The Cell thermal runaway and test 4 samples；

Module Test:

Initial Cell thermal runaway, and target cell is fine, no thermal propagation;

Not with BMS and Electronics controls

Unit test:

Indoor floor mounted non-residential use BESS

Unit Test: Initial Cell thermal runaway, and target cell is fine; No temperature increase for adjoint racks and walls.

See Annex 6 Diagram and dimensions of the test setup, the testing is conducted under two conditions:

Test condition 1: Testing is in room setup

Test condition 2: The testing is conducted in a container

Total inner height is 2.69m and

The surface of wall is a 75mm thickness 90min fire retarded rock wood and steal plate

9.2.13: The adjacent wall layout depends on end use system design

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Cl.	Requirement + Test	Result – Remark	Verdict
1	**Scope**		-
1.1	The test methodology in this standard determines the capability of a battery technology to undergo thermal runaway and then evaluates the fire and explosion hazard characteristics of those battery energy storage systems that have demonstrated a capability to undergo thermal runaway.		-
2	**Units of Measurement**		-
3	**Normative References**		-
4	**Glossary**		-
5	**General**		P
5.1	**Cell**		P
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report, including cell chemistry (e.g. NMC, LFP), the physical format of the cell (i.e. prismatic, cylindrical, pouch), cell electrical rating in capacity and nominal voltage, the overall dimensions of the cell, and weight.	**Cell chemistry:** LFP **Format of the cell:** Prismatic **Cell rating:** 3.2VDC, 105Ah **Dimension:** 36.3*130.2*239.8mm (with terminals) **Weight:** 2.276kg	P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973.	See clause 7.6.1	P
5.1.3	Refer to 7.6.1 for further details to be included in the cell level test report.		P
5.2	**Module**		P
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report, including the generic (e.g., metallic or nonmetallic) enclosure material, the general layout of the module contents and the electrical configuration of the cells in the modules and the modules in the BESS.	**Generic:** metallic **Enclosure material:** galvanized sheet **General layout of module contents:** See Annex 1 **Electrical configuration:** 2P24S	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973.	See clause 8.3	P
5.2.3	Refer to 8.3 for further details to be included in the module level test report		P
5.3	**Battery energy storage system unit**		P
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540 and include the manufacturer, model, electrical ratings, and energy capacity of all BESS.	See clause 9.7.3	P

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Cl.	Requirement + Test	Result – Remark	Verdict
5.3.2	For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS.	**Number of modules:** 15pcs **Electrical configuration:** 15S1P **Layout of the modules:** See Annex 2 **BMS:** 200500576SHA-001 and 200801759SHA-005 **Major components:** Refer to report 200801758SHA-001	NA
	It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.	UL1973 test report: 200601123SHA-001 UL9540 test report: 200801758SHA-001	P
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report.	Not an integral part	NA
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details to be included in the unit level and if applicable, installation level test reports		P
5.4	**Flow Batteries**	Not flow batteries	NA
5.4.1	For flow batteries, the report will cover the chemistry, a generic description of the electrolyte (s), the overall dimensions of the individual stack as well as the electrical rating in capacity and nominal voltage of the cell stack.		NA
	The report will also include information on the complete flow battery system including the manufacturer's name and model number of the system, the electrical rating in volts and rated storage capacity in Ah or Wh, the number of cells and stacks in the system, and the maximum volume of electrolyte(s) for the system.		NA
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973.		NA
5.4.3	See 7.6.2 for further details to be included in the flow battery thermal runaway determination level test report.		NA
	PERFORMANCE		P
6	**General**		P
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials, exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy.		P
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications. All samples shall be disposed of in accordance with local regulations.		P
7	**Cell Level**		P

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Cl.	Requirement + Test	Result – Remark	Verdict
7.1	**General**		P
7.1.1	This portion of the test establishes effective methods for forcing a cell into thermal runaway in a repeatable manner. These methods shall be used at the module, unit and installation level of testing.		P
	During this portion of the testing, the vent gas composition shall be gathered and analyzed and cell temperatures shall be monitored to determine the temperature when the cell vents and to verify that thermal runaway as defined in this standard, has occurred.		P
7.2	**Sample**		P
7.2.1	Cell samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles using a manufacturer specified methodology to verify that the cells are functional.		P
	Each cycle shall be defined as a charge to 100% SOC and then to an end of discharge voltage (EODV) specified by the cell manufacturer.		P
	During conditioning a relationship between open circuit voltage and SOC shall be determined through measurement of voltage and SOC.		P
	During conditioning the ambient temperature shall be maintained in accordance with the higher of the temperatures derived from 7.3.1.1 or the operating temperature in the cell manufacturer's specifications.		P
7.2.2	The cells to be tested shall be charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.		P
7.2.3	Cells with flexible laminate casings shall be constrained during the test in the manner that simulates the constraint in the BESS module to prevent excessive swelling during the test.		P
7.3	**Determination of thermal runaway methodology**		P
7.3.1	**General**		P
7.3.1.1	Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.		P
7.3.1.2	The propensity of the cell to exhibit thermal runaway shall be demonstrated by heating the cell with externally applied flexible film heaters that cover as much of the cell case as possible without covering safety features or terminals, for consistent heating of the internal cell electrode assembly. A surface heating rate of 4° C (7.2° F) to 7° C (12.6° F) per minute shall be applied to the cell.	Heating cell method used	P
	Determination of a maximum surface temperature end point criteria shall be developed based upon a review of cell design and chemistry.		P
	If external heating with a flexible film heater does not cause the cell to exhibit thermal runaway, one of the following methods shall be employed to cause thermal runaway:	Heating cell caused thermal runaway	N/A
	a) Mechanical (e.g. nail penetration);		N/A

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Cl.	Requirement + Test	Result – Remark	Verdict
	b) Electrical stresses in the form of overcharging, over discharging or external short-circuiting; or		N/A
	c) Use of alternate heating sources (e.g. oven).		N/A
7.3.1.3	With reference to 7.3.1.2, when using another cell abuse method to initiate thermal runaway, the details of that method shall be documented.	Heating cell caused thermal runaway	N/A
	See the Cell Failure Methods Appendix in UL 1973 for various cell abuse test methods that can be utilized.		N/A
7.3.1.4	With reference to 7.3.1.2, in the case of monobloc batteries such as lead acid or nickel cadmium, the monobloc battery can be treated as an individual cell for this testing.	Not monobloc batteries	N/A
7.3.1.5	Before beginning the test, a surface temperature shall be determined to approximate the temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition.		P
	For Li-ion cells, the surface temperature hold point shall be between 5°C (9°F) and 15°C (27°F) greater than the melting temperature of the cell separator material as determined from differential scanning calorimetry (DSC) data of the separator in accordance with UL 2591 (UL 746A).		P
	Thermal runaway may occur before this hold point temperature range is reached.		P
	However, if thermal runaway is not achieved at this hold point temperature after a period of 4 h, the cell heating rate according to 7.3.1.2 shall be reestablished until thermal runaway occurs or it is demonstrated that thermal runaway is not achievable by heating.	Thermal runaway achieved	N/A
7.3.1.6	If the cell is susceptible to thermal runaway by external heating, the cell shall be heated until thermal runaway has occurred.		P
	If the cell is not susceptible to thermal runaway by heating with a film heater, another method included in 7.3.1.2 shall be employed. See 7.3.1.7 – 7.3.1.9.	Heating cell caused thermal runaway	N/A
	If using another external heating method, the temperature ramp and maximum surface temperature outlined in 7.3.1.2 and 7.3.1.5 shall be used.		N/A
7.3.1.7	The cell's exterior surface temperature shall be measured continuously through the cell test with a thermocouple junction formed from 24-gauge or smaller, Type-K thermocouple wire.		P
	The location(s) of thermocouple (s) shall be determined during a construction review.		P
	At least one thermocouple shall be located below the heater film at the center of the cell surface (if the cell is prismatic this would be the center of the wider side of the cell) and one near the positive cell terminals.		P
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise shall be documented.		P
	The thermocouple located below the heater film at the center of the cell surface is used for this measurement.		P

