Annex EF14 of Dr E J Fordham Interested Party – Unique Reference: 20030698
EN010106 – Sunnica Energy Farm

Three items are included in this Annex

Note: the reports are supplied with names redacted as is usual for documents obtained under the Freedom of Information Act

1. **Cover letter** from Merseyside Fire and Rescue Service sent to Requesters for release of the subsequent reports under the Freedom of Information Act 2000

Dated: 17 March 2022

Please note this is **eighteen months** after the incident itself, in 15 September 2020, before the reports were made public

2. **Incident Investigation Team Report**

Authors: Incident Investigation Team,
Merseyside Fire and Rescue Service

Report: Fire Investigation Report 132-20

Incident number: 018965

Dated: March 2022

3. **Significant Incident Report**

Authors: Operational assurance Team
Merseyside Fire and Rescue Service

Incident: 018965 – 15092020

Version: 1.2

Dated: December 2021

Note: A first report is stated to have been "published" in November 2020 but Freedom of Information Act requests were denied under S.22 ("future publication") of the Act so in practice this report was not available until the release date of 17 March 2022

Merseyside Fire & Rescue Authority Headquarters
Strategy and Performance
Bridle Road
Bootle
Merseyside
L30 4YD

Telephone: 0151 296 4000
(Calls may be recorded)
[redacted]

Date: 17 March 2022

Your Ref: Our Ref: FOI/Orsted Bess

Dear Requester

FREEDOM OF INFORMATION ACT 2000 - INFORMATION REQUEST

You requested the following information:

Information relating to a fire incident at an Orsted Battery Energy Storage System (BESS) site, Carnegie Road, Liverpool on 15th September 2020.

Our response:

Please see attached the following reports: -

Incident Investigation Team Report
Significant Incident Report

If you have any queries or concerns, please do not hesitate to contact the Director of Strategy and Performance on the above numbers.

If you are dissatisfied with the handling of your request please contact the Information Management Officer, Merseyside Fire and Rescue Authority Headquarters, Bridle Road, Bootle, Merseyside, L30 4YD, email foiteam@merseyfire.gov.uk.

You can also contact the Information Commissioner at:

Information Commissioner's Office
Wycliffe House
Water Lane
Wilmslow
Cheshire
SK9 5AF

Telephone: 0303 123 1113

[redacted]

Yours sincerely

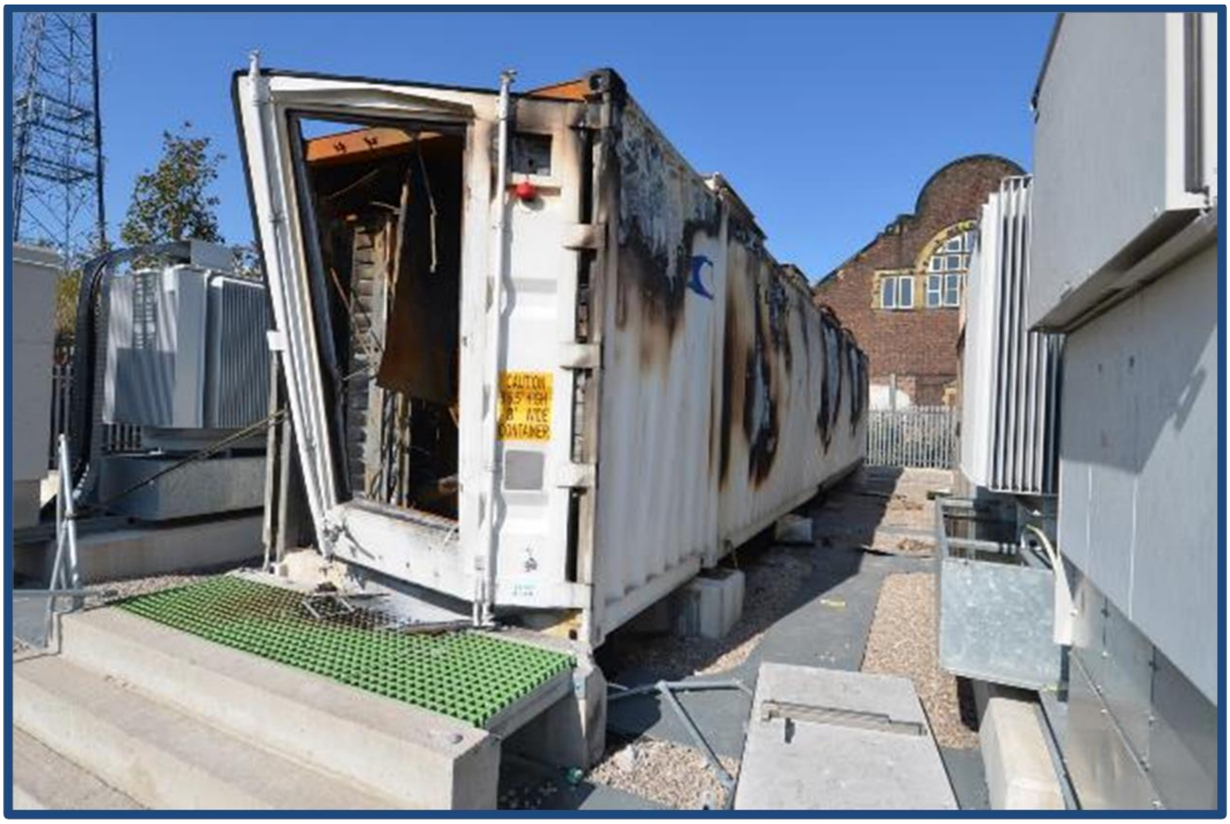
Sue Coker
Information Management Officer

MERSEYSIDE FIRE & RESCUE SERVICE

Incident Investigation Team

Community Prevention Dept.

Community Risk Management



Fire Investigation Report 132-20

Incident Number 018965

Ørsted BESS,

Carnegie Rd,

Liverpool,

L13 7HY

Compiled by Station Manager [redacted]

Incident Investigation Team, Merseyside Fire and Rescue Service

Contents

MERSEYSIDE FIRE & RESCUE SERVICE

INCIDENT INVESTIGATION TEAM

PREMISES:	Ørsted BESS, Carnegie Rd, Liverpool, L13 7HY
INCIDENT NUMBER	018965
DATE:	15th September 2020
TIME OF CALL:	00:49 hrs.
METHOD OF CALL:	999
TYPE OF PROPERTY:	Battery energy storage site BESS
AUTOMATIC FIRE DETECTION:	Yes
BUILDING OWNER:	Ørsted Energy
NUMBER OF FIRE APPLIANCES:	5 Fire Appliances, 1 High Volume Pump
INITIAL INCIDENT COMMANDER:	Watch Manager [redacted]
INCIDENT COMMANDER:	Group Manager [redacted]
HMEPO:	Station Manager [redacted]
FIRE INVESTIGATION OFFICER:	Station Manager [redacted]

1 SUMMARY

1.1 At 00:49hrs on 15th September 2020, calls were received by Merseyside Fire and Rescue (MFRS) Fire Control reporting an explosion with smoke and flames visible from the Fisheries, Lister Drive, Old Swan, near to Carnegie Rd. Two appliances, Old Swan [redacted] and Liverpool City [redacted] responded to the incident. They arrived within 5 minutes of the first call at a secure, double gated site, that had four 12m long shipping containers within the inner compound; one of these was alight and had signs of an explosion. Parts of this container were blown across the compound the furthest of which had travelled 23m.

1.2 The explosion was a result of a failure within Battery Zone 3-Rack 7 Module 6 (BZ3-R7M6) which led to a thermal runaway, which, in turn produced gases within the container culminating in a deflagration.

1.3 After reviewing all available evidence and the report provided by [redacted] following his review of the CT scans which were taken of the cells recovered from both the effected container and a neighbouring container, I have been unable to identify the root cause of the failure within module 6. There is evidence on the exemplar cells from the neighbouring container demonstrating that a gas build-up had occurred leading to some internal distortion within some of the cells.

2 PURPOSE OF REPORT

2.1 This report consists of 57 pages and outlines the details of the fire that occurred at Ørsted Battery Energy Storage Site (BESS), Carnegie Rd, and to identify the cause, origin of the fire and the subsequent fire spread. As such, I examined the scene of the fire to determine the area of origin and the most likely cause.

3 INVESTIGATION METHODOLOGY

3.1 *'**The Systematic Approach**: The systematic approach is based on the scientific method. This method provides an organisational and analytical process that is desirable and necessary in a successful fire investigation'*

3.2 This investigation was based around the 'scientific method' which is outlined below:[1]

- Recognise the need
- Define the problem
- Collect data
- Analyse the data
- Development of a hypothesis
- Test of the hypothesis
- Select final conclusion

3.3 To interpret and examine the scans taken of the cells, Merseyside Fire Service entered in to a consultancy agreement with [redacted] from [redacted] to undertake the analysis of the images. His findings have been used when forming my conclusion.

3.4 Ørsted has been cooperating closely with the MFRS both before the incident and during in the fire investigation. This has been done, from both sides, not only to carefully identify the source of the fire, but also to assist the MFRS in expanding its knowledge of batteries and further improve the fire safety standards for the whole industry. Ørsted is currently working on the rebuild of the site to the highest available safety standards, and, has and will continue to involve MFRS in the protocols and procedures to be in place before the asset is made operational again.

[1] 2020. *NFPA 921*. [S.l.]: NFPA, pp.921-20.

4 DESCRIPTION OF PROPERTY

4.1 Ørsted BESS, Carnegie Rd, Old Swan is a secure compound and is classed as a Battery Energy Storage Site which is used to balance the national grid load in times of high demand. This site, and others like it, are designed to store energy for longer durations to shift peaks of supply to match demand. The site is located next to a high voltage electrical substation.

Image 1 is a Google map of the site before the BESS was in place [2]

4.2 A company called "Ørsted" remotely manage the site, and were able to alert a key-holder that there had been an activation of the fire alarm system. The fire alarm system includes an internal and external strobe and sounder system.

The fire detection and suppression system alarms are linked to the NEC AEROS control software and the operational and maintenance interface report system alarms. This includes, related warning and alarms to site operators and NEC. *The AEROS control system measures module temperature and records the min/max of a rack. The thermistors are located in the centre of the cells, any heat radiating from a failing cell will have to pass up to six other cells before the temperature is recorded.*

4.3 The container affected by fire was at the end of the row, it exhibited clear signs of pressure building-up and deflagration. This was evident by the expansion and distortion of the sides and top of the container.

[2] BESS Site in photograph *Google Maps, 2021*

Image 2 shows the damaged container with signs of expansion/distortion that is equal across the container and not localised to the area of the initial failure.

4.4 The containers have four heating, ventilation, and air conditioning units (HVACs) fitted to the roof that maintain the internal temperature between 20^0 and 35^0 C and automatically activate when a reduction in temperature is required.

4.5 Each of the three containers had two smoke detectors fitted which cross zones with linear heat sensors (LHS) that melt at 88^0C. The system is remotely monitored in Denmark but the suppression system (which the sensors are connected to) is not set-up to be activated remotely.

4.6 All three containers are fitted with a NOVEC 1230 fire suppression system. The system contains 3.164kg of Halocarbon media that has a discharge time of 10 seconds. The media is contained in a vessel at the end of each container, it has pipe work running along the upper parts of the container terminating at discharge nozzle(s) and is triggered by the smoke detection and linear cable activating it, or a manual break glass located beneath the fire alarm panel.

5 INCIDENT BACKGROUND

5.1 Merseyside Fire and Rescue Service (MFRS) were alerted by multiple calls of an explosion and smoke in the area near the Fisheries. The first call was received on Tuesday 15th September 2020 at 00:49 hrs.

5.2 On arrival, the crews arrived to find a container on fire within the site. The site has a secure compound that is spilt in two and was secured by locked gates. This area contains a rest facility for engineers and also gives access via another gate to the containers. The first container is the control unit followed by three BESS containers. There are also two empty concrete pads where two more BESS could be placed. Next to each BESS is a high voltage switch Ring Main Unit (RMU) (yellow arrow on the photograph), Transformer 33kV – 415V (red arrow on the photograph) and a cooler inverter (blue arrow on the photograph). On the top of the BESS containers are four HVAC systems.

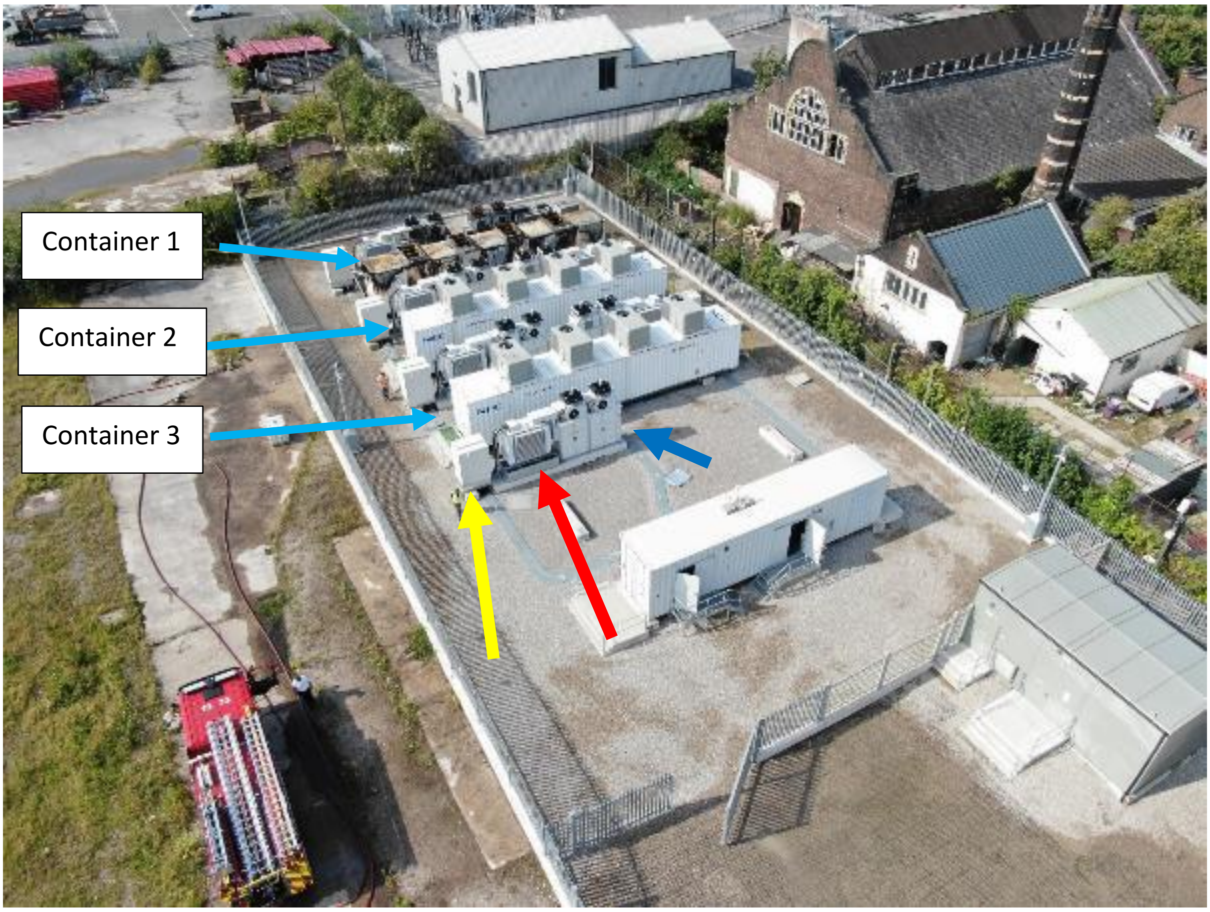


Image 3 shows the inner compound layout

5.3 The following time line includes partial data supplied by the responsible person and information collated as a part of my investigation. The data showed (S10 and S22 are specific NEC fault codes):

- *At 00:29:02 hrs event/fault with the rack temperature mismatch >10^0c S10, rack temperature spread out of range S22, module temperature above the maximum safe level S11 BZ3-Rack 7 Module 6*
- *A temperature rise of 40^0C in less than 2 minutes was recorded indicating a rapid independent excursion.*
- *00:29:36 Alarm for BZ3R7M6 temp above 45c max safe level*
- *00:31 hrs - Fire System Warning Zones 1-5 container 1 (Note: There is no discharge alarm). NEC received urgent alerts.*
- *00:31:02 hrs Smoke alarm went off. All communication to the rack has now stopped as the rack powered off.*
- *00:39 hrs - explosion occurs (Taken from CCTV provided by the responsible person RP)*
- *00:41 hrs - Fire system warning cleared - Ørsted control room in Denmark which monitors the site 24/7 event data shows that the user who cleared them was "kyv_adm/operator"*
- *00:49 hrs - Call received by MFRS from the public*
- *01:02 hrs - Call from Ørsted to NEC emergency line stating "Fire in control room alarm" and that emergency responders were called. This could have been a misinterpretation of location as this was a verbal conversation.*
- *01:18 hrs - Fire System Warning Zones 6-10 container 2 (no discharge alarm received regarding the Novec system)*
- *01:26 hrs (Call to Merseyside's Fire control was received from Denmark whilst crews were in attendance.)*
- *01:50 hrs -* [redacted] *(NEC USA) contacts Operations desk and customer offering support.*
- *01:53 hrs - Operations desk confirms site is on fire via email to* [redacted] *and fire department is on site*
- *02:19 hrs - Entire Site goes offline*
- *02:35 hrs - Ørsted confirms Scottish Power opened breaker and National Grid was informed. Fire "seems under control" per CCTV.*
- *03:47 hrs - Notified by operations desk (Ørsted to NEC) that the "fire in the container should be out now"*

5.4 The weather records in the local area from 00:00 hrs until 01:20 hrs, shows the wind blowing East to South East and a wind speed of around 5mph with a temperature of around 16^{O}C.[3]

Time	Temp	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:20 AM	17C	13C	82 %	ESE	5 mph	0 mph	30.00 in	0.0 in	Fair
12:50 AM	16C	12C	82 %	ESE	5 mph	0 mph	30.00 in	0.0 in	Fair
1:20 AM	16C	12C	82 %	ENE	5 mph	0 mph	30.00 in	0.0 in	Fair

Image 4 weather records

5.5 The temperatures within the containers prior to the system being shut down by the smoke detection system (container 1 and 2) and the site being shut down (container 3) shows that container 2 was below 25^{0}C and container 3 was below 27^{0}C.

5.6 The site was at ~86.9% state of charge and was discharging around 1.9mW. The site specification for maximum power is 20MW. The specified state of charge percentage operating range is 0 – 100%. Each rack has a power rating of +/- 224kW.

The aggregated energy throughput for the 48 hrs prior to the incident was:

- Net Energy Throughput (kWh) -21.1950362
- Discharge Energy (kWh) 332.0728309
- Charge Energy (kWh) -353.2678671

5.7 At the time of the incident the site had 3 racks off line, BZ8-R4, BZ9-R1 (Container 2) BZ12-R1 (Container 3).

---

[3] Weatherdata:https://www.wunderground.com/history/daily/EGGP/date/2020-9-15 [Accessed 12 Oct. 2020]

6 FIRE INVESTIGATION / FINDINGS

6.1 I initially attended the incident scene at 10:17hrs, where I received a briefing from the Officer In Charge (OIC) before photographing the scene and making some initial notes. The firefighting plan was to cool and monitor the fire as smoke was being produced when water from firefighting hoses was turned off. The unknown state of the power supplies in the damaged container prevented an internal scene examination being carried out due to the possibility of stranded energy at this time. I documented the scene and gathered information from relevant personnel.

6.2 A number of photographs were taken by the initial officers that attended during the firefighting phase.

6.3 The responsible person for Cobalt Energy (acting for Ørsted Energy to provide technical advice) attended and explained how the site operated. He provided me with contact details for the management team in America and Denmark. A responsible person for NEC Energy Solutions was also in attendance.

6.4 He informed me that the event occurred in a purpose fitted ISO container which is used to stabilise the National Grid; for example, absorbing energy when there is less demand and feeding the National Grid when demand is high.

6.5 The affected container holds 5 Battery Zones, 9 racks per zone and 17 modules which is an assembly containing lithium ion cells. (Image 5)

6.6 Racks line both sides of the container and each rack has a vented doors. (Image 6 & 9)

Image 5 is an example of how the containers are set up [4]

[4] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.

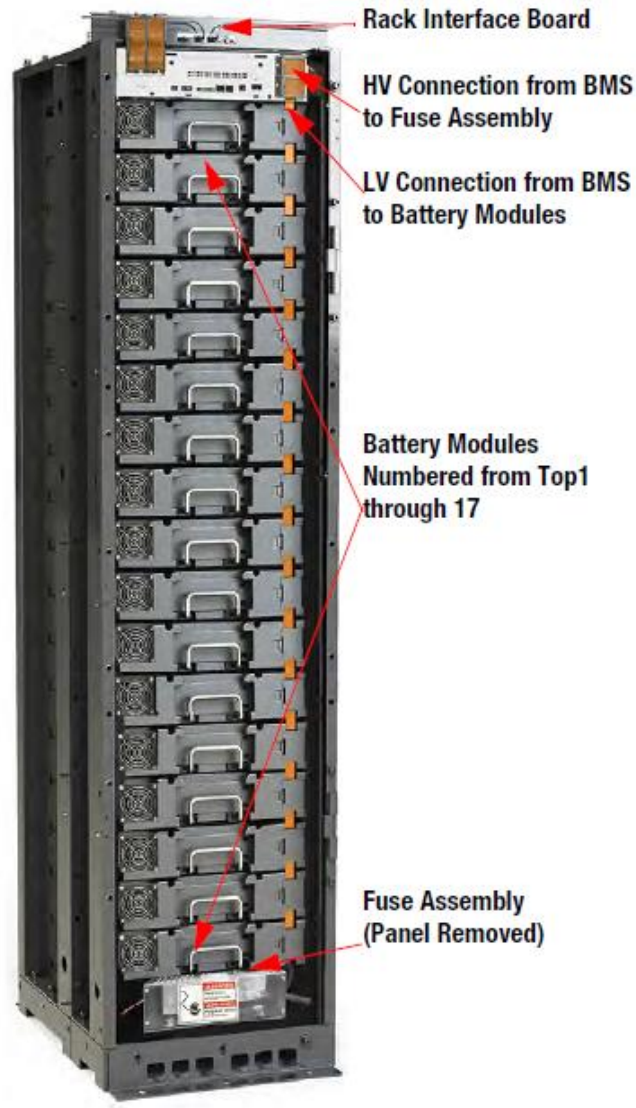


Image 6 shows the arrangement of racks in the container which have rusted since the fire indicating they are made from a carbon steel. Fans are fitted to the racks to blow cold air that is produced by the HVAC through each module. [5]

[5] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.

Image 7 is an example of the Control System Monitors at the Module, Rack, Zone, Powerblock and System Levels[6]

[6] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.

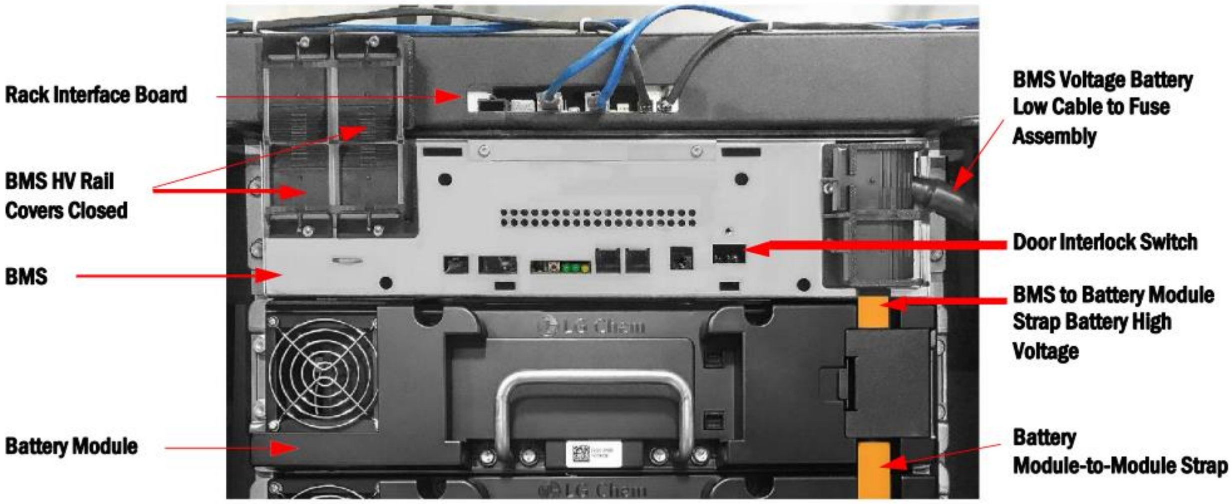


Image 8 shows the MD Rack, BMS, BMS HV strap and the battery module detailed view.[7]

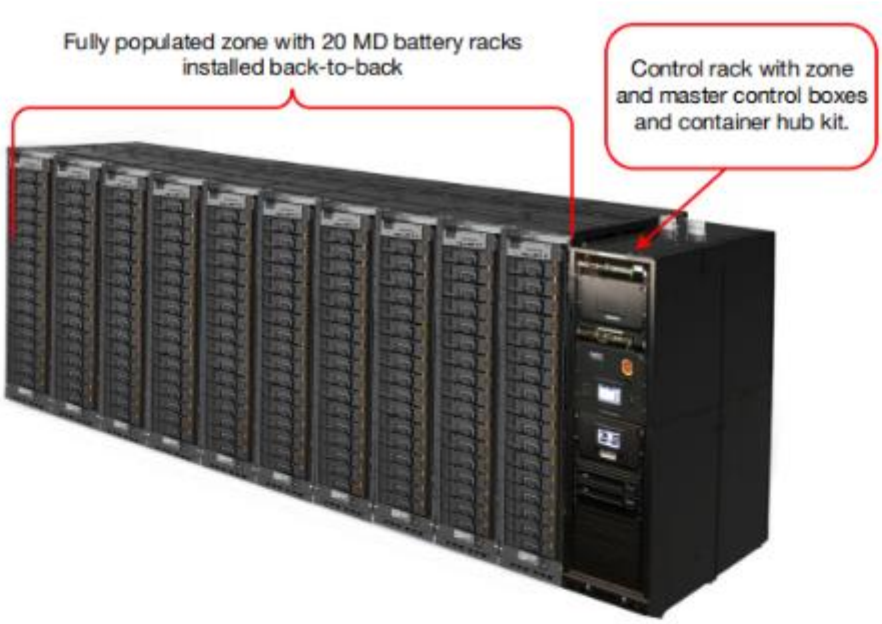


Image 9 is an example of a populated array of 20 racks (two rows of 10, installed back to back) and a control rack.[8]

6.7 Documents have been provided that show that there is a preventive maintenance (PM) plan in place: This is completed by the company service team who plan and perform the PM and provide a service report to the customer. I am in receipt of the PM which was conducted in August of 2020 and the last 3 Fire inspections paperwork covering April 13 2021, May 11 2020 and Feb 13 2020. They use a checklist that appears suitable and sufficient for reporting and customise it to represent the sites actual number of zones, HVAC, inverters, etc. The service teams' site visit reports should also include a copy of the PM checklist. The completed service report, site inventory equipment list and PM checklist are then stored in NECs service system. The last service was performed on the 26th August 2020.

[7] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022.
[8] NEC Energy Solutions, Inc, supplied to MFRS 3rd February 2022

6.8 Orsted are not aware of any Industry standard for what is considered "adequate" maintenance but conduct maintenance in conjunction with the warranty agreement and what is recommended by the provider.

6.9 ASET who have conducted the inspection have stated:

'We carry out a service on the fire alarm system installed in the LV/HV unit, this is required every 6 months. At the same time we carry out testing of the fire suppression systems in each battery unit and check operation of the firing pin using the automatic detection and MCP method. This only has to be carried out every 12 months, however we always test the suppression system whilst on site testing the fire alarm panel. (So every 6 months the full suppression system is tested).

6.10 On 23rd July 2020, NEC issued a LG Module extended replacement Service Campaign following which a plan was put in to place to switch out any relevant modules.

This service bulletin stated that:

LG has initiated a battery module replacement program related to a manufacture date in 2017 at a plant in Nanjing, China. LG has stated that this replacement program was prompted by the Korean Government's investigation Committee report concerning events experienced by large-scale energy storage systems in Korea in 2019. LG states this replacement program is being done out of an overabundance of caution and is voluntarily replacing batteries due to its commitment to continuous improvement for customers and industry stakeholders. LG does not acknowledge there is a defect in their modules that contributed to the Korea events. A list of recalled modules for each site is attached.

NEC Service Engineers will coordinate with customers to arrange the change out. Battery module replacement will be conducted according to standard procedures and NEC will handle all the logistics of getting modules to/from sites. [9]

6.11 On the 15th September 2020, the monitoring system recorded at 00:29 hrs: an event/fault with the rack temperature mismatch. The rack temperature spread out of range and the module temperature increased to above the maximum safe level. A temperature rise of $40^{0}C$ in less than 2 minutes was also recorded indicating a rapid independent excursion.

[9] 2020. *LG Module Extended Replacement Service Campaign*. SRO-1220. NEC, p.1.

6.12 During the early stages of my investigation, I conducted a scene examination without entering the damaged container and, I also documented an exemplar container on the same site for comparison this was due to concerns involving stranded energy and contamination. I noted the following:

- Light weight parts of the HVAC system had been thrown up to 23m from the container towards the control room within the fence line.
- The container walls and roof had bowed outwards.
- All four HVACs had come detached from their fittings and landed in a row alongside the container and did not display much fire damage (see photo 4 & 5 in section 13).
- The door closest to The Fisheries had been blown off its hinges and had ripped through the yellow safety rails before landing in the compound. These doors are of substantial weight and it would have taken great internal pressure and force to eject them to the distance observed.
- The larger door at the opposite end to the internal CCTV camera (there are internal CCTV cameras in each container and externally in the compound) was blown open with the smaller door becoming detached and landing next to the container (see photo 2 section 13).
- The internal racking and contents had been extensively damaged and there was significant evidence that the internal container suffered weakening from the heat and the blast (see photo 6 section 13).
- On inspecting the suppression pipework, I noted that the discharge heads were missing and only appeared to have been attached by three threads. The responsible person informed me that PTFE tape and lock tight sealant was used to keep the heads in place.
- The containers are fitted with a NOVEC automatic fire detection system that operates on a double knock system which has two independent fire detection devices: 1, Automatic Smoke Detection System and 2, linear heat sensors (LHS)

6.13 Each of the containers on site had been built in China around 2018 to the NFPA 855 standard (standard for the installation of stationary energy storage systems), although this may not be the most recent edition of the NFPA standards. At the time of writing this report I am unaware of which

edition of NFPA 855 was used. At the time of writing this report there were no UK equivalent standard in place.

6.14 The containers are lined with a foam insulation that is fitted for thermal insulation. Each container has a separation of approximately 5m from the next with inverters and transformers providing a barrier between them.

7 TESTING AND INSPECTIONS (prior to the event)

7.1 The modules were declared compliant with UL9540 (an American industry standard for safety energy storage systems and equipment) I have requested a copy of the UL9540 standard and a copy of any documentary evidence that confirms compliance to this standard. To date this evidence has not been made available to this investigation.

7.2 Ørsted informed me that they have exchanged 32 modules in the past on this site and have noted that there were no signs of swelling of the cells or any signs of failure or damage across their sites.

7.3 The responsible person, when asked, did not have any documentary confirmation to show what tests have been conducted by the manufacturer, supplier or customer regarding the safety of the cells, or if they have been tested to destruction. It has been confirmed by the responsible person for the site that, testing under the transportation regulations UN38.3 was conducted for T1-T5 and T7, I am not in possession of the results. The tests are as follows:

T1 – Altitude Simulation (Primary and Secondary Cells and Batteries)

T2 – Thermal Test (Primary and Secondary Cells and Batteries)

T3 – Vibration (Primary and Secondary Cells and Batteries)

T4 – Shock (Primary and Secondary Cells and Batteries)

T5 – External Short Circuit (Primary and Secondary Cells and Batteries)

T6 – Impact (Primary and Secondary Cells)

T7 – Overcharge (Secondary Batteries)

T8 – Forced Discharge (Primary and Secondary Cells)

7.4 Prior to the incident, data shows that none of the cells within the effected container showed signs of charging slower than normal or any other anomalies.