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Cl.	Requirement + Test	Result – Remark	Verdict
	If using the other cell abuse methods, the thermocouples would be located at the same locations on the cells as noted in 7.3.1.7.		P
7.3.1.9	The temperature at the onset of thermal runaway shall be documented.		P
	Onset of thermal runaway shall be determined by the point at which the rate of change of the surface temperature of the cell exceeds that of the externally applied heat input if utilizing the external heater method. As defined in 4.17, thermal runaway is a condition where there is heating of the cell in an uncontrolled manner and should not be confused with overheating leading to venting only.		P
	Cell venting may occur first, but it is necessary to continue heating when using the heater method until thermal runaway occurs.		P
	With other stress methods, it will be necessary to continue applying the stress such as mechanical or electrical stress until onset of thermal runaway occurs.		P
	If there is a transitory temperature dip during the cell venting, the heat input may need to be increased to bring it back to the heating rate range.		P
7.3.1.10	When using methods other than the heater method, the stresses shall be applied to the cell until thermal runaway occurs.		P
	Thermal runaway as defined in 4.17, is considered to have occurred, regardless of the method of stress chosen, when there is a rapid increase in temperature as shown in Figure 7.1 and should not be confused with simple overheating leading to venting.		P
7.3.1.11	If the cell exhibits thermal runaway behavior (using any method), 3 additional samples shall be tested using the same method and exhibit thermal runaway to demonstrate repeatability.		P
	The vent temperature and thermal runaway onset temperatures shall be averaged over the tested samples (excluding the gas vent capture sample).		P
	This average temperature shall be used to establish the temperature limits for the other test levels of this standard.		P
7.3.2	**Flow battery thermal runaway determination tests**	Not Flow battery	NA
7.3.2.1	For flow battery technology, the propensity for thermal runaway shall be demonstrated by testing the energy reservoir according to the test methods of 7.3.2.2 through 7.3.2.6 as applicable to the flow battery technology.		NA
7.3.2.2	The flammability of the electrolytes shall be determined based upon a suitable test method to determine flammability.		NA
7.3.2.3	For flow battery systems with two electrolytes, the flammability of the liquid electrolytes shall be demonstrated by subjecting each electrolyte to the appropriate test method outlined in 7.3.2.2.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
7.3.2.4	The temperature increase possible due to a flow battery failure where there are two electrolytes shall be demonstrated by charging the energy reservoir in a test flow battery assembly to 100% SOC, and then directly mixing the two electrolyte materials in a closed container within approximately 1 min.		NA
7.3.2.5	For flow battery technologies with one active electrolyte containing solid metal particles the appropriate test method of 7.3.2.2 is conducted to determine the flash point temperature.		NA
7.3.2.6	If a flash point has been observed for a flow battery technology with one active electrolyte containing solid metal particles, a test battery representative of the flow battery system shall be subjected to an overcharge test and short circuit test in accordance with UL 1973 while monitoring the temperature of the energy reservoir.		NA
7.4	**Cell vent gas composition test**		P
7.4.1	Cell vent gas shall be generated and captured by forcing a cell into thermal runaway with the methodology developed in 7.3, inside a pressure vessel, which is large enough to accommodate cells, but not so large as to influence measurement of the gas composition.		P
	An 82-L (21.7-gal) pressure vessel is recommended for this purpose for most sizes of commercially available cells.		P
	The test shall be initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume. The initial atmospheric conditions prior to testing shall be noted.		P
7.4.2	Cell vent gas composition shall be determined using Gas Chromatography (GC) with detection techniques for quantifying component gases or equivalent gas analysis techniques, to identify hydrocarbon gases that represent an ignition or explosion hazard as well as other additional gases requested to be measured.		P
	Hydrogen gas shall be measured with a sensor capable of measuring in excess of 30% by volume. The initial atmospheric conditions prior to testing shall be noted.		P
7.4.3	Upon determination of the cell vent gas composition per 7.4.2, the lower flammability limit of the cell vent gas shall be determined on samples of the synthetically replicated gas mixture in accordance with ASTM E918, testing at both ambient and cell vent temperatures		P
7.4.4	The synthetically replicated gas mixture shall be used to determine gas burning velocity in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817.		P
7.4.5	The synthetically replicated gas mixture shall be used to determine Pmax in accordance with EN15967.		P
7.5	**Off gas composition for flow battery systems**	Not flow battery systems	NA

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Cl.	Requirement + Test	Result – Remark	Verdict
7.5.1	The off gas composition from the flow battery testing of 7.3.2 shall be determined by conducting the test method of 7.3.2.2 in a closed container and capturing the off gasses generated, and by collecting the off gasses generated at vent openings and vent ducts during the overcharge and short circuit testing of 7.3.2.4 and 7.3.2.6 as applicable to the flow battery technology. Composition of these captured gases and their flammability limit shall be determined through the methods outlined in 7.4.2 and 7.4.3 at both ambient temperature and the maximum temperature measured.		NA
7.5.2	The volume of flammable gases measured during the testing shall be scaled to the maximum energy reservoir for the intended flow battery system in order to determine the potential total flammable gas that can be produced by the system under a fault condition that leads to off gassing. This information shall be provided in the report.		NA
7.6	**Cell level test report**		P
7.6.1	The report on cell level testing shall include the following:		P
	a) Cell manufacturer name and cell model number	Narada Power Source Co., Ltd. Cell Model: FE105A	P
	b) Cell details		P
	cell chemistry (e.g. NMC, LFP),	LFP	P
	physical format of the cell (i.e. prismatic, cylindrical, pouch	Prismatic	P
	cell electrical rating in capacity and nominal voltage	3.2V, 105AH	P
	overall dimensions of the cell, and weight	2.276kg 36.3*130.2*239.8mm(with terminals)	P
	If comply with UL 1973.	Yes 200601123SHA-001	P
	c) Energy storage technology (and whether UL 9540 compliant);	Yes 200801758SHA-001	P
	d) The rated energy storage capacity of the cell (e.g. Ampere-hours);	3.2V ,105AH	P
	e) Voltage and current obtained during conditioning of the cell;	Charging:3.65V, 105A, Discharging :2.5V, 105A	P
	f) Open-circuit voltage of the cell at initiation of test;	3.385V	P
	G Methods attempted and used to initiate thermal runaway;	Heat	P

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Cl.	Requirement + Test	Result – Remark	Verdict
	h) Surface temperature at which gases are first vented and the average temperature of the samples tested excluding the gas collection sample;	1# 135.5 ℃ 2# 133.2℃ 3#130.9℃ 4#124.4℃ average temperature：131.0℃	P
	I Surface temperature (and location of maximum temperature) prior to thermal runaway and average temperature of the samples tested excluding the gas collection sample;	1# 185.7℃ 2# 161.5℃ 3#192.2℃ 4#145.9℃ average temperature：171.3℃	P
	j) Flammable gas generation and composition measurements	1.55m3 Appended Tables 7.4	P
	k) The lower flammability limit of the cell vent gas;	3.45% (LEL)	P
	l) Burning velocity of the cell vent gas; and	142.216MPa/s (Maximum explosive pressure rising speed)	P
	m) Pmax of the cell vent gas.	Venting Pressure 1# 0.11725 MPa 2# 0.11725 MPa 3# 0.11575 MPa 4# 0.11225MPa Average Pmax：0.11563Mpa Explosion Pressure Pmax：0.733MPa	P
7.7	**Performance – cell level test**		NA
7.7.1	Module level testing in Section 8 is not required if the following performance conditions are met:		NA
	a) Thermal runaway cannot be induced in the cell; and		P
	b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.	Vent gas is flammable	N/A
7.7.2	BESS that contain cells that all comply with the criteria in 7.7.1 shall be suitable for installation in residential dwelling units.		NA
7.8	**Performance – flow battery thermal runaway determination tests**	Not flow battery	NA
7.8.1	For flow batteries, no further testing is required if the following performance conditions are met during the flow battery thermal runaway determination test:		NA
	a) The electrolyte(s) subjected to the test method in accordance with 7.3.2.2 does not ignite; or		NA
	b) The flash point temperature(s) measured in the test of 7.3.2.2 exceed the maximum temperature measured on the energy reservoir during the overcharge and short circuit tests of 7.3.2.4 or 7.3.2.6 by at least 5°C (9°F); and		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
	c) The flash point temperature(s) measured in the test of 7.3.2.2 exceed the maximum temperature of the mixed solution measured in accordance with 7.3.2.4 by at least 5°C (9°F) for systems with two active electrolytes.		NA
7.8.2	Flammable off gassing during the abnormal tests are addressed as outlined in 7.5.2 by scaling the results in accordance with the largest anticipated flow battery energy reservoir.		NA
8	**Module Level**		P
8.1	**Sample**		P
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, to verify that the module is functional.		P
	Each cycle shall be defined as a charge to 100% SOC and allowed to rest a maximum of 8 h and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer.		P
	During conditioning the ambient temperature and conditions shall be maintained in accordance with 8.2.1.		P
8.1.2	The module to be tested shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test.		P
	The module voltage shall be determined by measuring at the module terminals after charging up to the fully charged condition and before beginning testing.		P
	The sample module shall stabilize for a minimum of one hour prior to testing.		P
8.1.3	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	Not with BMS and Electronics controls	P
8.2	**Test method**		P
8.2.1	Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.	25 ±5°C， 50 ±25% RH	P
8.2.2	The test shall be conducted under a smoke collection hood that is sized appropriately to collect the gasses generated from the module.		P
8.2.3	The weight of the module shall be recorded before and after testing is completed to determine weight loss.		P
8.2.4	The number of cells within the module that are forced into thermal runaway can be one or multiple cells, and is dependent upon the energy contained within the individual cells. A sufficient number of cells shall be forced into thermal runaway to create a condition of cell to cell propagation within the module.		P
	For example, it may be necessary to force nine, 3-Ah cells into thermal runaway as opposed to one, 30-Ah cell in order to get cell to cell propagation.	Energy is big enough for one cell	P