7.5 The site is inspected every month. The inspections are general examinations and groundwork maintenance lasting for approximately 6 to 8 hrs. This includes a basic inspection inside the containers consisting of a 15-minute visual inspection.

7.6 NEC conduct longer maintenance sessions every 6 months on the batteries which includes a thermal check of the power connections after running at full load for 20 minutes. Workers are on site for two days over this period and normally have the fire systems maintenance contractors with them at the same time.

8 CAUSE OF THE FIRE (Range of ignition sources)

8.1 During the course of the investigation and scene examination I considered a number of ignition sources including; deliberate ignition and cell defect**.** Other sources of ignition such as, smoking and fireworks were ruled out, as there was no evidence to suggest that these were likely sources of ignition due to the security of the site, the container being secured and the CCTV footage showing that no one had been on site leading up to the ignition.

8.2 I have conducted an internal examination of the container and affected rack as well as an examination of exemplar modules taken from the other containers.

8.3 Examination of the identified racks, modules and remaining cells in situ was conducted jointly in May 2021. In the time since the incident occurred there has been on site security at all times. Although some parts of the container were exposed to the elements, the area of interest was protected by the walls and roof of both the container and the rack itself.

8.4 The co-operation Ørsted and other relivant parties has aided me with my investigation. This has been through the sharing of information, research, data and joint examinations.

8.5 **Deliberate ignition**

The investigation found no evidence that the fire was caused by deliberate ignition, in drawing this conclusion I considered both the CCTV footage and that the site was secure with restricted access.

8.6 **Cell failure**

Due to the extent of the damage to the racks and modules within the container, I have relied on the information provided by the responsible people for the site and equipment, along with the data that has been captured from the sites management system and the examination of scans of both damaged and exemplar cells by [redacted]. The data shows that there were issues with battery zone BZ3-R7M6 prior to the explosion.

8.6.1 When reviewing the internal CCTV, there is evidence of fumes and vapours (produced by thermal runaway of the cell) transiting through the container at low level until reaching the door closest to the Fisheries which is where the camera was positioned. Light can be seen at the opposite end of the container which appears to be the emergency lightings which was illuminating the exit signs.

8.6.2 The vapours are likely to be the result of a cell or cells venting as a consequence of overheating. The cause of which is unknown at this time but, it could be attributed to either:

- Thermal abuse – exposed to high heat from external sources; (no evidence found in data provided)
- Electrical abuse – overcharging, rapid discharging, unbalancing; (no evidence found in data provided)
- Mechanical abuse – development of an internal short circuit, leading to a high current flow with consequent local heating; (no evidence found in data provided)
- Internal defects – detritus, other contaminants; (due to the cell damage I was unable to discount any defects internally)
- Environmental abuse – seismic, flooding, absent or poorly designed HVACs. (no evidence found in data provided)

8.6.3 The failure of the cells caused it to enter thermal runaway. *The thermal runaway can be described as 3.3.20. The condition when an electro- chemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.* (NFPA 855 , 2020) (NFPA 855 , 2020)

Ørsted informed me that: ***Some swelling is expected to occur during normal operation of a well-manufactured lithium-ion cell. Gas generation in the cell, which causes swelling, is a result of electrolyte decomposition. There is minor incompatibility between the liquid electrolyte and electrodes used in conventional, commercially available cells. As such, the electrolyte breaks down where it meets the electrode, resulting in gas generation and solid passive layer that forms over the electrode surfaces. Additionally, any external temperature increases could cause further electrolyte degradation within the cell and lead to swelling. As I have not seen the design specification I have been unable to verify if the swelling is a design feature.***

It is possible that the cells have been fitted close together in the module limiting any expansion area. This would present increased thermal contact between the cells. At this point the internal vapours and fumes would then vent which was witnessed filling the container on the internal CCTV.

The following was also noted from the CCTV footage:

- 00:37 hrs the doors appear to be in the closed position. The power is still on to the container and the racks and the lights can be seen on the alarm panel.
- 00:38 hrs camera becomes obscured with smoke/vapours gasses
- 00:39 hrs vision becomes clear and the doors are open. The smoke and vapours dissipate and items can be seen on the floor of the container.
- The external camera shows the doors being blown off and a spray of flame and sparks briefly being expelled before dying back
- 00:57 hrs Significant free burning now visible on the external camera

The module data showed as failing first was on the replacement program which was planned for changing in December 2020 and is referenced in section 6.8 page 15.

Based on my investigations, the evidence is consistent with the initial cell having suffered an exothermic reaction which then lead to a thermal runaway which resulted in flammable and toxic vapours being produced. Work conducted by Pacific Northwest National Laboratory shows that cells can give off the following toxic vapours:

Hydrogen Fluoride, Hydrogen Sulphide, Hydrogen Chloride, Hydrogen Cyanide, Hydrogen,

Propylene, Methane, Carbon Monoxide, Sulphur Dioxide, Ethylene, Ethane

The internal CCTV shows the vapours (vented gases-droplets of organic solvent from the cells) building up at low level filling the container as to started to reach their flammable limits, before coming into contact with an ignition source, the exact ignition source within the container is not known. The vapours ignited causing a deflagration which blew off both doors and caused the HVACs to come detached from the roof as well as deforming the container.

9 FIRE SPREAD

9.1 The thermal runaway started in module BZ3-R7M6 when the lithium ion battery cells failed. This led to a rapid rise of temperature of this cell which then caused a chain reaction of the other cells within

the module. The vapours being given off by the cells subsequently filled the compartment and activated the detection system. As the reaction remained localised, within rack three, in zone seven, and modules BZ3R7M1, BZ3R7M2, BZ3R7M3, BZ3R7M4, BZ3R7M5, BZ3R7M6, BZ3R7M7, BZ3R7M17 and run 1 to 17 from top to bottom, (data shared by Ørsted as seen in image 6 page 13). The BMS reported a maximum temperature being reached. This localised containment prevented linear heat cable being affected, which consequently led to the suppression system not activating immediately.

9.2 After attending a joint online examination of the cylinder and activator due to Covid restrictions, it indicated that the suppression system had been released electronically (the pin was in the activated position). The records from the monitoring system suggests that this was not whilst the communications were still functioning. i.e. the system did not operate due to the detection system in conjunction with the thermal wire. It is my opinion that it possibly activated as the event escalated and after communications were lost at the point when the deflagration occurred. The deflagration moving through the container would have had the force to trigger the break glass point below the fire alarm panel.

9.3 The examination of the suppression assembly also showed that the bursting disk had operated, which may be due to the cylinder discharging as the release valve resets and seals the cylinder; as the fire heated the sealed vessel, the bursting disk might have then triggered/operated. Alternatively, the activator could have triggered, but failed to release the contents, leaving it full and causing the bursting disk to operate when it was heated.

10 CONCLUSION

10.1 The findings of this investigation conclude that this event occurred following a failure within Battery Zone 3-Rack 7 Module 6 (BZ3-R7M6) which led to a thermal runaway. The thermal runaway caused the cell to vent vapours and, when a flame was present within the container ignited vapours/gases causing a deflagration forcing the doors off ether end and causing the HVACs to become unmounted from the roof. I have been unable to identify the root cause of the failure within module 6.

10.2 The suppression system was most likely discharged due to the deflagration which either, activated the alarm or the pressure activated the break glass media trigger below the alarm panel.

10.3 Following [redacted] review of the CT scans he has stated:

X-ray Computed Tomography (CT) provides a non-destructive tool for 3D imaging which has been widely applied to batteries. The physical size of the object is inversely proportional to the resolution

that can be achieved (i.e. smaller feature sizes are observable in smaller samples); therefore owing to the large form factor of the batteries in question, the resolution that has been achieved is limited and only macroscopic features within the cell architecture are visible.

Furthermore, the fire damaged batteries recovered from the incident had undergone such significant failure, that the scans of these batteries have not provided substantive insight as all registration of the cell architecture has been lost. This is not uncommon in battery failures where the excessively high temperatures during thermal runaway processes can destroy the cell components.

X-ray images of exemplar cells recovered from neighbouring containers do provide some information relating to the state of health of the (non-failed) cells. Clearly, these cells have not undergone failure and to my understanding were in operation up until the point of the incident, after which they were recovered from the scene having not themselves failed. Within these exemplar cells, there are indication of gas generation; this has been observed both by a simple visual inspection of the cells (which shows pockets of gas immediately adjacent to the cell surface), and by X-ray CT which shows the presence of gas leading to distortion of the cell architecture in some cases.

Gas generation in Li-ion batteries principally occurs due to electrolyte decomposition – this can happen due to excessive heat, or over-voltage in service (which could be external or could be a result of a defect with the cell or BMS), but is more likely associated with solid electrolyte interphase (SEI) formation during formation and operation:

The electrolytes used in Li ion batteries are not stable across the full voltage window of operation, and they decompose to form a SEI layer at the anode. This happens in large measure during the original manufacturing process where the cells undergo a highly managed 'formation process' whereby the cells are cycled at very low rates to form a stable SEI. The accompanying gas generation can then be managed, by degassing the cell before production is finalised. Some cell geometries have hard cases and 'empty space' which can accommodate the generated gas, but pouch cells would usually require degassing as the soft casing material cannot withstand over pressure, and there is not empty volume for generated gas. After manufacture, the formation of the SEI layer will continue but at a much lower rate, and there before the accompanying gas evolution is much lower. SEI will continue to form over the lifetime of the cell, but excessive SEI

formation and accompanying gas evolution causing the cell to swell is of concern and has safety implications.

Within the exemplar cells, there is evidence of gas generation, although not to the extent that it has caused failure. Without a granular understanding of the operational history of each of these exemplar cells, it is not possible to assign the root cause of this gas generation with certainty, or to predict how this may have progressed were the cells to continue operational service. However, the presence of gassing indicates that the exemplar cell's state-of-health had degraded.

11 GLOSSARY OF TERMS

Area of Origin

The specific location or place where the fire initially started.

Automatic Fire Detection (AFD)

A fire alarm system comprising components for automatically detecting a fire, initiating an alarm of fire and initiating other action as arranged; the system may include manual call points.

BESS

Battery Energy Storage Systems

BMS

Battery Management System

Burn Pattern

Created when applied heat flux are above the critical thresholds to scorch, melt, char or ignite a surface.

Combustion

Oxidisation that generates detectable heat and light.

Deflagration

A very rapid oxidation with the evolution of heat and light and the generation of a low-energy pressure wave that can accomplish damage. The reaction proceeds between fuel elements at subsonic speed.

Exemplar

A person or thing serving as a typical example or appropriate model

Exothermic reaction

Generating or giving off heat during a chemical reaction

Fire

A rapid oxidation process with the evolution of light and heat in varying intensities.

Fire Investigation

The process of determining the origin, cause and development of a fire or explosion.

Fire Spread/Development

The movement of fire from one place to another

Flame

The luminous portion of burning gases or vapours.

Fire Appliance

An appliance that is capable of carrying a multitude of equipment and firefighting media (such as water and foam) to deal with different types of emergencies.

Fire Control

A control room used to handle emergency calls for the fire services and mobilise resources to deal with incidents.

GBS

Grid balancing system

Heat transfer

Spread of thermal energy by convection, conduction or radiation.

HMEPO

Hazardous Materials and Environmental Protection Officer

Ignition

The process of initiating self-sustaining combustion.

Linear heat detection

The heat from a fire causes the LHS cable's special insulation to melt at a specific temperature, allowing the two conductors to short together, thus creating an alarm condition on the fire control panel. The LHS cable may also be used as a stand-alone contact device. The LHS normal operating state is an open circuit.

Lithium-Ion Battery Energy Storage Systems:

A system comprised of one or more lithium-ion batteries assembled together, capable of storing energy in order to supply electrical energy at a future time

Point of Origin: The physical location where a heat source and a fuel come into contact with each other and a fire begins.

Radiated Heat: Energy radiated by solids, liquids or gases in the form of electromagnetic waves as a result of their temperature.

Self-heating

An exothermic chemical or biological process that can generate enough heat to become an ignition source; spontaneous ignition.

Stored/Stranded Energy:

A condition where the system has been electrically isolated but there is still residual charge in the batteries.

Suppression system

Fire suppression systems are used to extinguish or prevent the spread of fire in a building. Suppression systems use a combination of dry chemicals and/or wet agents to suppress equipment fires.

Scientific Method:

The systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypothesis.

Smoke:

Airborne products of incomplete combustion.

Soot:

Black particles of carbon produced in a flame

Thermal runaway:

Thermal runaway is defined with in NFPA 855 3.3.20 2020 as, Thermal Runaway. The condition when an electro- chemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.

Vapour:

The gas phase of a substance, particularly of those that are normally liquids or solids at ordinary temperatures.

Signed

[redacted]

Station Manager

Incident Investigation Team

08th February 2022

12 AERIAL VIEW OF SITE

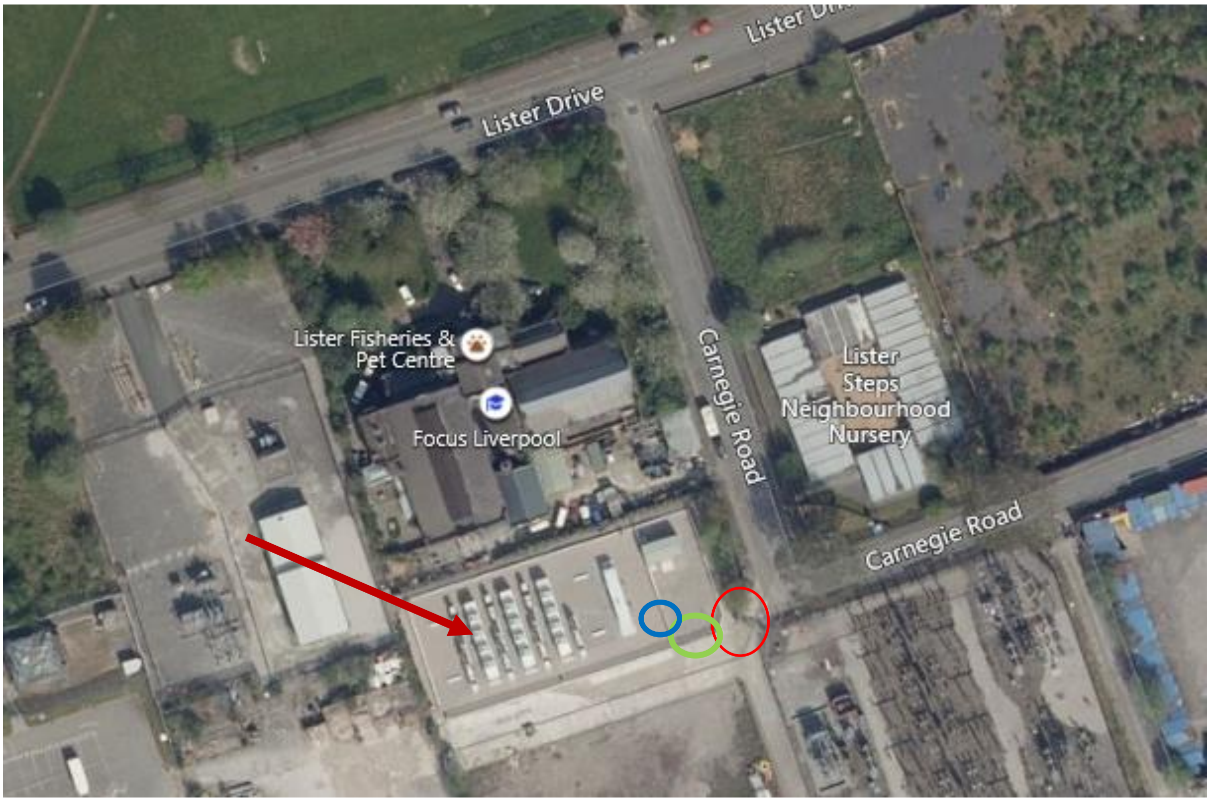
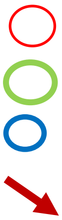


Image 15



Main gate was secure on arrival

Second gate

Third gate

Affected container

13 KEY PHOTOGRAPHS

	Description	Frame number
1	Over view of the scene	IIT_5248
2	Air unit overview	DJI_0237
3	Left aspect of container one	IIT_5290
4	Right aspect of container one	IIT_5303
5	HVACS after coming dismounted from the container roof	IIT_5329
6	Internal view of container one from the Fisheries side.	IIT_5519
7	Consumer unit in container one	IIT_5518
8	NOVEC system in container one with damaged pipe work	IIT_5516
9	NOVEC system in unit two	IIT_5505
10	Alarm panel, emergency activation points and consumer unit	IIT_5504
11	External CCTV pre blast	CCTV
12	External CCTV at point of blast for the door fails	CCTV
13	External CCTV showing flaming discharge consistent with a failing Lithium cell failing	CCTV
14	External CCTV showing the door being blown open and the smaller door coming detached	CCTV
15	Internal CCTV showing the activated alarm panel to the bottom left, the NOVEC system to the bottom right and the fire exit door in the bottom centre.	CCTV
16	Internal CCTV 00:37 vision begins to become obscured	CCTV
17	Internal CCTV 00:38 vision becomes clearer and the fire exit door has failed. No power can be seen on the fire alarm panel	CCTV
18	R7 Z3 after the containers had been cut in to sections	MB0_7375
19	Location that module 6 would have been pre fire. The modules had melted and collapsed	MB0_7397
20	R7 after the side of the rack had been cut away	MB0_7402
21	Close up of the module of interest before removal	MB0_7421
22	Shows the flooring at the foot of R7. The floor had wood boarding fitted which had burnt through.	MB0_7450

1

Overview of the scene

2

Air unit overview. The red arrows show the resting place of the doors

Fire Investigation

3

Left aspect of container 1

Fire Investigation

4

Right aspect of container one

5

HVACS after coming dismounted from the container roof

6

Internal view of container one from the Fisheries side

7

Consumer unit in container one

8

NOVEC system in container one with damaged pipe work

9

NOVEC system in unit two

10

Alarm panel, emergency activation points and consumer unit

11

External CCTV pre blast

12

External CCTV at point of blast for the door fails

Fire Investigation

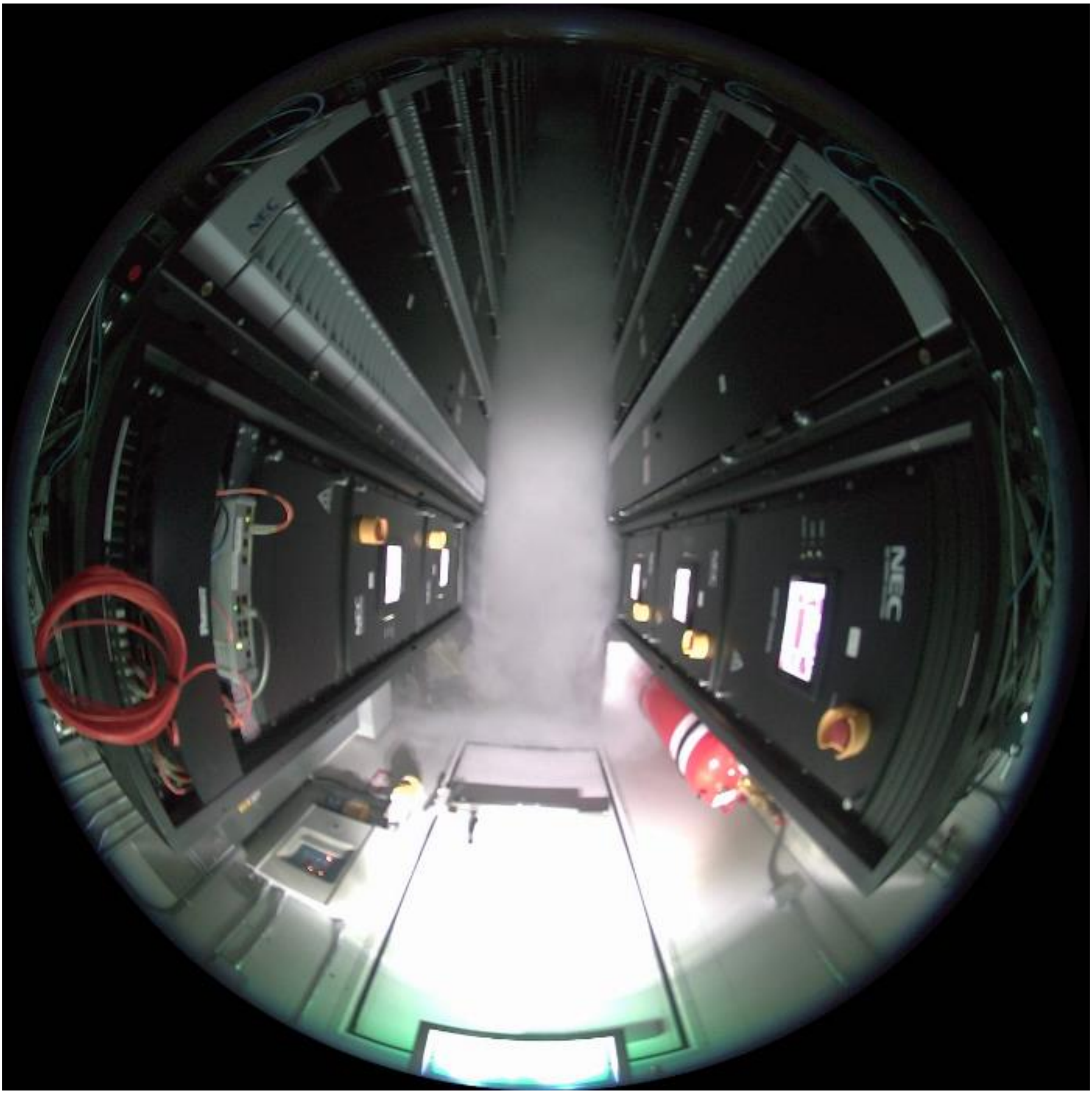
13

External CCTV showing flaming discharge consistent with a failing Lithium cell

14

External CCTV showing the door being blown open and the smaller door coming detached

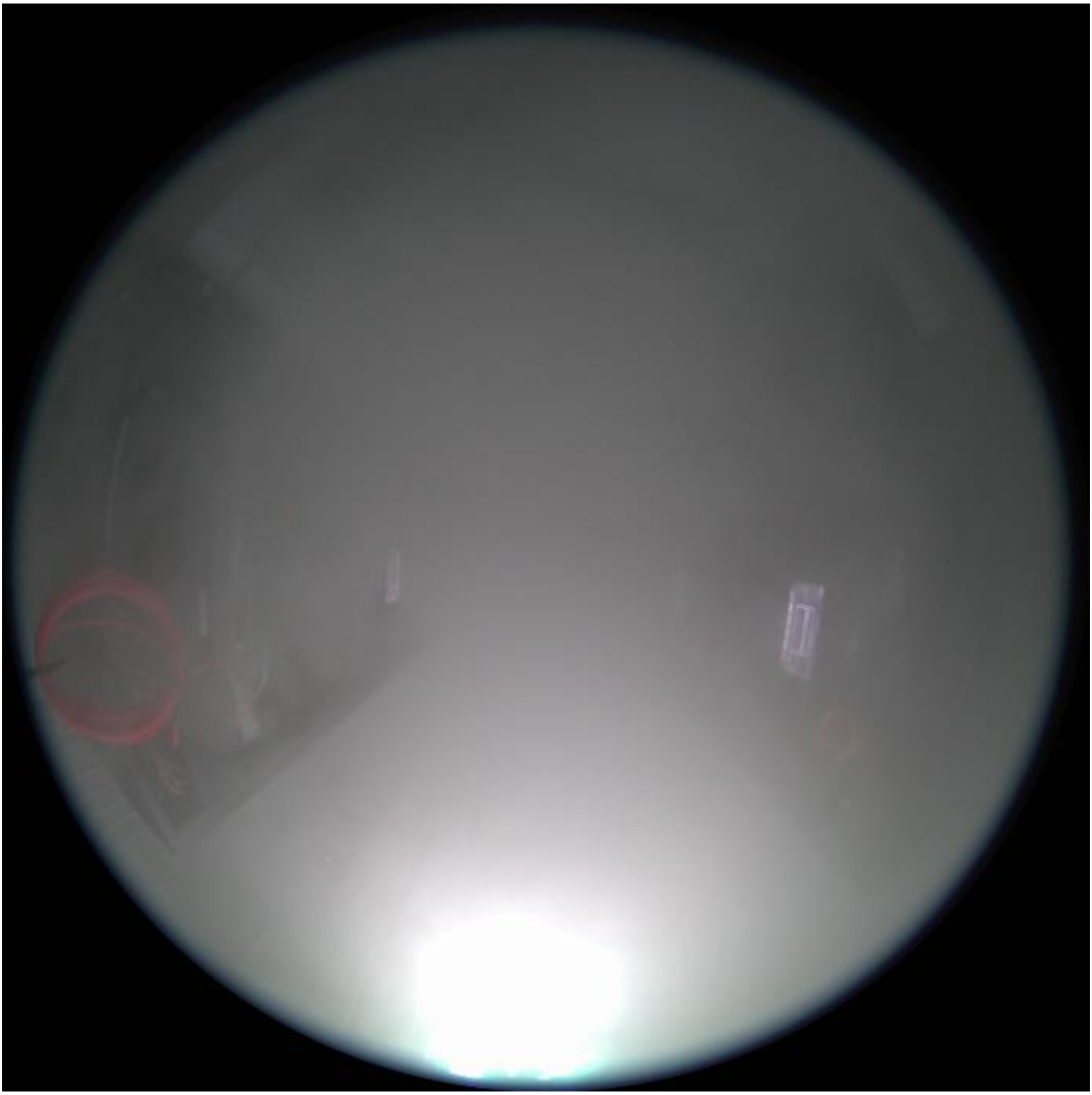
15



Internal CCTV showing the activated alarm panel to the bottom left, the NOVEC system to the bottom right and the fire exit door in the bottom centre. The fish eye view is due to the position of the CCTV camera located on the ceiling near the rear door. A vapour cloud can be scene within the container

Fire Investigation

16



Internal CCTV 00:37 vision begins to become obscured by the vapour cloud

17

Internal CCTV 00:38 vision becomes clearer and the fire exit door has failed. No power can be seen on the fire alarm panel

Fire Investigation

18

Image MB0_7375 shows R7 Z3 after the containers had been cut in to sections.

Fire Investigation

19

Image MB0_7397 shows where module 6 would have been pre fire. The modules had melted and collapsed.

20

Image MB0_7402 shows the side view of R7 after the side of the rack had been cut away. This view shows how the modules have collapsed making recover difficult. To remove them through the front would have pulled the module apart so, they had to be recovered sideways.

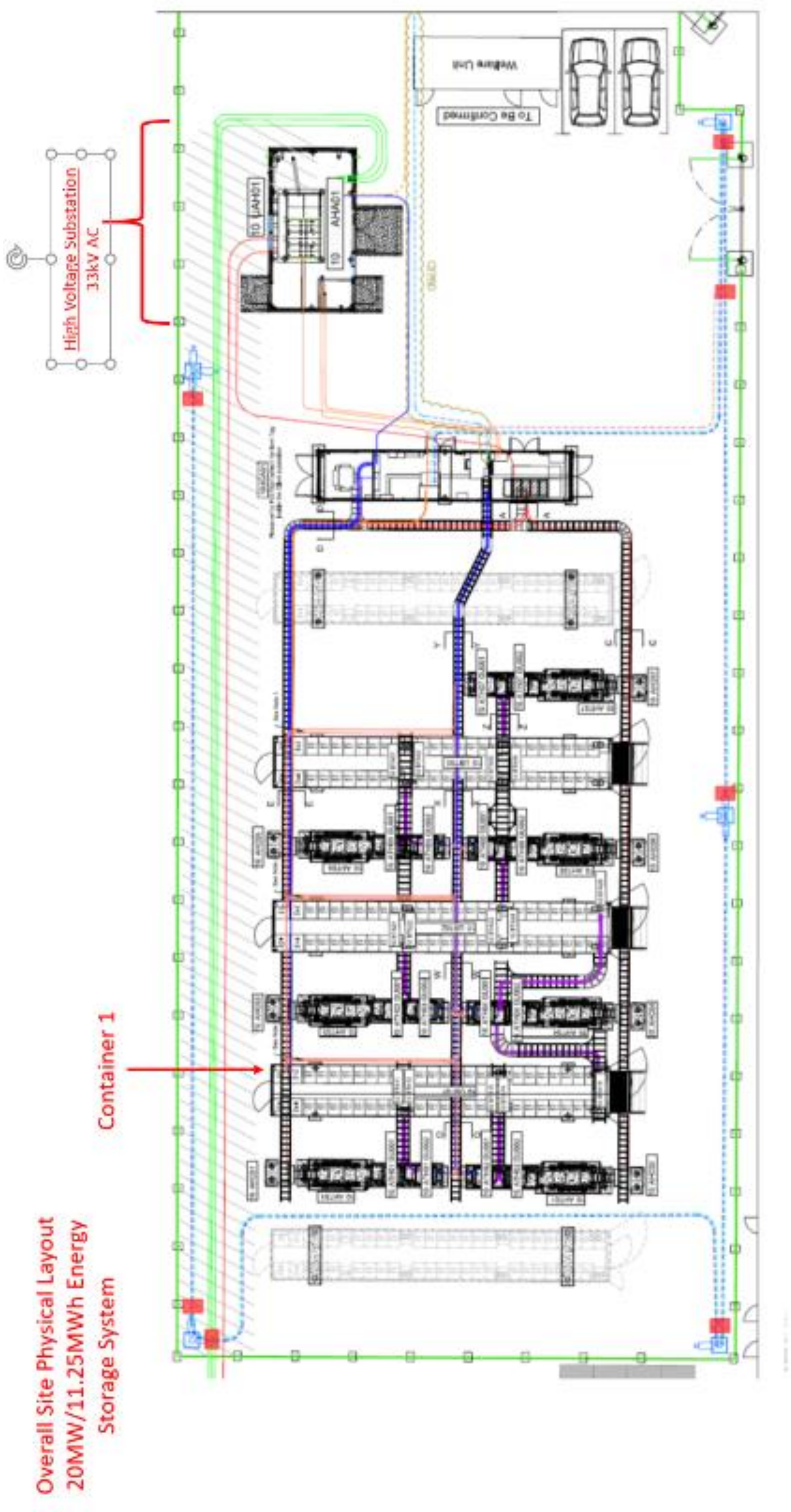
21

Image MB0_7421 is a close up of the module of interest before removal.