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Cl.	Requirement + Test	Result – Remark	Verdict
	The location of the cell (s) forced into thermal runaway shall be selected to present the greatest thermal exposure to adjacent cells that are not forced into thermal runaway.		P
	Factors to be taken into consideration shall include selecting locations within the module where heat transfer is maximized to other cells, cooling by ventilation is restricted or limited, and thermal sensors, detection and suppression discharge points are remote.		P
8.2.5	The methodology used for initiating thermal runaway pursuant to 7.2 shall be used to initiate thermal runaway within the module.		P
8.2.6	With reference to 8.2.5, occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway, as determined in Section 7.		P
8.2.7	The module shall be placed on top of a noncombustible horizontal surface with the module orientation representative of its intended final installation.		P
8.2.8	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry.		P
8.2.9	The chemical heat release rate shall be measured for the duration of the test. See 8.2.10.		P
8.2.10	The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.		P
	The instrumentation shall be located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices. See 8.2.11.		P
8.2.11	With reference to 8.2.10, calculate the chemical heat release rate at each of the flows as follows:		P
	$HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}} \right] \times \frac{\dot{m}_e}{1 + \varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$		P
8.2.12	Vent gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer, and velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.		P
8.2.13	The hydrocarbon content of the vent gas shall be measure using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.		P
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter shall be measured using a white light source and photo detector for the duration of the test, and the smoke release rate shall be calculated. See 8.2.15.		P

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Cl.	Requirement + Test	Result – Remark	Verdict
8.2.15	Smoke release rate shall be calculated as follows:		P
	$SRR = 2.303\left(\frac{V}{D}\right)Log_{10}\left(\frac{I_o}{I}\right)$		P
8.3	**Module level test report**		P
	a) Module manufacturer name and model number (and whether UL 1973 compliant);	Narada, 76.8NESP200 200601123SHA-001	P
	b) Number of cells in module;	48 pcs	P
	c) Module configuration with cells in series and parallel	2 parallel 24 series	P
	d) Module construction features per 5.2;		
	e) Module voltage corresponding to the tested SOC	100%SOC 86.4V	P
	f) Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway;	Heating; 1 Cell; Detail in Annex 3	P
	g) Heat release rate versus time data;	Appended Curve 8.3	P
	h) Flammable gas generation and composition data	Appended Tables 8.3	P
	i) Peak smoke release rate and total smoke release data.	0.018m^2/s based on 1m* 2m; 1.768m^3 (flammable gas according to 8.3 h))	P
	j) Observation(s) of flying debris or explosive discharge of gases	No flying debris or explosive discharge of gases	P
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	No sparks, electrical arcs, or other electrical events;	P
	l) Identification/location of cells(s) that exhibited thermal runaway within the module		P
	m) Locations and visual estimations of flame extension and duration from the module shall be documented	No Flame extension	P
	n) Module weight loss based on measurements per 8.2.3; and	0.836kg	P
	o) Video of the test		P
8.4	**Performance at module level testing**		NA
	Unit level testing in Section 9 is not required if the following performance conditions are met during the module level test:		NA
	a) Thermal runaway is contained by module design; and	No thermal propagation, but vented gas spill out of module enclosure	NA
	b) Cell vent gas is nonflammable as determined by the cell level test.		NA
9	**Unit Level**		P
9.1	**Sample and test configuration**		P
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section.		P

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Cl.	Requirement + Test	Result – Remark	Verdict
	Test configurations include the following:		P
	a) Indoor floor mounted non-residential use BESS;		P
	b) Indoor floor mounted residential use BESS;		NA
	c) Outdoor ground mounted non-residential use BESS;		NA
	d) Outdoor ground mounted residential use BESS;		NA
	e) Indoor wall mounted non-residential use BESS;		NA
	f) Indoor wall mounted residential use BESS;		NA
	g) Outdoor wall mounted non-residential use BESS;		NA
	h) Outdoor wall mounted residential use BESS; and		NA
	i) Rooftop and open garage non-residential use BESS installations.		NA
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation.		P
	Tests conducted for indoor floor mounted installations shall be considered representative of both indoor floor mounted and outdoor ground mounted installations with fire propagation hazards and separation distances between initiating and target units representative of the installation.	Test condition 1	P
	Tests shall be conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.	Test condition 1	P
	The results of such tests shall be considered to also represent an outdoor installation. Examples of potential test configurations.	Test condition 1	P
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:	Test condition 1	P
	a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph;	Test condition 1	P
	b) The temperature range is within 10°C to 40°C (50°F to 104°F);	Test condition 1	P
	c) The humidity is < 90% RH;	Test condition 1	P
	d) There is sufficient light to observe the testing;	Test condition 1	P
	e) There is no precipitation during the testing;	Test condition 1	P
	f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and	Test condition 1	P
	g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.	Test condition 1	P
9.1.3	Depending upon the configuration and design of the BESS, this testing to determine fire characterization can be done at the battery system level.		P

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Cl.	Requirement + Test	Result – Remark	Verdict
	The suitability of this approach shall be determined based upon the overall design of the BESS and an analysis of the battery system as representative of the overall BESS for fire characterization concerns.		P
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.		P
	Combustible components that interconnect the initiating and target BESS units shall be included.		P
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.		P
	The target BESS unit module enclosures do not need to contain cells.		P
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC), in accordance with the manufacturer's specifications, for conducting the tests in this standard.		P
	After charging and prior to testing, the initiating BESS shall rest for a maximum period of 8 h at room ambient.		P
9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT.	No fire suppression	NA
	If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.		NA
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.	No such BMS	NA
	This does not include a fire suppression control in accordance with UL 840 that is external to the BESS, but provided as part of an integral fire suppression system per 9.1.7.		NA
9.2	**Test method – Indoor floor mounted BESS units**		P
9.2.1	Samples and test configurations are in accordance with 9.1.		P
	During the test, the test room environment shall be controlled to prevent drafts that may affect test results. At the start of the test, the room ambient temperature shall not be less than 10°C (50°F) nor more than 32°C (90°F).		P
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed, latched and locked at the beginning and duration of the test.		P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.		P
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		P
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Test condition 1	P

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Cl.	Requirement + Test	Result – Remark	Verdict
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	Test condition 1	P
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		P
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test, and the smoke release rate shall be calculated as described in 8.2.15.		P
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively.		P
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated using an atomized heptane diffusion burner. The calibration shall be performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		P
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct. See 9.2.12.		P
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$		P
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation as noted in 9.1.	Test condition 1	P
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and	Test condition 1	P
	b) Adjacent BESS units.	Test condition 1	P
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction.		P
	If the intended installation is composed completely of noncombustible construction in which wall assemblies, cables, wiring and any other combustible materials are not to be present in the BESS installation, then the report should note that the installation shall contain no combustible construction and that surface temperature rises can be deemed not applicable.		P
9.2.16	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples.		P

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Cl.	Requirement + Test	Result – Remark	Verdict
	The thermocouples for measuring the temperature on wall surfaces shall be horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure from the initiating BESS unit.		P
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires.		P
	The thermocouple tip shall be depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and held in thermal contact with the surface at that point by the use of pressure-sensitive paper tape.		P
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:		P
	a) Both are collinear with the vertical thermocouple array;		P
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		P
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		P
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		P
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		P
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned at the mid height of the initiating unit in the center of the accessible means of egress.		P
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.		P
	Each non-initiating module enclosure within the initiating BESS unit shall be 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.		P
	Additional thermocouples shall be placed to account for convoluted enclosure interior geometries.		P
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
	The cheesecloth shall be untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.		NA
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:		P
	a) The position of the module shall be selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test; and		P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test (Section 8).		P
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct.		P
	Gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		P
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection.		P
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;		P
	b) The fire propagates to adjacent units or to adjacent walls; or		P
	c) A condition hazardous to test staff or the test facility requires mitigation.		P
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.		NA
9.3	**Test method – Outdoor ground mounted units**		NA
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2.		NA
	If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		NA
9.3.2	Outdoor ground mounted residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2 except as noted in 9.3.3 and 9.3.4.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
	Heat flux measurements for the accessible means of egress shall be measured in accordance with 9.2.20. If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		NA
9.3.3	Test samples shall be installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.2).		NA
	The sample shall be mounted on a support substrate and spaced from the wall in accordance with the minimum separation distances specified by the manufacturer.		NA
	The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black.		NA
	The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units.		NA
	The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.2.		NA
9.3.4	Target BESS shall be installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications.		NA
	The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		NA
9.4	**Test Method – Indoor wall mounted units**		NA
9.4.1	Testing of indoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.3.		NA
9.4.2	The test shall be conducted in a standard NFPA 286 fire test room, 3.66 × 2.44 × 2.44-m (12 × 8 × 8-ft) high, with a 0.76 × 2.13-m (2-1/2 × 7-ft) high opening. The room shall be constructed with 16-mm (5/8-in) gypsum wall board installed on wood studs and painted flat black.		NA
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening, with the center located 1.22-m (4-ft) above the floor, and halfway between adjacent walls.		NA
9.4.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS.		NA
	The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		NA
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
9.4.6	The gas collection methods shall be in accordance with 9.2. For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.		NA
9.4.7	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		NA
	The cheesecloth shall be 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.		NA
9.5	**Test Method – Outdoor wall mounted units**		NA
9.5.1	Testing of outdoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.4.		NA
	If intended for outdoor use only wall mount installations, the smoke release rate, the convective and chemical heat release rate; and the content, velocity and temperature of the released vent gases need not be measured.		NA
9.5.2	Test samples shall be mounted on an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.4). The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black.		NA
	The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units. The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.4.		NA
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 1.22-m (4-ft) above the floor, and halfway between wall edges.		NA
9.5.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS.		NA
	The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		NA
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		NA
9.5.6	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		NA
	The cheesecloth shall be untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm2 (1 in2) area.		NA
9.6	**Rooftop and open garage installations**		NA
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations shall be in accordance with 9.2.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
9.6.2	If intended for rooftop and open garage use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		NA
9.7	**Unit level test report**		P
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P
	a) Indoor floor mounted non-residential use BESS;	Indoor floor mounted non-residential	P
	b) Indoor floor mounted residential use BESS;		NA
	c) Outdoor ground mounted non-residential use BESS;		NA
	d) Outdoor ground mounted residential use BESS;		NA
	e) Indoor wall mounted non-residential use BESS;		NA
	f) Indoor wall mounted residential use BESS;		NA
	g) Outdoor wall mounted non-residential use BESS;		NA
	h) Outdoor wall mounted residential use BESS;		NA
	i) Rooftop installed non-residential use BESS; or		NA
	j) Open garage installed non-residential use BESS.		NA
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report.	Indoor ground mounted	P
9.7.3	The report shall include the following, as applicable:		P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	Manufacturer: Narada Model number: 76.8NESP200*15pcs Refer to 5002817-200801758SHA-001	P
	b) Number of modules in the initiating BESS unit;	15 pcs modules	P
	c) The construction of the initiating BESS unit per 5.3;	See Annex 4	P
	d) Fire protection features/detection/suppression systems within unit;	No such systems	NA
	e) Module voltage(s) corresponding to the tested SOC;	100%SOC 86.4V	P
	f) The thermal runaway initiation method used;	Heating	P
	g) Location of the initiating module within the BESS unit;	Middle of battery rack, between two units. See Annex 5.	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See Annex 6	P
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	No flaming outside the initiating BESS enclosure	P
	j) Chemical and convective heat release rate versus time data;	Same as Appended Curve 8.3 g)	P

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Cl.	Requirement + Test	Result – Remark	Verdict
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See Annex 6	P
	l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See Annex 6	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	22 ℃	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;	22 ℃	P
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	0kW/m^2	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;	0kW/m^2	P
	q) Gas generation and composition data;	Same as Appended Table 8.3	P
	r) Peak smoke release rate and total smoke release data;	0.018m^2/s based on 1m* 2m; 1.768m^3 (flammable gas according to 8.3 h))	P
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;		NA
	t) Observation of flying debris or explosive discharge of gases;	No flying debris or explosive discharge of gases;	P
	u) Observation of re-ignition(s) from thermal runaway events;	No re-ignition(s) from thermal runaway events;	P
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	No sparks, electrical arcs, or other electrical events;	P
	w) Observations of the damage to:		P
	1) The initiating BESS unit;	No	P
	2) Target BESS units;	No	P
	3) Adjacent walls, ceilings, or soffits; and	No	P
	x) Photos and video of the test.	See Annex 9	P
9.8	**Performance at unit level testing**		P
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.		P
	Non-Residential Installations:		P
	Indoor Floor Mounted:		P
	a) Flaming outside the initiating BESS unit is not observed;	No flaming outside the initiating BESS unit	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	No temperature increase of target BESS unit	P

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Cl.	Requirement + Test	Result – Remark	Verdict
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;	No temperature increase of the wall surface, remain same as room environment temperature	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	No explosion hazards are observed	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	Not exceed 1.3 kW/m^2	P
	Outdoor Ground Mounted:		NA
	a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		NA
	Indoor Wall Mounted:		NA
	a) Flaming outside the initiating BESS unit is not observed;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		NA
	Outdoor Wall Mounted:		NA
	a) Flaming outside the initiating BESS unit is not observed;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
	c) For BESS units intended for installation on walls with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		NA
	<u>Rooftop and Open Garages:</u>		NA
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		NA
	<u>Residential Installations</u>		NA
	<u>Indoor Floor Mounted:</u>		NA
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.		NA
	<u>Outdoor Ground Mounted:</u>		NA
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for near exposures, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		NA
	<u>Indoor Wall Mounted:</u>		NA
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		NA
	e) The concentration of flammable gas does not exceed 25% LFL for the smallest intended room installation size.		NA
	<u>Outdoor Wall Mounted:</u>		NA
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		NA
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		NA
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15; and		NA
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases.		NA
10	**Installation Level**	Not required see clause 9.8	NA
10.1	**General**		NA

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Cl.	Requirement + Test	Result – Remark	Verdict
10.1.1	The installation level test method assesses the effectiveness of the fire and explosion mitigation methods for the BESS in its intended installation. The installation level testing does not apply to residential use BESS.		NA
	a) Test Method 1 – "Effectiveness of sprinklers" is used to evaluate the effectiveness of sprinkler fire protection and explosion mitigation methods installed in accordance with code requirements.		NA
	b) Test Method 2 – "Effectiveness of fire protection plan" is used to evaluate the effectiveness of other fire and explosion mitigation methods.		NA
10.1.2	Installation level testing is not appropriate for units only intended for outdoor use or residential use.		NA
10.2	**Sample**		NA
10.2.1	The samples (initiating BESS and target BESS) and their preparation for testing, including separation distances from walls, shall be identical to that used for the unit level test in Section 9.		NA
10.2.2	A flame indicator consisting of a cable tray with fire rated cables that complies with UL 1685 and representative of the installation per the manufacturer's specifications shall be deployed above the BESS at a distance specified by end-use installation.		NA
	If the installation requires that cabling be installed below the BESS, then the flame indicator is not needed.		NA
10.3	**Test method 1 – Effectiveness of sprinklers**		NA
10.3.1~10.3.11	Prepared according standard		NA
10.3.12	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:		NA
10.3.13	The composition of BESS unit vent gases shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), total hydrocarbon analyzer, and hydrogen analyzer. The gas composition sampling port shall be located in the ceiling jet, 25-mm (1-in) below the ceiling.		NA
10.3.14	The test shall be terminated if:		NA
	a) Temperatures measured inside each module of the initiating BESS return to below the cell vent temperature;		NA
	b) The fire propagates to adjacent units or to adjacent walls; or		NA
	c) A condition hazardous to test staff or the test facility requires mitigation.		NA
10.3.15	The initiating unit shall be under observation for 24 h after conclusion of the installation test to determine that re-ignition does not occur.		NA

ANSI/CAN/UL 9540A			
Cl.	Requirement + Test	Result – Remark	Verdict

10.4	**Installation level test report – Test method 1 – Effectiveness of sprinklers**		NA
10.4.1	The report on installation level testing shall include the following:		NA
	a) Unit manufacturer name and model number (and whether compliant with UL 9540);		NA
	b) Number of modules in the initiating BESS unit;		NA
	c) The construction of the initiating BESS unit per 5.3;		NA
	d) Module voltage(s) of initiating BESS corresponding to the tested SOC;		NA
	e) The thermal runaway initiation method used;		NA
	f) Diagram and dimensions of the test setup including location of the initiating and target BESS units, and the locations of walls and ceilings;		NA
	g) Location of initiating module within the BESS unit;		NA
	h) Separation distances from the initiating BESS unit to;		NA
	i) Separation distances from the initiating BESS unit to target BESS units;		NA
	j) Distances of the flame indicator (if used) with respect to the BESS;		NA
	k) Maximum temperature at the ceiling;		NA
	l) Distance of fire spread within the flame indicator;		NA
	m) The maximum wall surface and target BESS unit temperatures achieved during the test and the location of the measuring thermocouple;		NA
	n) The maximum incident heat flux on target wall surfaces and target BESS units;		NA
	o) Voltages of initiating BESS;		NA
	p) Total number of sprinklers that operated and length of time the sprinklers operated during the test;		NA
	q) Gas generation and composition data, if measured;		NA
	r) Observation of flaming outside of the test room;		NA
	s) Observation of flying debris or explosive discharge of gases;		NA
	t) Observation of re-ignition(s) from thermal runaway events;		NA
	u) Observations of the damage to:		NA
	1) The initiating BESS unit;		NA
	2) Target BESS units; and		NA
	3) Adjacent walls;		NA
	v) Photos and video of the test;		NA
	w) Fire protection features/detection/suppression systems within unit; and		NA
	x) Sprinkler K-factor, RTI, manufacturer and model, number of sprinklers and layout.		NA