22

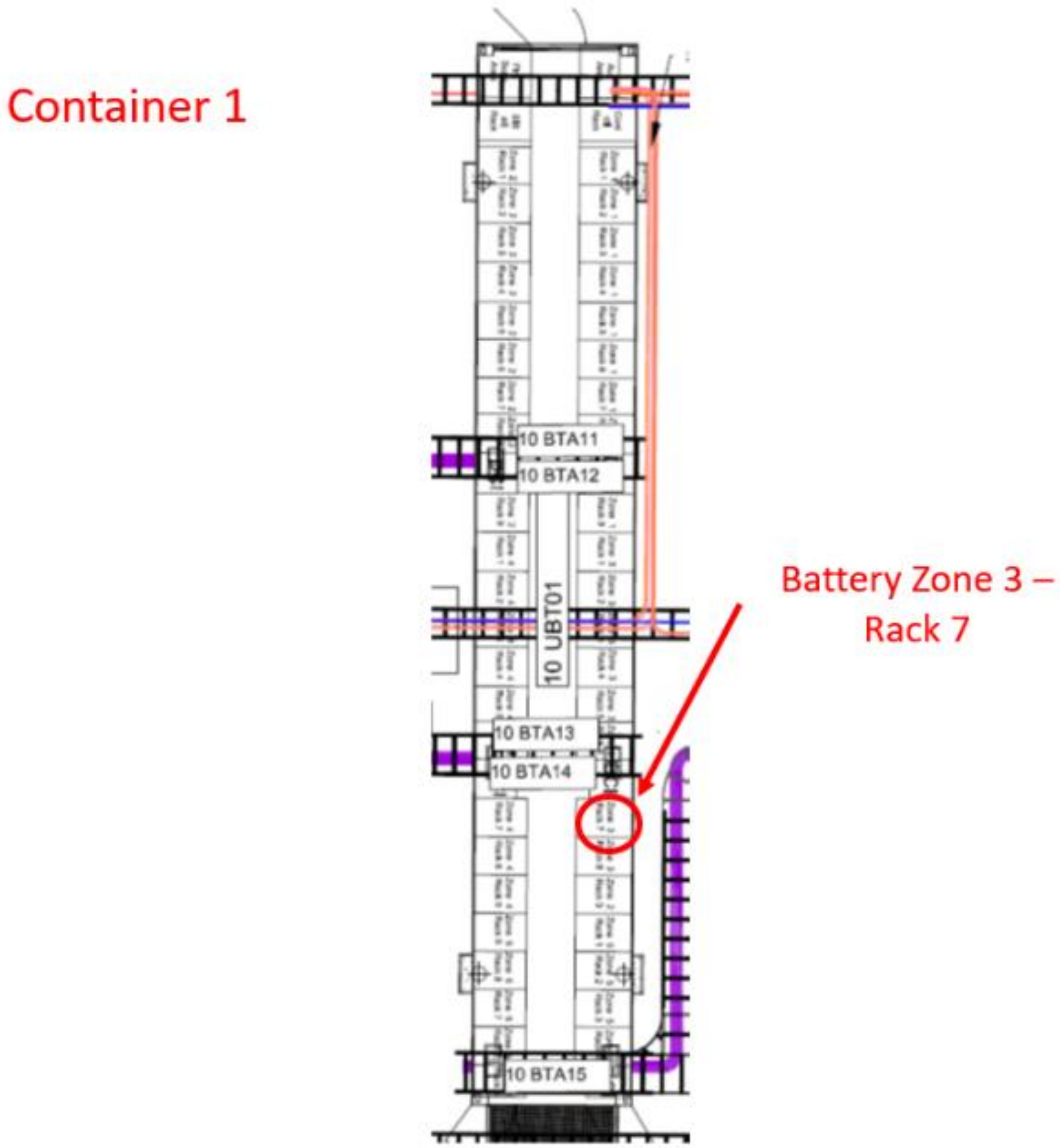
Image MB0_7450 shows the flooring at the foot of R7. The floor had wood boarding fitted which had burnt through.

APPENDIX A Plans



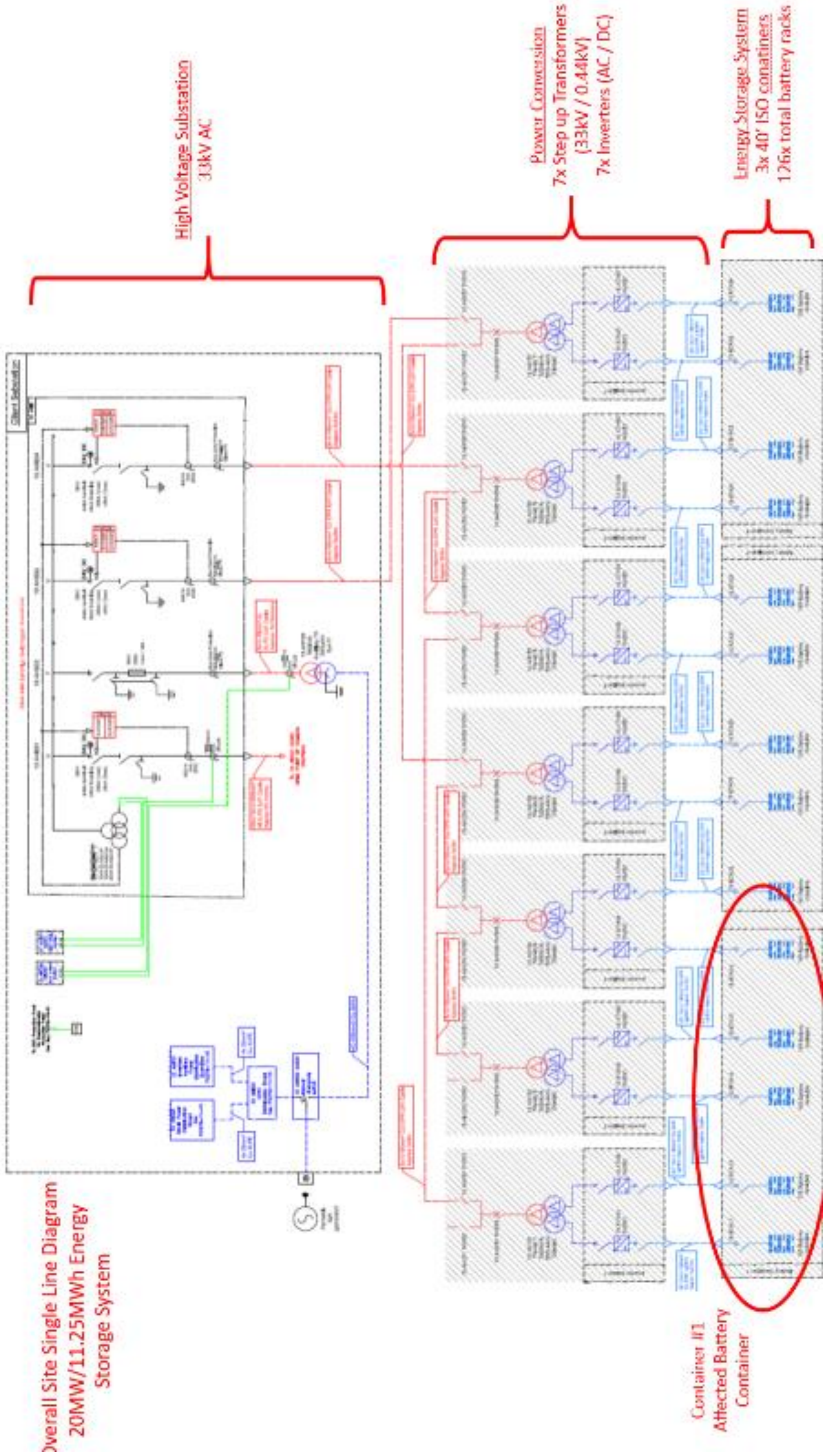
Plan 1 shows the over view of the sites physical layout[10]

[10] 2020. *Overall Site Physical Layout*.



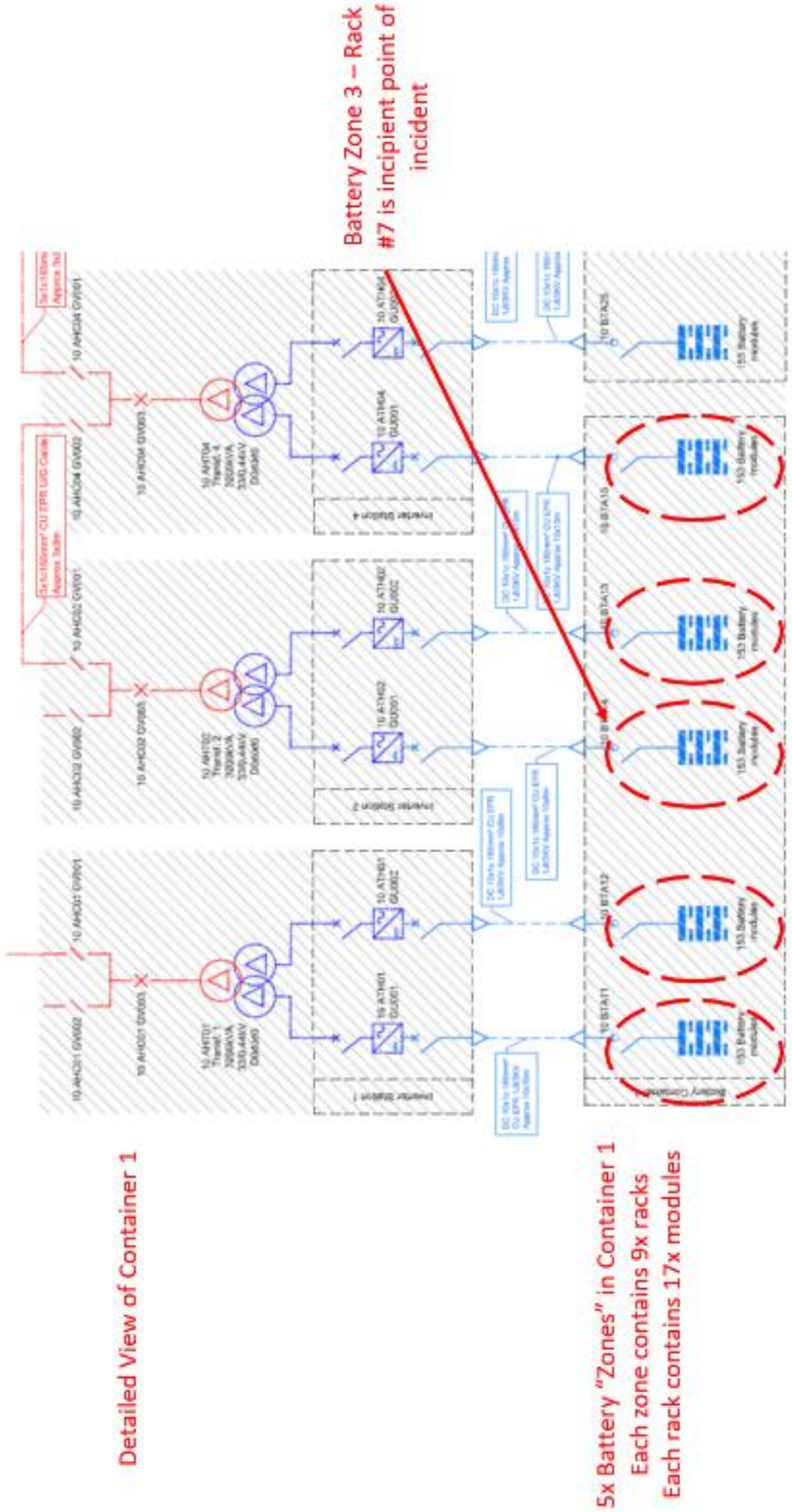
Plan 2 shows the layout of container 1 which is the effected container[11]

[11] 2020. *Overall Site Physical Layout*.



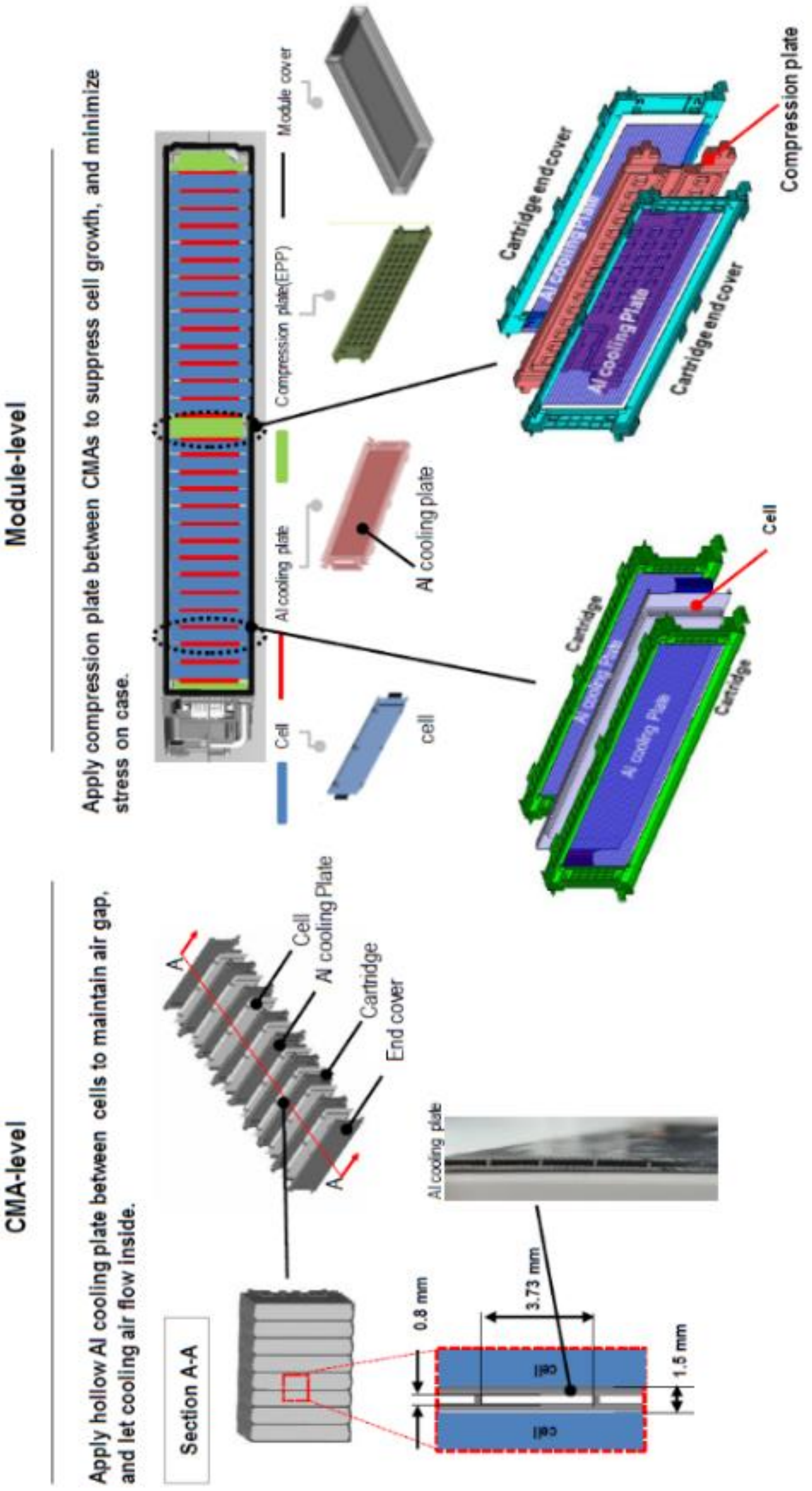
Plan 3 [12]

[12] 2020. *Overall Site Physical Layout*.



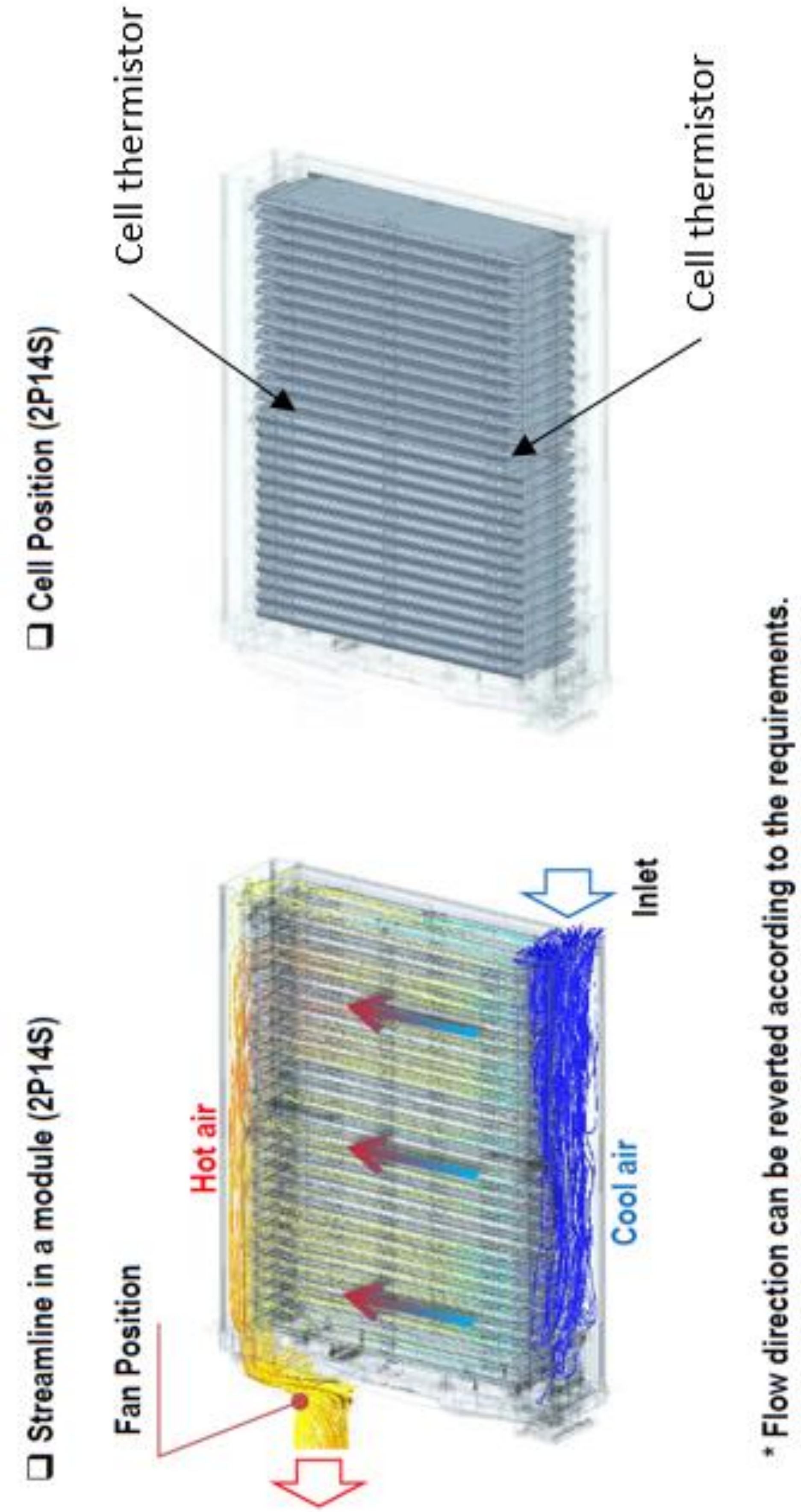
Plan 4[13]

13 2020. [redacted], p.4.



Plan 5 is JP3-2P ACP Module Disassembly[14]

[14] 2020. NEC *Rack, Module & Cell Details*.



Plan 6 JP3-2P ACP Module Air Flow[15]

[15] 2020. NEC *Rack, Module & Cell Details*.

APPENDIX B Codes

During my investigation I asked the responsible person which of the following codes applied to this site.

A, Energy Storage Systems

- UL9540, MESA — Yes
- ASME TES-1, — NECA Not listed
- NFPA 791 — Not listed

B, Installation/application

- NFPA855 — Yes
- NFPA 70 — Yes
- UL 9540 — Yes
- IEEE C2 — Yes
- IEEE 1635/ASHRAE 21 — Not Listed
- IEEE P1578 — Not listed
- DNVGL GRIDSTOR — Not listed
- FM GLOBAL 5-33 — Not listed – insurers normally reference NFPA
- NECA 416 — Not listed

C, System components

- UL 1973 — Yes
- UL 1974 — Not Listed
- UL 810A — Not listed
- UL1741 — Yes
- CSA 22.2 no 340-201 — Not listed
- IEEE 1547 — Yes
- IEEE1679 series — Not listed

There does not seem to be any clear UK industrial standard that I have found at the time of writing this report. There has been a Domestic Battery Energy Storage System review in to safety risks published in September 2020 and I am awaiting to see if the standards will cover commercial BESS. [16]

[16] (BEIS Research Paper Number 2020/037)

SIGNIFICANT INCIDENT REPORT

Incident: 018965 - 15092020

Address: Orsted BESS, Carnegie Road, Liverpool, L137HY

Date of incident: 15th September 2020

Author: Operational Assurance Team

Version 1.2

PURPOSE

A Significant Incident Report (SIR) is completed by Merseyside Fire and Rescue Service's (MFRS) Operational Assurance Team (OAT) following an event/incident to reflect on the actions of the attending personnel, how procedures were implemented and the utilisation of the equipment. The aim of the review is to ensure the Service continues to improve and maximise all opportunities that support operational learning and the Service's Mission Statement of 'Safer, Stronger Communities, Safe Effective Firefighters'.

The report will identify that a significant incident has occurred and will provide:

- Basic details of the incident, including maps and photos wherever possible.
- Details of the resources deployed, performance and any issues arising.
- Areas for consideration for improvement and lessons learned.

Where an SIR is considered appropriate for shared learning, based on reasons of Firefighter safety and/or effectiveness, internal MFRS governance may direct this report to be shared with other Fire and Rescue professionals and/or appropriate third parties.

VERSION CONTROL

This SIR is version 1.2. dated December 2021

It is an updated report from the first report, which was published in November 2020. This report now provides updated information as a direct result of the conclusion and findings from the Fire Investigation (FI) report.

Contents

1 SUMMARY AND KEY LEARNING

Merseyside Fire and Rescue Service (MFRS) attended a fire incident at an Orsted **Battery Energy Storage System** (BESS) site, on Carnegie Road, Liverpool, 15th September 2020. The full details of the attendance, operational findings and lessons learned are contained within the following report. The key learning points are highlighted below:

1. BESS is a rapidly emerging technology with a growing number of sites nationally and internationally.
2. BESS include several different battery types; the Orsted BESS on Carnegie Road is the **lithium ion** (Li-Ion) type of BESS.
3. Whilst there have been a number of significant BESS fires internationally, the Orsted BESS fire incident in Liverpool appears to be the first significant fire of its type to occur within the UK.
4. **MFRS' Operational Risk Information** available for responding crews specific to this site and the hazards associated with BESS was inadequate. This highlighted an internal gap for effective processing of certain Site Specific Risk Information (SSRI) and further highlights a broader gap on the awareness and understanding of BESS sites and their inherent fire risks.
5. The Carnegie Road site is remotely managed and operated by Orsted who are based in Denmark. Isolation can be requested via Scottish Power.
6. The initial fire investigation found that an **automatic fire alarm system** was present and actuated due to the ignition of flammable gases inside the BESS unit.
7. The conclusion of the Fire Investigation (FI) confirms that an **automatic fire suppression system** was fitted and did actuate however, actuation was most likely due to the deflagration, which either activated the alarm or, the pressure activated the break glass media trigger by the alarm panel.
8. The fire caused a **significant blast** event, with debris being propelled between 6 and 23m from the point of origin. This explosion occurred prior to the arrival of responding fire crews.
9. The explosion potential is a significant **risk to emergency responders** that has caused significant injury to firefighters at fire incidents on international BESS sites.

10. The presence of residential premises adjacent to the Carnegie Road BESS site raises concerns regarding the **'off-site potential'** from fire incident risks at BESS sites to the local community.

11. The nature of Li-Ion cells makes them susceptible to a phenomenon called "**thermal runaway**". NFPA 855 3.3.20 Thermal Runaway[1]. The condition when an electro- chemical cell increases its temperature through self-heating in an uncontrollable fashion and progresses when the cell's heat generation is at a higher rate than it can dissipate, potentially leading to off-gassing, fire, or explosion.

12. Once water was applied, the resulting run-off contained **Hydrofluoric Acid (HF)** (confirmed by Bureau Veritas) as a product of reaction between the cells and water contact. "Firefighting run-off was low due to the container involved being sited on a gravel base. Run-off was periodically checked for contamination, which was low. Appropriate environmental protection measures were put in place at the earliest opportunity". The run-off was mainly contained to the site.

13. Bureau Veritas (BV) scientific advisers identified the potential for the **smoke plume** to contain HF and **Hydrochloric Acids (HCl)** as a product of burning lithium cells, however, the dilution rate within the plume deemed the concentration as negligible.

14. Further investigation is underway to fully understand the **regulatory regime** that applies to BESS sites and this incident was brought to the attention of the NFCC (National Fire Chief's Council) Ops Committee, the Health and Safety Executive (HSE) and Home Office (HO). National Operational Guidance (NOG) were also informed to determine current UKFRS risk assessment standards when responding to similar incidents.

[1] NFPA 855 3.3.20 Thermal Runaway

2 INCIDENT DETAILS:

At 00:49hrs on 15th September 2020, MFRS Fire Control received numerous calls reporting a large explosion with smoke and flames visible in the vicinity of the Lister Fisheries and Pet Centre, Lister Drive, Tuebrook, near to Carnegie Road.

Two appliances, from Old Swan fire station [redacted] and Liverpool City Centre fire station [redacted] were mobilised to the incident as per the pre-determined attendance. On arrival, they discovered a large container unit fully involved in fire with evidence consistent of a blast. One of the container doors had been ejected from its setting and was laying some 6 metres away within the secure compound. The compound is highlighted in yellow on the map below:

The first crew established a main jet as an initial defensive firefighting tactic and after a thorough assessment the Incident Commander (IC) identified that the installation was an electrical battery system. A second branch was placed to protect the nearby Fisheries building.

An early assistance message for "make pumps 5" was sent to request resources to support water provision and personnel demands. A Station Manager (SM) was mobilised and assumed command of the incident at 01:32 hours, implementing a sectorised command structure for the effective control of the incident. At this point, it was confirmed that on-site signage identified that the site was a Li-Ion BESS comprising of three storage units and one control unit.

The fire was limited to one of the storage units. Firefighting actions were elevated in response to the incident with a total of three main jets and two ground monitors for cooling and protecting surrounding risks.

At 01:23 hours, Fire Control attempted to contact the listed key holder and responsible person for the site. The key holder did not answer the call so the control operator left an answerphone message.

Orsted Energy, who are responsible for remotely managing the site from Denmark, first made contact with Fire Control at approximately 01:30 hours. Orsted advised that the site posed a substantial electrical hazard to emergency responders stating that the storage unit which was involved in fire was a high voltage energy storage system with a 33 kV connection to the grid. Orsted were able to alert a key holder to attend.

An automatic fire suppression system was present and during the course of the incident had activated however, actuation was most likely due to the deflagration, which either activated the alarm or, the pressure activated the break glass media trigger by the alarm panel.

Due to the nature of the contents, the incident was declared as a fire containing hazardous materials and a Hazardous Materials Environmental Protection Officer (HMEPO) was requested. The HMEPO established communications with BV (3rd party scientific support to MFRS) en route to advise of the incident.

At 01:35 hours, a Group Manager (GM) was informed of the incident and determined to attend based on the hazardous nature of the incident. The GM was on scene at 01:49 hours and later took charge of the incident.

Further information was provided by Orsted at 01:59 hours confirming a **33 kV high voltage** battery hazard within the unit and the presence of Li-Ion cells. BV via the HMEPO provided additional information on the hazards likely to be associated with this incident type including the potential presence of HF in the smoke plume.

A multi-agency meeting was held at 02:25 hours. Messages regarding the toxicity of the plume were communicated via the HMEPO to the scene of operations and the immediate community through warn and inform. Temperature monitoring of the nearest adjacent unit commenced with initial readings of 45ºC at 02:25 hours.

As near-by hydrant fed water supplies were inadequate to meet the needs of the ongoing firefighting, a High Volume Pump (HVP) was requested via National Resilience Fire Control for the purposes of augmenting water supplies, this was mobilised at 02:19 hours.

Firefighting action from Sector 1.

2 ground monitors at work.

Fisheries building visible upper right corner.

Following the initial request by Fire Control at 01:18 hours for the attendance of Scottish Power; at 02:46 hours Scottish Power confirmed that the 33 kV element of the site had been isolated.

The HMEPO identified that there was potential for the presence of HF being released due to the nature of the fire. This release would be mixed in an unknown concentration with the firefighting water run-off. At this point, the water was being managed in an on-site gravel soak away under the containers on site.

At 02:51 hours, the GM assumed command due to the complexity and protracted nature of the incident and off-site potential. An Orsted Technical Officer was mobilised to the incident from Lincoln (estimated time of arrival 04:30 hours).

At 03:27, hours testing of the firefighting water run-off commenced with an initial reading of pH 8, confirming the presence of a base alkali in the water run-off.

It had been identified that an occupied property was attached to the Fisheries and Pet Centre and by 04:19 hours fire crews had investigated and confirmed that the occupier was unharmed.

Orsted continued to actively monitor the incident remotely via the CCTV system which enabled them to provide additional precautionary risk information regarding the hazards of operating in the vicinity of the involved container.

The HMEPO conducted a further set of pH testing at 04:10 hours and found the levels at pH 7. The run-off water was still being contained on site.

Due to elevated temperature levels from within the affected unit, operational tactics continued to deploy cooling techniques and temperature monitoring.

At 04:52 hours, the Orsted Technical Officer arrived at scene and liaised with the IC and provided specialist advice.

Defensive firefighting continued on site for a total of 59 hours, involving predominantly a 2 pump attendance (concluding 17th September). During this period, the Incident Investigation Team attended to commence their investigation and establish the cause of the fire. HMEPOs continued to conduct localised environmental monitoring throughout this period.

Aerial footage was recorded from scene following a request to [redacted] for the use of a drone (attending at 12:41hours on 16th of September).

Firefighting operations ceased with a full external handover at 10:44 hours on 17th September. At the point of hand over the pH levels within the water run-off were neutral (pH 7) but high alkaline levels were recorded within the unit (pH 14).

All operational MFRS resources left site by 11:00 hours on the 17th September.

3 TIMELINE:

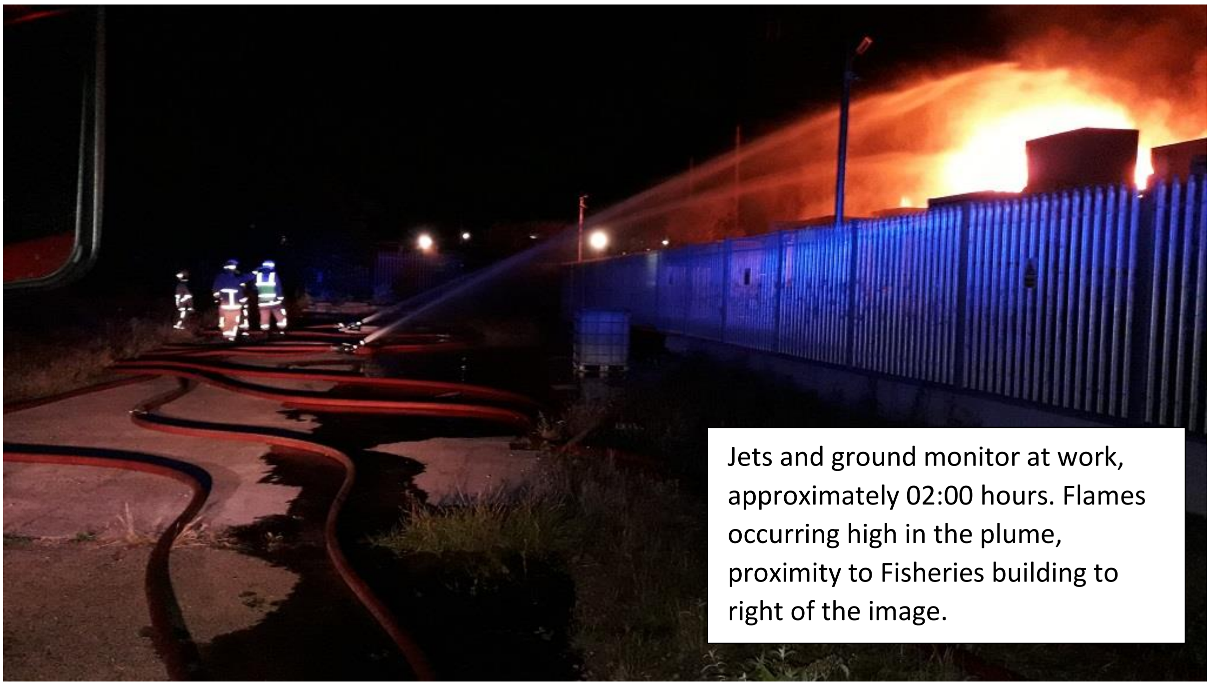
Time	Orsted Bess Incident (No. 018965) 15th September 2020
00:49	First call received by MFRS Fire Control.
00:52	Appliances mobilised to large explosion near the Fisheries, Lister Drive
00:54	Numerous calls received to large explosion with smoke and flames
00:57	First appliance, [redacted], in attendance
01:03	Informative message, crews attempting to gain access
01:06	Assistance Message Make Pumps 5
01:11	Informative Message from WM, large refrigeration unit well alight, 1 Main Jet
01:18	Informative Message from WM, large grid battery system container involved, 1 Main Branch and 2nd Main Branch to protect Fisheries building
01:25	SM in attendance
01:32	Informative Message from SM, 2 main jets and 1 ground monitor on battery storage and boundary cooling of adjacent containers.
01:34	SM advised of call from Orsted Energy, Denmark
01:42	SM OA in attendance
01:49	GM in attendance
01:55	SM declares a Hazmat Incident
01:59	Further call from Denmark. They are monitoring incident on CCTV. 33 kV and High Voltage
02:00	SM HMEPO requests BV to discuss incident
02:19	Request HVP
02:25	SM informative. Multi-Agency meeting with police. Made aware of toxicity of smoke plume. Temperature readings of adjacent containers. Sector 1, 2 ground monitors and 1 main jet. Sector 3, 2 main jets
02:34	MFRS Corporate Communications officer informed
02:39	Level 1 Welfare requested
02:46	SM requests Fire Control to inform Environment Agency of possible HF in water run-off
02:46	Scottish Power confirm power has been isolated on 33 kW network
02:49	HVP booked mobile to incident
02:51	GM Incident Commander
02:56	HVP In attendance
02:57	Orsted Energy sending 2 technical officers
02:57	United Utilities requested to increase water pressure
03:27	From GM, water tests show a reading of 8 to 9 pH
03:39	From Orsted Energy in Denmark, Monitoring CCTV, informed Fire Control that FF's must not enter battery containers

04:19	SM Informative message states that adjacent Fisheries Building has been checked internally
04:25	SM HMEPO has updated EA on progress and are confirmed correct actions
06:43	WM now IC 2 pumps required and now for remainder
STOP	10:44 on 17th September 2020 by WM [redacted]

4 Incident Photographs:

Fire development from the unit at approximately 01:30 hours.