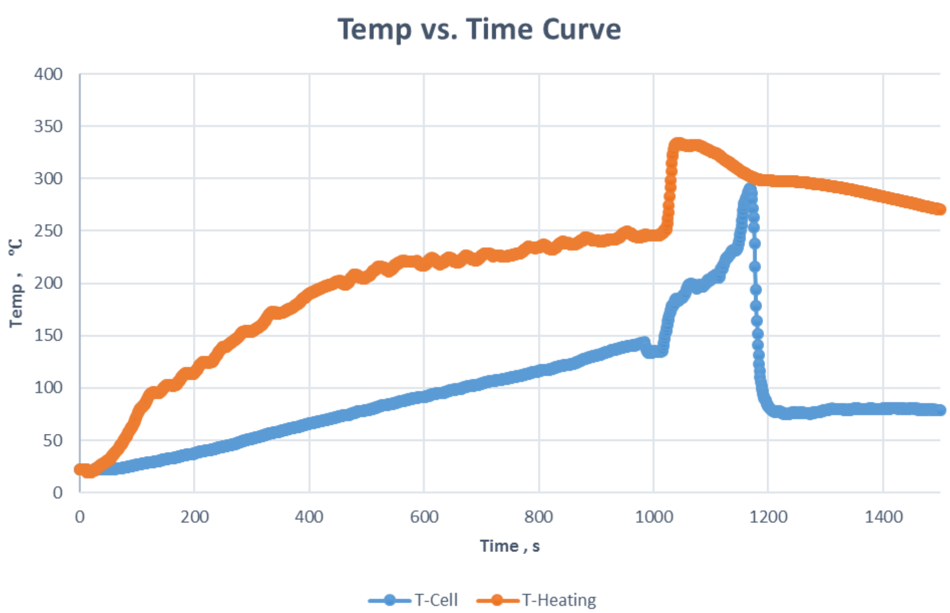
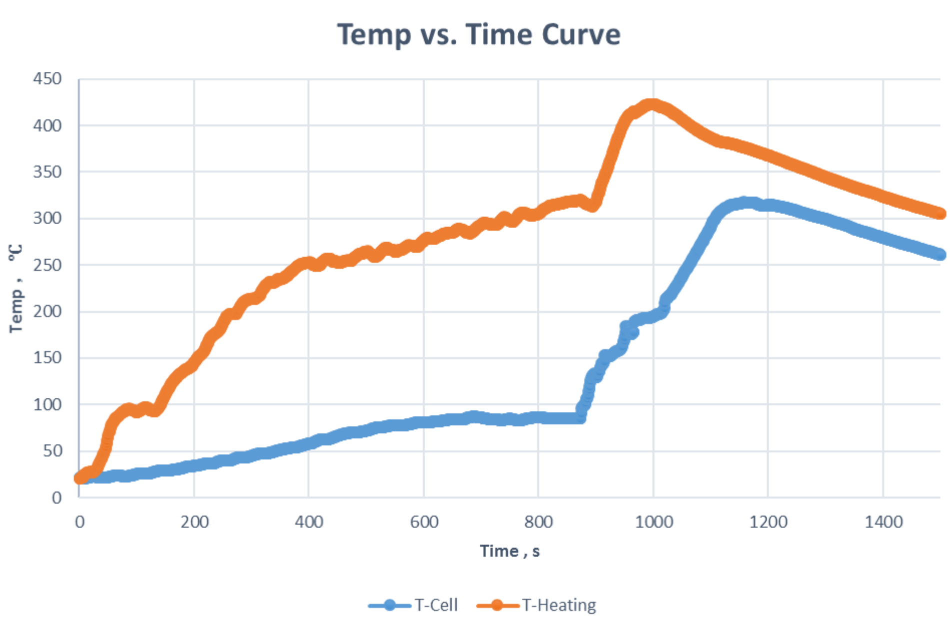
ANSI/CAN/UL 9540A			
Cl.	Requirement + Test	Result – Remark	Verdict

10.5	**Performance – Test method 1 – Effectiveness of sprinklers**		NA
10.5.1	For BESS units intended for installation in locations with combustible construction, surface temperature measurements along instrumented wall surfaces shall not exceed a temperature rise of 97°C (175°F) above ambient. Surface temperature rise is not applicable if the intended installation is composed completely of noncombustible materials in which wall assemblies, cables, wiring and any other combustible materials are not to be present in the BESS installation. In this case, the report shall note that the installation shall contain no combustible materials.		NA
10.5.1~10.5.8	Prepared according standard		NA
10.6	**Test method 2 – Effectiveness of fire protection plan**		NA
10.6.1	The test method 2 test set-up and test procedures are identical to that in 10.3, except instead of the sprinkler system set up of 10.3.2, the room shall be fitted with the specified fire protection and explosion mitigation equipment representative of a planned installation for the tested BESS system.		NA
10.7	**Installation level test report – Test method 2 – Effectiveness of fire protection plan**		NA
10.7.1	The report on installation level testing shall include the following:		NA
	a) The report information in 10.4.1 items (a) – (u), and (v) if applicable;		NA
	b) Fire protection features/detection/suppression systems within installation; and		NA
	c) Length of time of operation of the clean agent, or other suppression system in addition to any sprinklers used.		NA
10.8	**Performance – Test method 2 – Effectiveness of fire protection plan**		NA
10.8.1	See 10.5 for performance criteria.		NA
ANNEX A (INFORMATIVE)	**Test Concepts And Application Of Test Results To Installations**		-
ANNEX B (INFORMATIVE)	**Safety Recommendations for Testing**		-

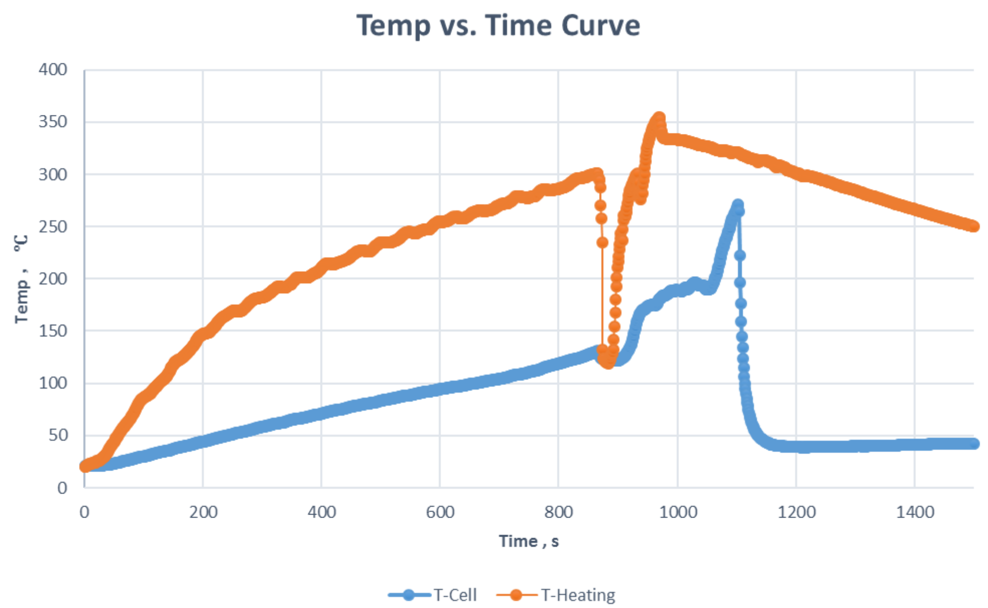
Appended Tables:

Table 7.4 Cell vent gas composition -Gas Components								
CO_2	CO	H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	C_3H_6	C_3H_8
22.84	6.65	45.33	5.55	0.24	10.51	2.15	3.56	0.59