Note the intensity of fire and therefore heat from the centre of the unit and extension of flame into the plume.



Jets and ground monitor at work, approximately 02:00 hours. Flames occurring high in the plume, proximity to Fisheries building to right of the image.

Ground monitors in use and personnel upwind of plume approximately 03:00 hours.

Information on plume toxicity gained at this point.

Ground monitor in use at approximately 05:15hrs.

Note sections of railings opened by MFRS to allow straight play of monitor jet.

Image above: Taken from [redacted] AIR Unit. Full extent of damage visible. Roof mounted cooling units ejected to side of unit. Pressure damage visible along length of unit. Note scorching of top edge of second unit to mid-right of image. Firefighting tactics mitigated further spread and damaged beyond original unit and blast.

Image left: FI Photography, note pressure damage and expansion of unit above burn line pattern. Remains of cooling unit pictured to left hand side.

5 Operational Assurance Team Areas for Further Investigation

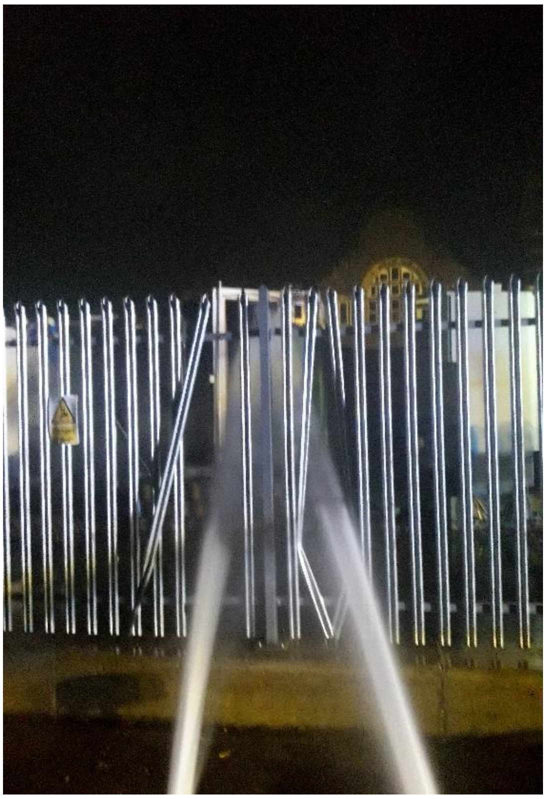
Foreword: Due to the unique nature of this incident, the areas for investigation will include details of the construction, hazards and issues presented by Li-Ion units when involved in fire

Pre-Determined Attendance (PDA):

The initial PDA of two appliances is in accordance with MFRS mobilising action plans attached to an incident type of a reported explosion/fire in the open. This information was given by the caller prior to alerting crews.

Firefighting Tactics:

Water was used as the sole firefighting medium for the duration of the incident due to its immediate cooling properties. The initial attending crews utilised main jets from the edge of the compound due to anticipated firefighter risks.



After the recognition that this site was an electrical grid battery installation, the immediate tactical plan was to adopt defensive firefighting tactics by implementing covering jets around the unit and not to deploy firefighters into the immediate vicinity.

When resources allowed further ground monitors were brought into use to contain the fire, mitigate further fire spread and protect surrounding buildings.

The fire was brought under control by 06:30 hours; however, the energy dissipated by the fire and continual recycling of heat from the Li-Ion store was to prove an issue during the latter stages of the incident as it continued to burn. This incident type required a continual and prolonged cycle of cooling and temperature monitoring. The initial incident commander considered the use of Compressed Air Foam System (CAFS) and discounted it as an appropriate firefighting media based on the nature of the incident.

Observation: The selection of water was appropriate to the requirements of the incident.

Observation: The unintended consequence of the firefighting action was the release of HF. This occurs due to hydrogen fluoride elements within the unit being produced during the combustion process. The tactic of applying water is correct and necessary to resolve the incident type. A containment strategy was not necessary for this particular incident due to the drain and soak away.

Action: To notify the wider UKFRS sector and share findings through the National Fire Chief's Council (NFCC) and National Operational Learning (NOL) for the continued development of National Operational Guidance (NOG). This action was completed by MFRS November 2020.

Water Supplies:

Immediate water supplies were identified with hydrants being located at the junction of Carnegie Road and Lister Drive for the provision of initial jets. As the incident developed consideration was given to whether the original hydrant and further hydrants identified off Green Lane and Carnegie Road would be sufficient to support operations.

A High Volume Pump (HVP) was requested to support operations. The HVP was mobilised from Belle Vale fire station and located at Green Lane to inspect a 600mm hydrant as identified through the Mobile Data Terminal (MDT). Concurrently, a second set of hydrants had been utilised from Lister Drive and water supplies were deemed adequate to feed 2 ground monitors and 3 main jets. This was to be the maximum required water output for the incident enabling the HVP to be released.

Observation: The MDT hydrant overlays were used to good effect, identifying two nearby and separate mains and a large bore 600 mm hydrant.

Hazardous Material Environmental Protection Officer:

A HMEPO was requested to attend the incident to support the incident commander with information on hazards associated with the smoke plume and water run-off. The HMEPO established communications with BV who act as our 3rd party specialist scientific support. BV were able to advise of the potential for Hydrogen Fluoride to be released from the fire which when mixed with water would produce Hydrofluoric Acid potentially in the smoke plume and in the water run-off.

HF is clear and colourless liquid which is both corrosive and toxic, it is however a weak acid and easily diluted.

A CHEMET report was not requested on the night as wind speeds were low, and conditions were dry. The plume was slow moving and of short range in a northerly direction. There were no residential properties in the vicinity and firefighting operations were reconfigured to be conducted upwind. All agencies on site were informed of the potential hazards and media messaging sent out to warn and inform residents beyond the initial cordons.

The HMEPO conducted testing of the water run-off, returning results ranging between 8 and 9 pH suggesting a base (alkali) being present.

It was reported that the on-site soak away was filled with gravel covered with a fine lime/cement powder, which may have contributed to the alkaline results. All water was contained within this area. Other possibilities for these results include the easy dilution of the acid with the amounts of water being applied to the fire and the water reacting with the Li-Ion from the site to produce lithium hydroxide in the water. This being an alkali which in turn would react with any acid to neutralise it.

Observation: Notable practice from the HMEPO in contacting BV early, in recognition that the risk may be new or unanticipated. Good standard of information fed in from BV and from Orsted via Fire Control.

Observation: The plume hazards were not confirmed but highly suspected to contain HF. Decision to inform crews to remain upwind supported Firefighter safety. Corporate Communications requested to promote close windows/doors message to partner agencies.

Observation: The run-off was tested and confirmed to be moderately alkaline in nature and although HF was considered to be present, HF has a pH of 3.27 per 1 mol and so should show as red/orange during pH testing. The alkaline return of 8-9 suggests that the vast drain base contained a lime element which has potentially neutralized any acidic run off. Whether this was by design or was a coincidence is unknown.

Observation: Final pH readings confirm neutral readings outside of the unit and a high alkaline content within, (pH of 14) consistent with the base metals used in Li-Ion cells. These metals include cobalt, nickel or manganese ions which are alkaline in nature. It is unconfirmed which metal, if not all, were present within the unit.

Action: Identified installations within station areas have revisited Site Specific Risk Information (SSRI) to include health, chemical and environmental hazards underpinned by informed data. This information has been gathered by operational crews in line with existing procedures for familiarisation of local risks.

Action: The SSRI refresh considered combined chemical and health hazards within typical units and should be clearly identifiable to MFRS personnel accessing the risk information for any future incidents at BESS sites. This information should be present and easily obtainable on site.

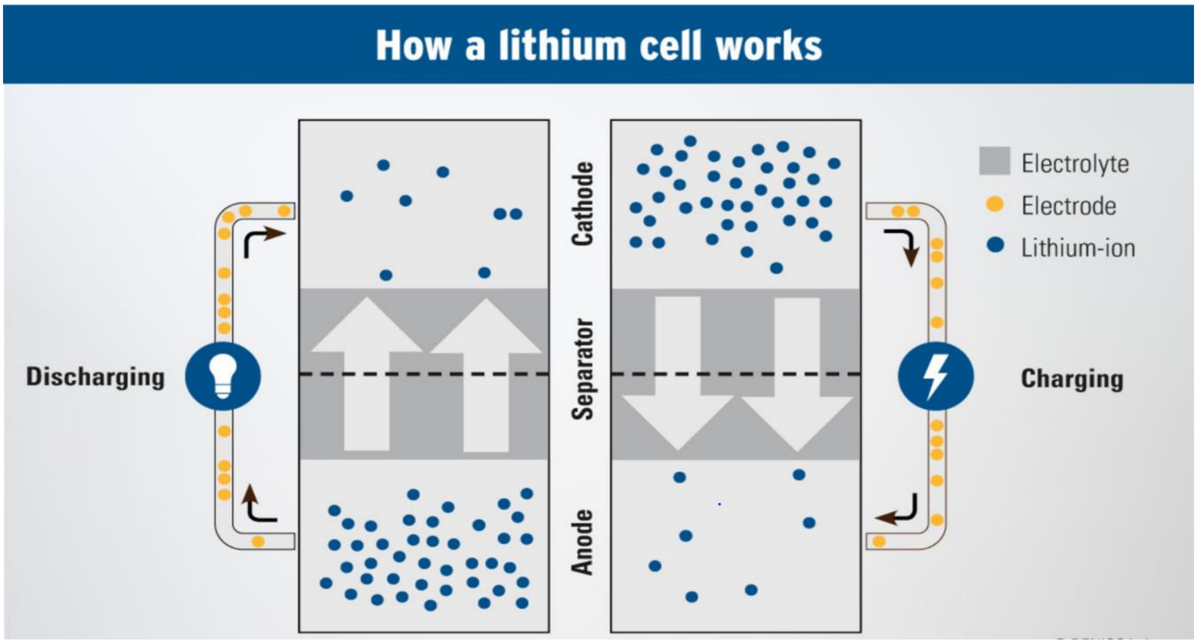
Action: The HMEPO role was crucial in this instance in preserving Firefighter safety. Fire Control action plans have been amended to mobilise a HMEPO if units of a similar nature are identified and involved in fire in future incidents.

Understanding Lithium Ion Battery Units:

A distinction between primary (non-rechargeable) and secondary (rechargeable) lithium ion (Li-Ion) units is required to understand the operation of BESS units. It is reported that the BESS units contain **rechargeable, secondary type** units. A pack (or unit) contains varying amounts of Li-Ion cells. Each cell has a positive (**cathode**) and negative (**anode**) electrode which are connected by an ion-conducting medium (**electrolyte**). **In Li-Ion installations, it is important to note that the electrolyte is a liquid which is readily miscible with applied water.**

Within each cell is a component called the **separator**, which is a physical barrier that prevents internal electrical shorting due to contact between anode and cathode, while allowing ions to pass through.

This information is represented in the **diagram** below: (Copyright Denios Ltd – public domain).



Testing for industry the use of Li-Ion batteries includes 'performance when subjected to: Altitude, Vibration, Mechanical Shock, Forced Discharge, Crush, Blow and Thermal Exposure.

At this point, it is important to be aware that technical information received at the incident suggests the risk of flammability is enhanced when cells are at 100 degrees Celsius or above. This information was provided by BV and reconfirmed by BV as part of quality assurance of this document. The temperature within the units is controlled by the fixed units situated on the roof of each storage container.

Data on risk factors for fire are shown below: (Copyright Denios Ltd – public domain):

Risk of fire due to overcharging or high temperatures

If lithium energy storage is overloaded or exposed to high temperatures, cells may overheat. The so-called thermal runaway is a highly exothermic reaction that can cause the stored lithium to ignite and cause a metal fire. The high heat energy initially leads to evaporation of the electrolyte, resulting in additional heat and combustible gases. If the ignition temperature of a gas is exceeded, it ignites and in turn sets the reactive lithium on fire. Already the thermal run through of only one cell is sufficient to heat up the neighboring cells of the battery pack so far that a momentous chain reaction is created. Once set in motion, it only takes a few minutes for the battery to explode.

Fire hazard due to deep discharge

A deep discharge of lithium-ion batteries is a fire hazard. If lithium-ion batteries are not used for a long time, they can completely discharge. Cold outside temperatures - for example, during the winter months - may favour this effect. Again, it comes to the decomposition of the electrolyte liquid and consequently to the formation of easily combustible gases. If an attempt is subsequently made to recharge the deeply discharged lithium-ion cells, the supplied energy can no longer be correctly converted due to the lack of electrolyte fluid. It can cause a short circuit or a fire.

Fire hazard due to mechanical damage

When handling lithium-ion batteries, there is always a certain risk of damaging them. Collisions with operating vehicles, a fall on hard ground or squeezing under incorrect storage conditions are just a few examples. If cells are deformed as a result, this can lead to internal short-circuiting and fire of the battery. Also impurities in the production of the cells themselves can not be excluded 100%. In rare cases, it is possible that particles that are falsely released into the cell during production damage them from the inside over time. Here, too, internal short circuits can occur.

From this data, we can see the use of the term "**thermal runaway**", which we defined above on page 4, item 11.