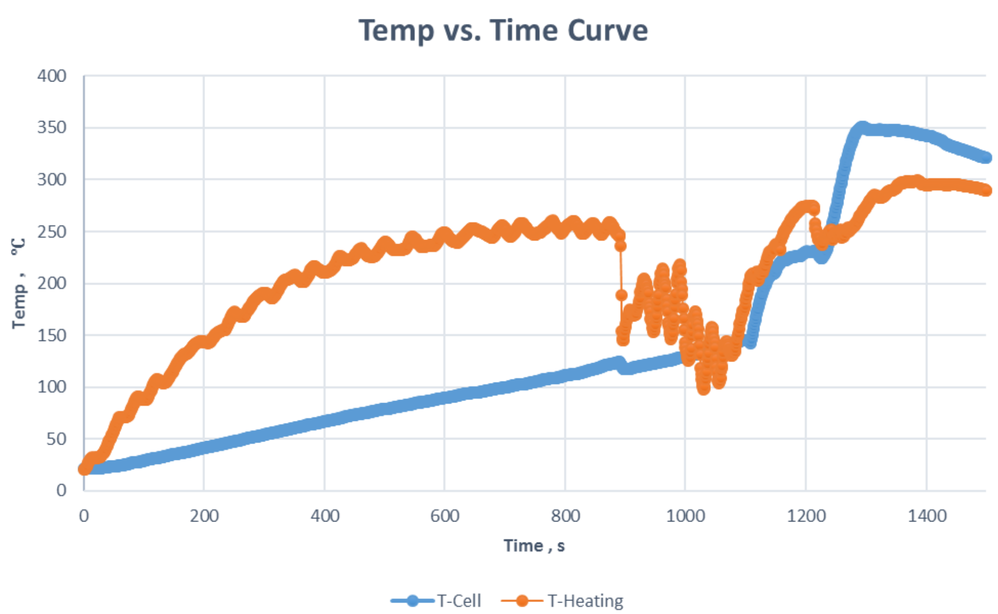
Temperature measure curve Cell

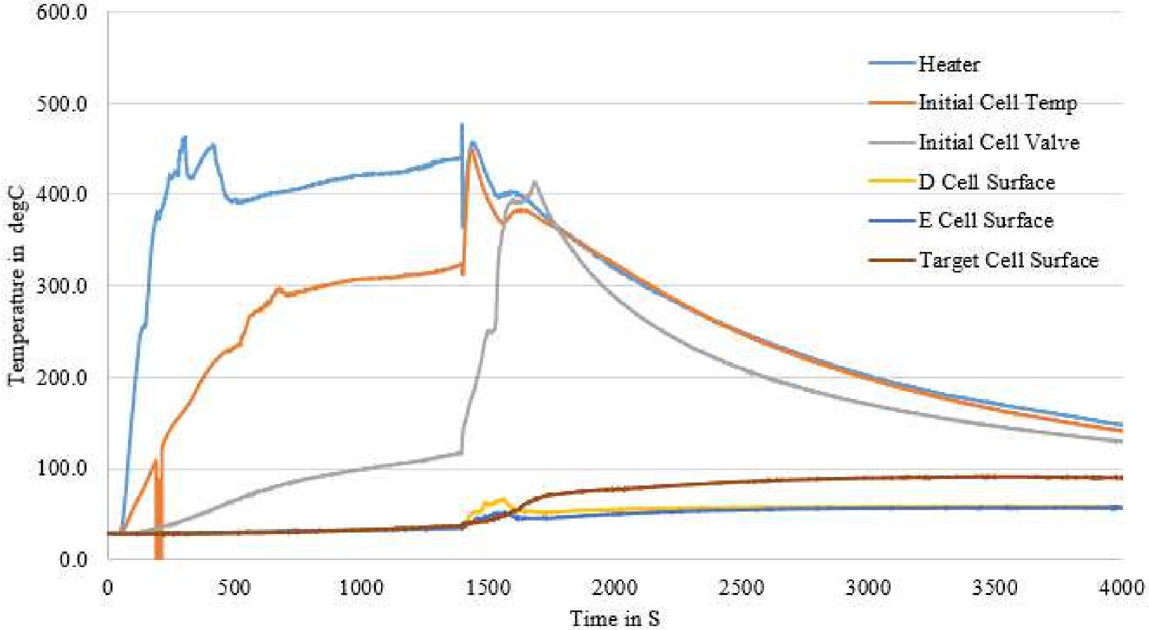
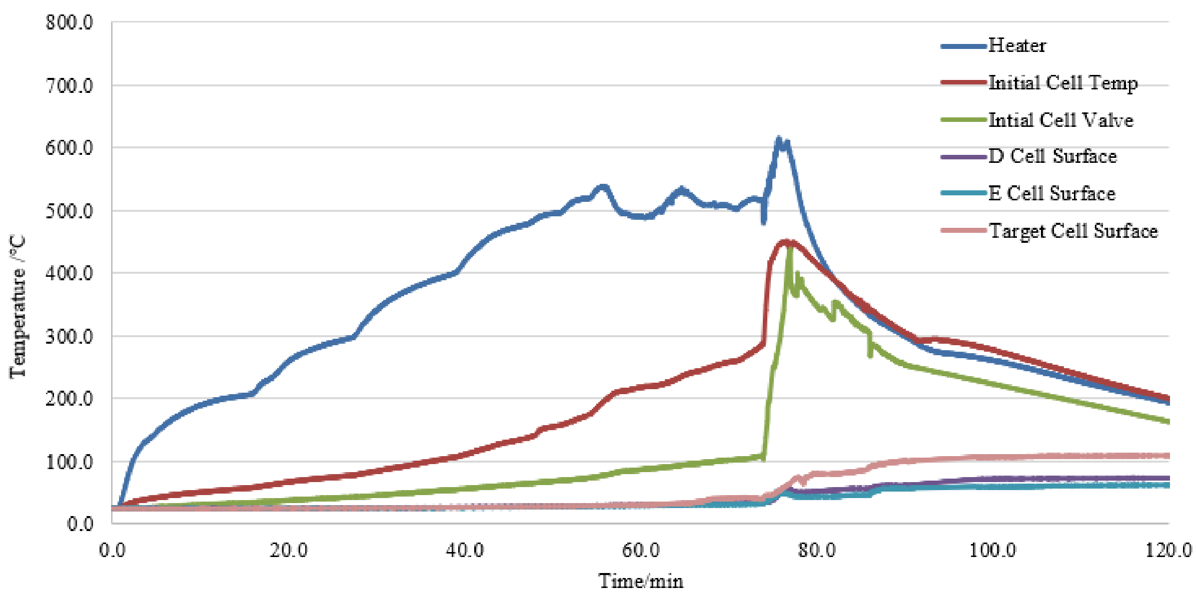
Curve of Temperature
Sample1

Sample 2


Curve of Temperature
Sample3

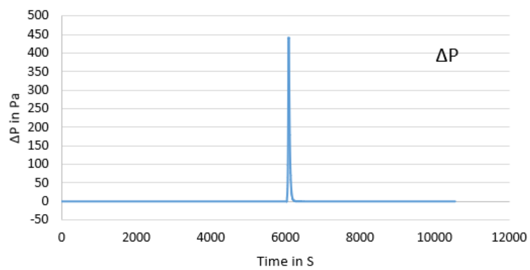


Sample 4

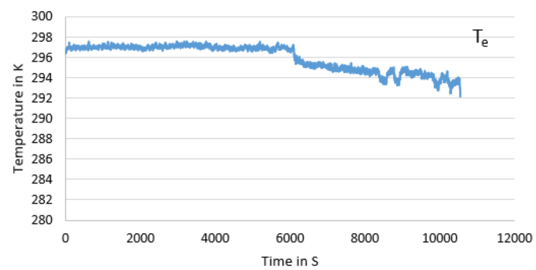


Curve of Temperature
Module

Unit


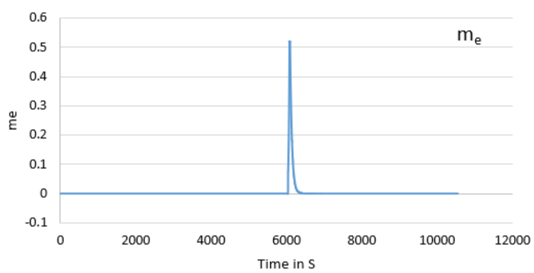
Appended Curve: 8.3 g) Heat release rate versus time data



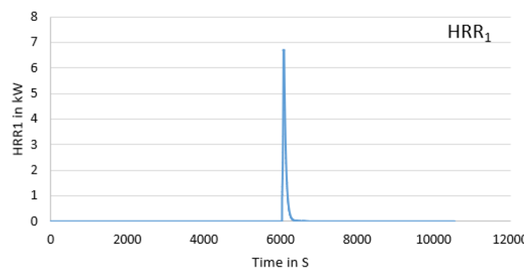
ΔP is adjusted to 0, before cell venting and after smoke is cleared



Orifice plate is 3m higher than test sample, so, its temperature is same as room temperature



m_e is a caculated result according to ΔP and T_e

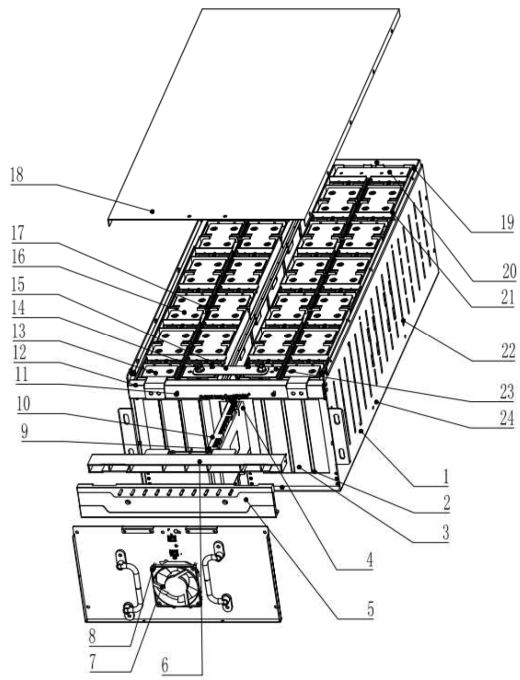


HRR_1 is a calculated result.
Test sample has no flame, so HRR_1 is small.

Appended Table: 8.3 h) Flammable gas generation and composition data

Table 8.3 Flammable gas generation and composition data								
CO2	CO	H2	CH4	C2H2	C2H4	C2H6	C3H6	C3H8
17.15	4.90	58.38	4.37	0.23	7.80	1.64	3.20	0.48

Annex 1: Drawing

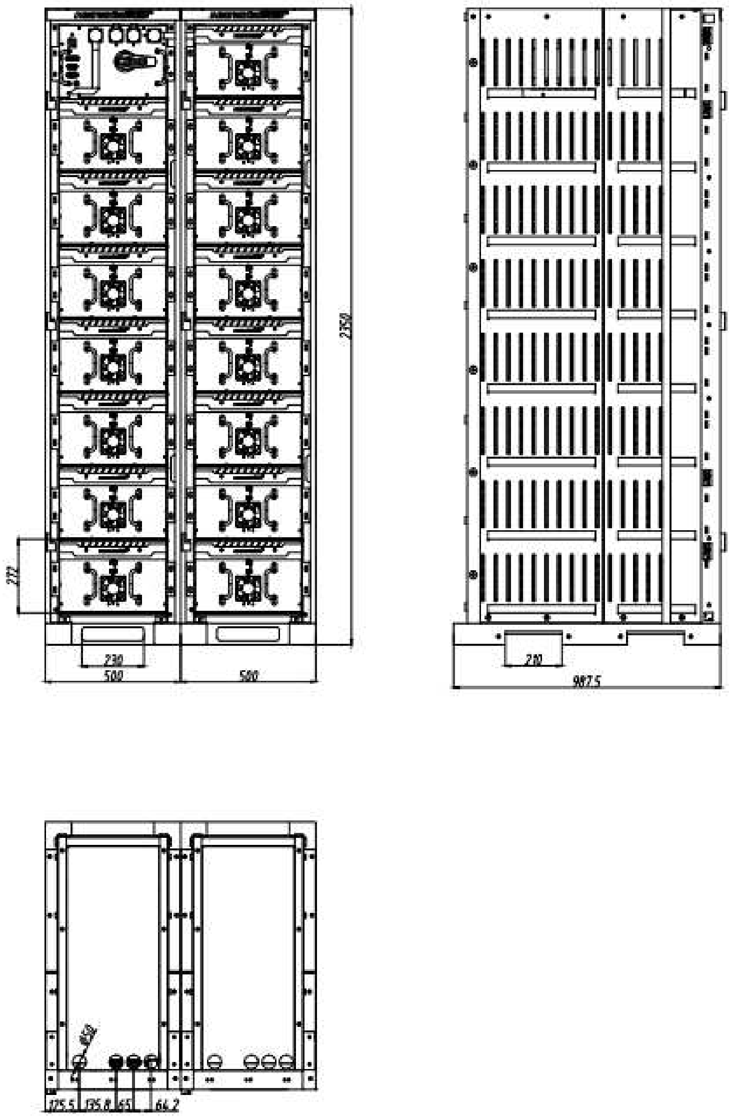


NO.	Name	Description	quantity	Materials	Weight	SUM.	Mark
24	PFES250X24A.00-02	Bottom epoxy	1	ERB t=0.5mm			
23	PFES250X16.00-03	Transfer LvPai	2	AL1060			
22	PFES250X24A.00-01	Side epoxy	2	ERB t=0.5mm			
21	PFES250X16.00-08	upper bracket	6	PP+20%GF			
20	PFES250X16.00-01	Connection LvPai	2	AL1060 H24			
19	PFES210X16A1.00-08	Front	4	Epoxy t=0.5mm			L=60mm
18	PFES250X24A.00-03	Top epoxy plate	1	ERB t=0.5mm			
17	PFES250X16.00-12	Low voltage acquisition	1				
16	PFES250X16.00-02	Connection LvPai	20	AL1060 H24			
15	PFES250X16.00-05	connected copper bar	1	red copperT2			
14	Nuts /M8	Nuts/M8	2				
13	PFES250X16.00-04	Terminal bracket	2	AL1060 H24			
12	PFES250X16.00-06	Terminal support	1	PP+20%GF			
11	Bolt/M4×16	Bolt/M4×16	2	304			
10	PFES210X16A1.00-05	Bracket insulating board	2	ERB t=0.5mm			
9	BMU,PCB,WH	BMU,PCB,WH	1				
8	Nuts/M3	Nuts/M3	4	304			
7	fan/3414NHH	fan/3414NHH	1				
6	PFES250X16.00-07	mound layer	1	PP+20%GF			
5	PFES250X16.00-11	shield	1	PP+20%GF			
4	Nuts /M4	Nuts /M4	4	304			
3	FE125A batteries	FE125A batteries	48				
2	PFES250X16.00-09	lower bracket	6	PP+20%GF			
1	PFES250X24A.01	PFES250X24A	1	SGCC			

NARADA

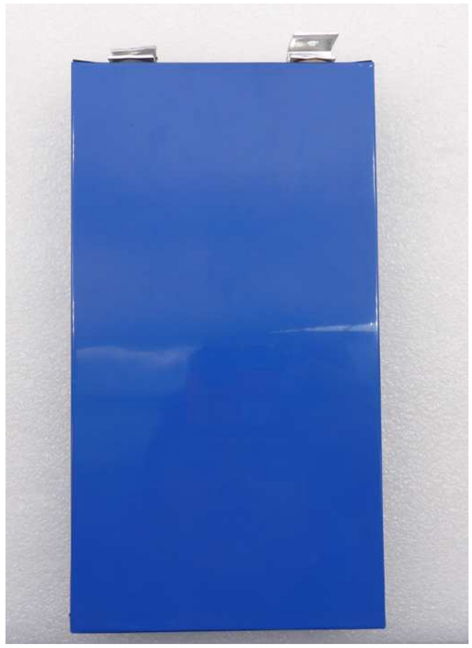
Mark | Place | Rev. document NO. | Signature | Date
Design | Standard check up
Proof
Technology check
Approve
Drawing mark | Weight (kg) | Proportion
Total:1 page | First page

Annex 2: Drawings



							NARADA
Mark	Place	Rev. document NO.	Signature	Date			76.8V NESP Rack drawing
Design	Standard check up			Drawing mark	Weight (kg)	Proportion	
Proof							ZNG
Technology check							
	Approve			Total:1 page	First page		

Annex3: Photos

Overview-cell

Overview-cell


Annex1: Photos

Overview -after testing

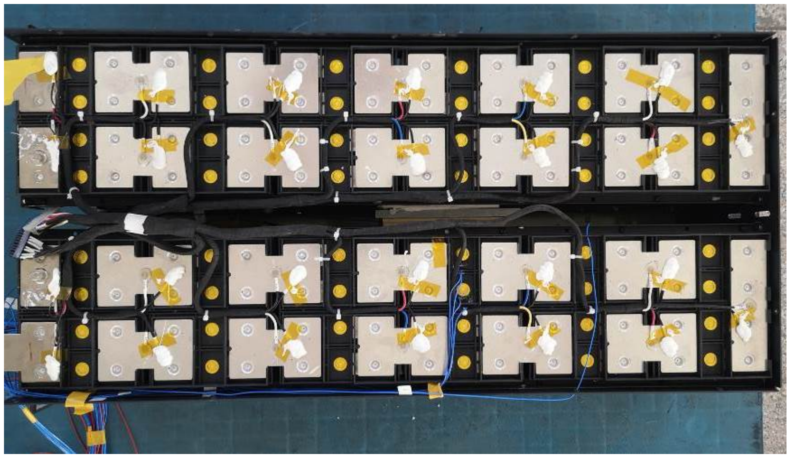
Overview -after testing


Annex 4-Photos

Overview - module

Overview - module


Annex4x-Photos

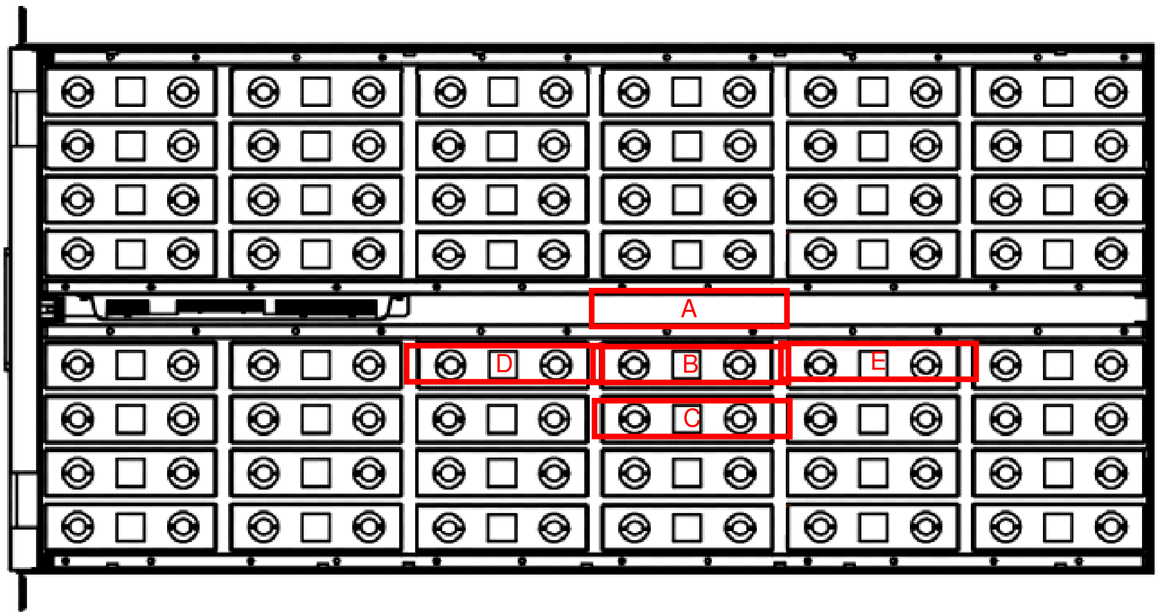
Overview – module before test

Overview – module at test


Annex3-Photos of Unit

Overview – Unit

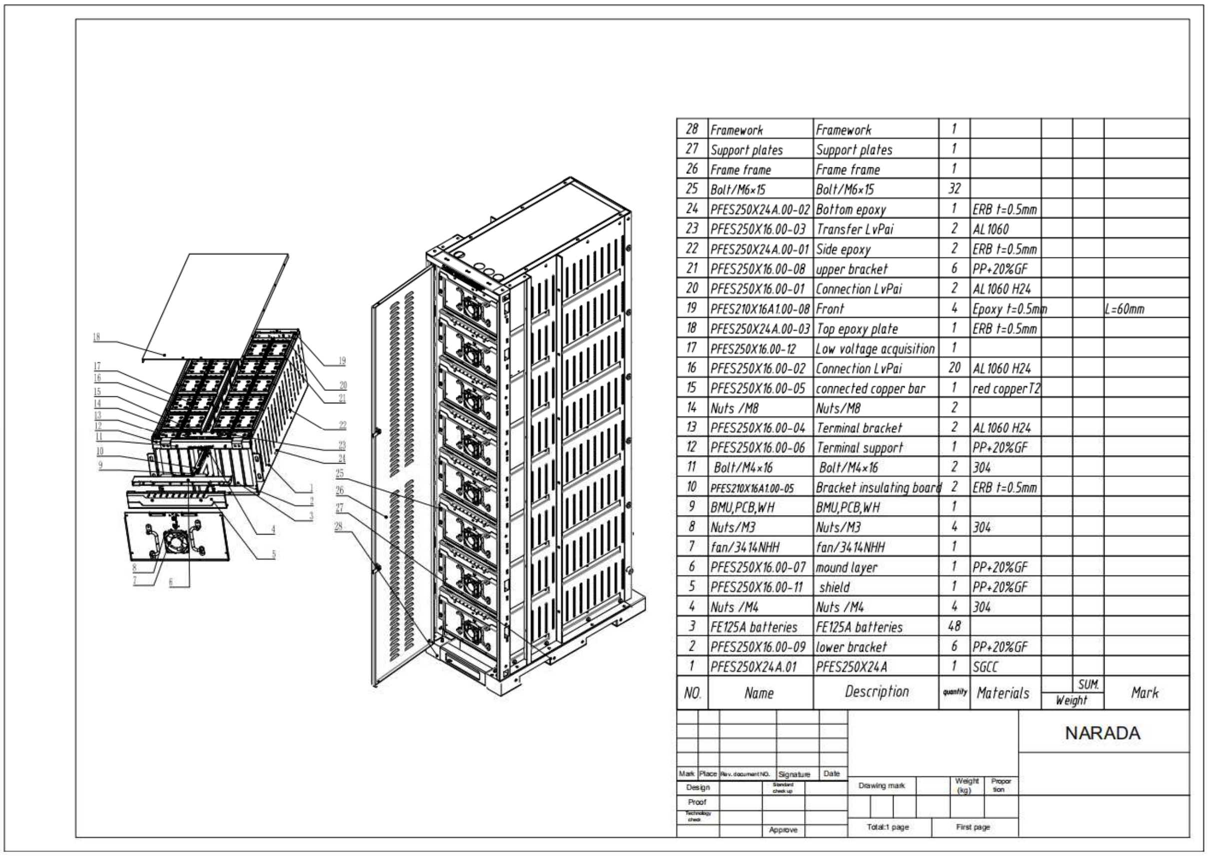
Overview – Unit


Annex 5 Description of 8.3

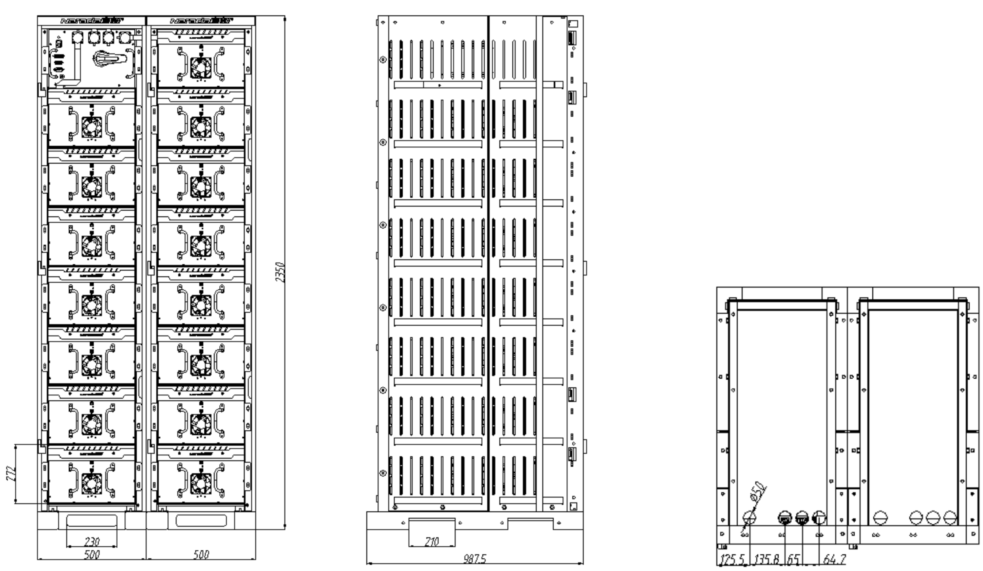
Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway

Make initial cell thermal runaway by heating; Heat 1 cell, its position is marked as B. Note: A: Heat Film B: Initial Cell C: Target Cell D: Adjoint Cell 1 E: Adjoint Cell 2

Annex 6 The construction of the initiating BESS unit

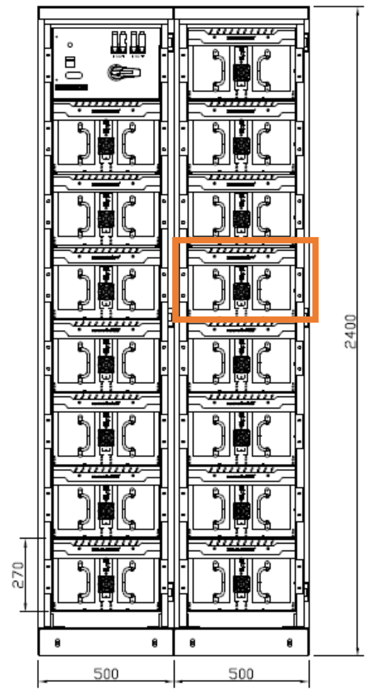
Internal construction for BESS unit



Dimensions for BESS Unit



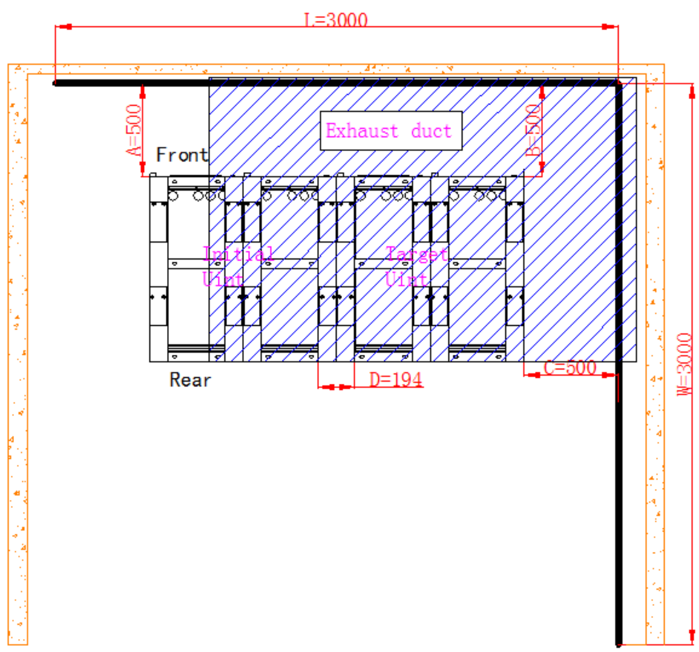
Annex 7 Location of the initiating module within the BESS unit;



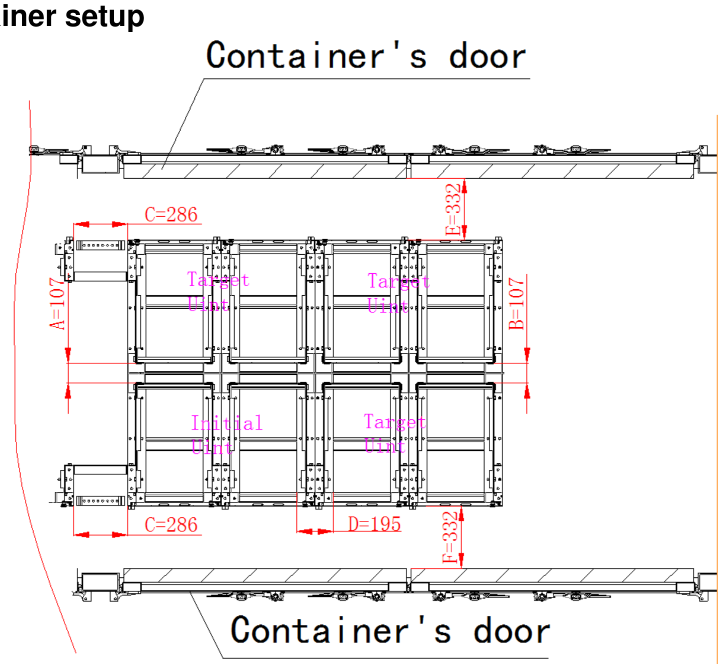
Location of Intial Module is marked as in orange square.

Annex 8 Diagram and dimensions of the test setup

Test1: In room setup



Test 2: In container setup



Annex 9 Photos of the unit test
Test 1

Overview – Unit before test

Overview – Unit at test


Annex 9 Photos of the unit test
Test 1

Overview – Unit after test


Annex 9 Photos of the unit test
Test 2

Overview – Unit before test

Overview – Unit at test


Annex 9 Photos of the unit test
Test 2

Overview – Unit after test

Overview – Unit after test