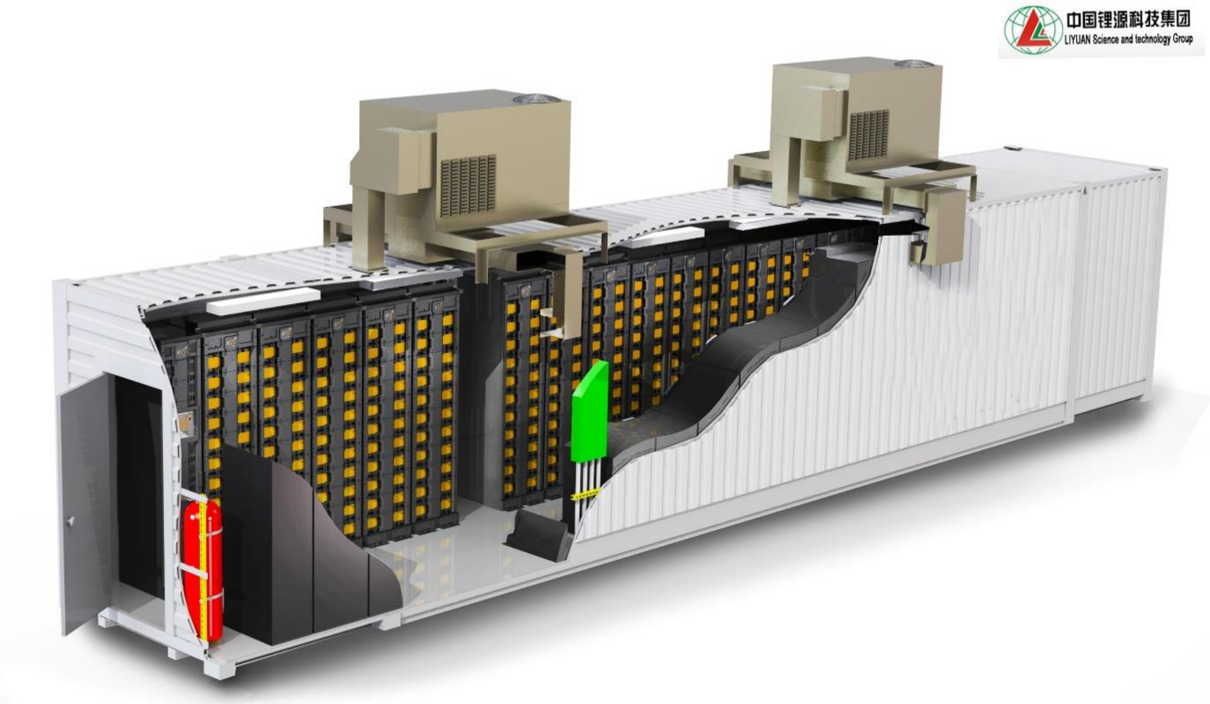
The most likely scenario is that HF conversion is part of the gas evolution during thermal runaway. The liquid electrolyte rarely escapes as liquid and HF would more be gaseous pollutant that is entrained by firewater or deposited on surfaces by the gases.

<u>Li-Ion BESS unit construction:</u>

The system is containerised in a single or multiple steel containers. Battery racks line the walls of the container and there is access from one or both ends of the containers. It should noted that BESS designs are evolving to allow for better venting and battery rack access from outside of the containers, often with no ability for human access. These trends and changes are being seen irregularly through the global market with some countries adopting new codes and driving design changes at a more rapid pace than others.

The system installed at Carnegie road is of a traditional design with Li-Ion cells configured along the walls or vertices of each unit, with conductors terminating in a single point to the destination and charging/control unit. A fixed fire suppression system is installed to control ignition of batteries, usually as a deluge or flooding system comprising of a chemical. In the case of the Orsted incident, this was NOVEC 1230.

Finally, a series of cooling units are fixed to the roof to remove heated air from the unit and maintain safe operating temperatures. A typical design that is representative of Orsted's installation is shown below.



Industry Recommendation for extinguishing Li-Ion Fires:

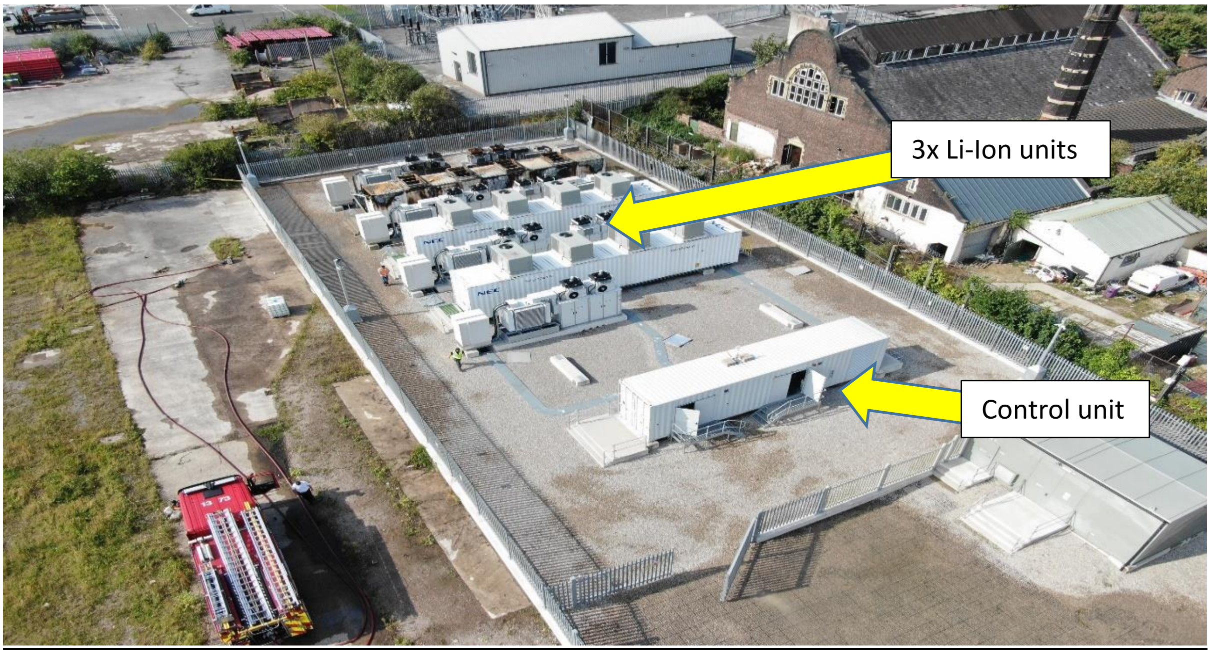
Industry guidance on extinguishing fires involving Li-Ion cells states that the combustion process liberates oxygen and as such, a fire involving a BESS unit should be identified as a "Class D" metal fire and extinguished using a proprietary powder or granular agent.

A typical granular agent would be silicon oxide, which acts as a thermal blanket when exposed to fire, melting and forming a crust over involved objects. An alternative to the above, is an aerosol agent classed as a non-halon under legislation and which is fixable to the internal aspect of the unit.

NOVEC 1230, the extinguishing agent fixed to the Orsted unit, is the latter type of agent, an aerosol of fluorinated ketones. The installation is pressurised with nitrogen, and is released on detection of fire conditions within the unit. NOVEC 1230 is stored as a liquid but discharges as an aerosol, evaporating 50 times quicker than water, absorbing heat and smothering any fire progression.

Industry guidance does not preclude the use of water due to cooling effects and ready availability. It does, however, warn that fluorinated products such as HF or other acids such as hydrochloric acid may be secreted in run offs or vapours and that any soak away may cause environmental damage. This was consistent with BV advice on the night of the Orsted incident.

[redacted] AIR unit aerial view of Orsted BESS:



International Incidents: (with links)

This incident is the first significant reported fire involving a Li-Ion BESS unit in the UK. As such, the intent of this report is to inform internally, then nationally through the NFCC and NOL, to support firefighter safety and ensure professional knowledge is current with emerging risks. At an international level, incidents of note have taken place in North America and in Korea:

Arizona Incident

On April 19th 2019, an explosion occurred during firefighting activities at a lithium ion BESS unit in the Arizona desert. The initial firefighting crew were supported by a HAZMAT team who were detailed to enter the compound, take gas readings and effect an entry with a jet to the BESS unit.

On entry to the unit, a major blast deflagration event took place, injuring four personnel including the Captain of the crew. Two of the four injured were airlifted from the scene following attempts by the crew to intubate and secure airways. Of the four, the following injuries were received (with call signs):

- E193 Captain suffered a traumatic brain injury, an eye injury, spine damage, broken ribs, a broken scapula, thermal and chemical burns, internal bleeding, two broken ankles, and a broken foot.
- E193 FE suffered a traumatic brain injury, a collapsed lung, broken ribs, a broken leg, a separated shoulder, laceration of the liver, thermal and chemical burns, a missing tooth, and facial lacerations.
- HM193 FF1 suffered an injured Achilles tendon, a fractured patella, a broken leg, nerve damage in his leg, spine damage, thermal burns, tooth damage, and facial lacerations.
- HM193 FF2 suffered facial lacerations.
- Surprise Fire-Medical Department E304 Captain, E304 FF, BR304 FF, and T304 FF, as well as one officer from the Surprise Police Department, were transported to the Banner Del E Webb Medical Centre and observed overnight for exposure to HCN. These individuals were released from the hospital the following morning with no noticeable lasting effects from HCN exposure.

The full report is available at https://ulfirefightersafety.org/posts/four-firefighters-injured-in-lithium-ion-battery-energy-storage-system-explosion.html

South Korea Incident

A second article detailing 23 Li-Ion BESS fires in South Korea during 2018 can be found online via https://www.energy-storage.news/news/koreas-ess-fires-batteries-not-to-blame-but-industry-takes-hit-anyway. The article details the emerging use of Li-Ion units as a green, alternative power source.

Further to the above, a Danish article highlights the issue that BESS units are not restricted to ground-level sites but can be incorporated with residential settings. The image (right) shows a BESS on a low-rise apartment block roof (the full article can be found online via:

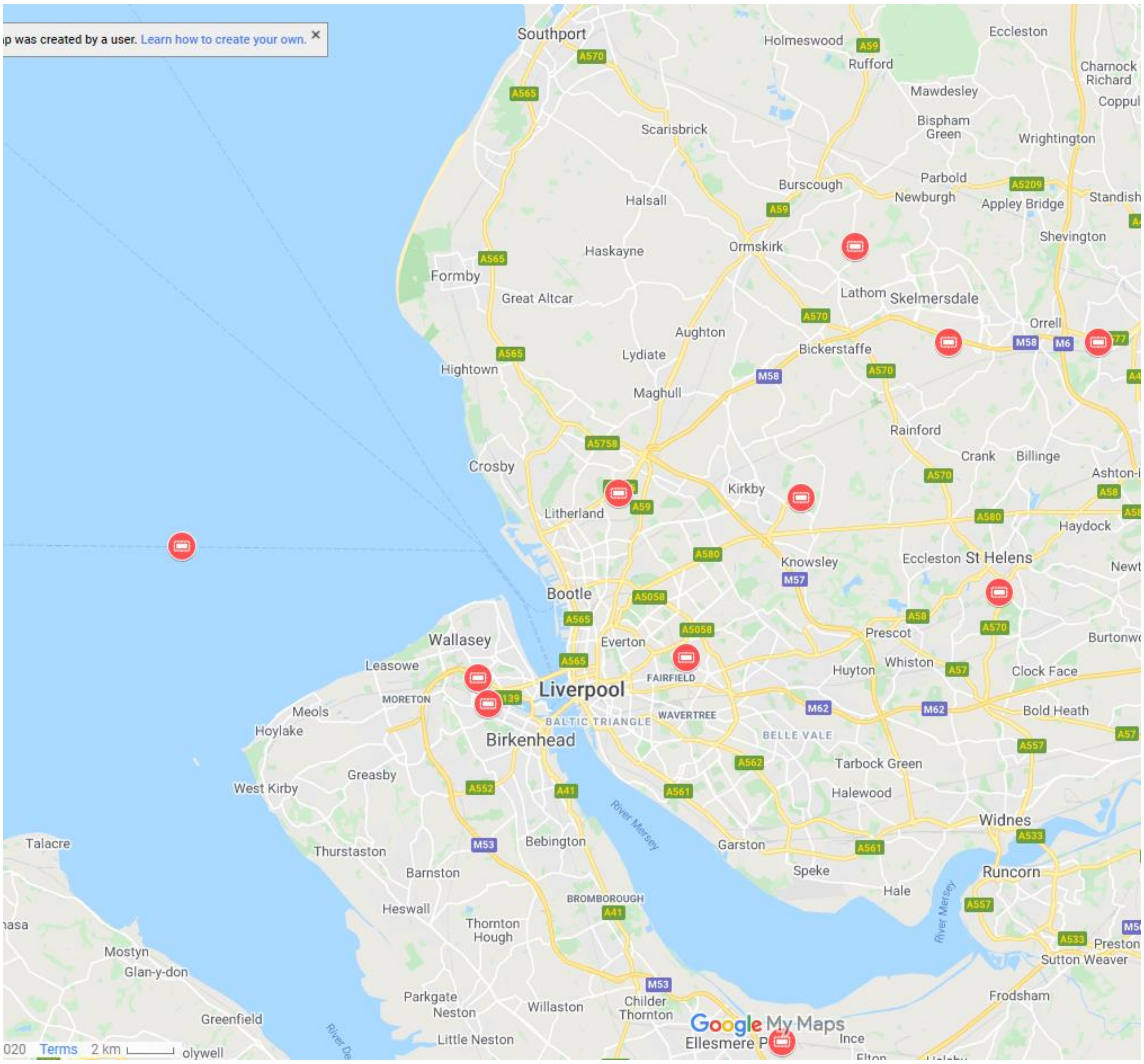
[redacted]

BESS Sites in Merseyside

The diagram below represents sites operational or under construction in Merseyside. A full map of UK sites is available by following the link:

[redacted]

Sites are identified by white bar on red background.



Map covering Merseyside and part of the North West region

6 INCIDENT INVESTIGATION TEAM FINDINGS:

MFRS' Incident Investigation Team attended the incident to determine the origin and cause of the fire as well as the subsequent fire spread. The fire investigation has concluded and a full Fire Investigation report has been compiled in line with current MFRS investigation procedures. Immediately following the incident and as detailed in the previous SIR a summary from the initial Fire Investigation (FI) findings stated:

'Upon an Initial scene assessment photographs and air unit footage were captured along with a briefing from the responsible person on how the site and plant works. After an external examination of the container and reviewing data from CCTV footage, there is evidence of a deflagration due to the ignition of gases that had been given off from the lithium battery cells. This would have been a mix of toxic and explosive fumes. When LiBs (Lithium ion Batteries) go into thermal runaway they generate a dense, white vapour containing hydrogen, hydrogen cyanide, hydrogen chloride, a large range of flammable/explosive hydrocarbons, carbon monoxide, carbon dioxide and droplets of the organic solvents used in the cells'

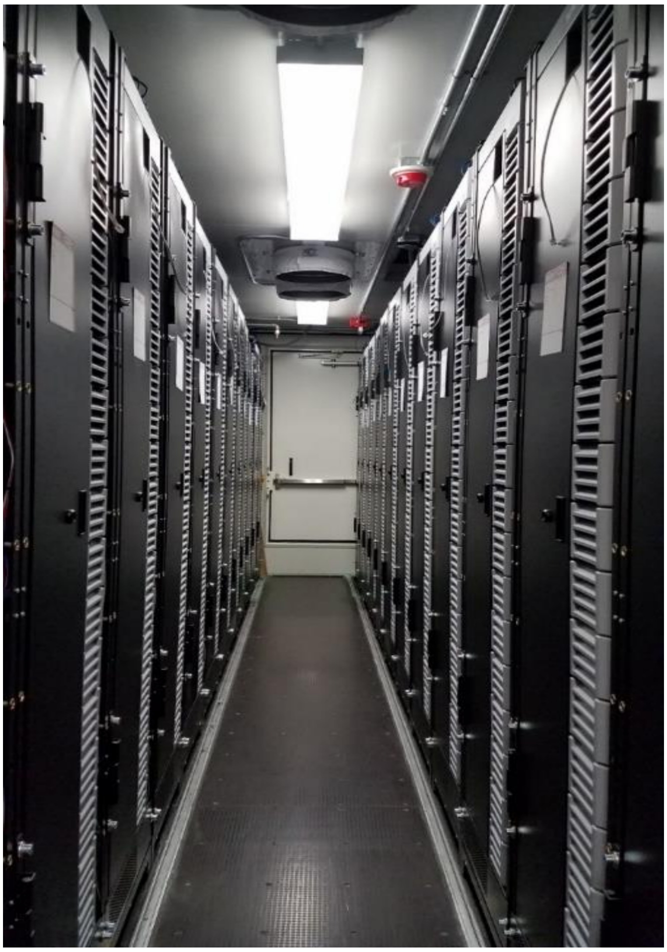
The initial suspected cause was deemed by the FI as:

'Accidental ignition caused by a lithium battery failure transitioning into thermal runaway'.

Since the conclusion of the full Fire Investigation and final report, and as part of this addendum SIR, it has been confirmed by investigators that the NOVEC 1230 suppression system did activate at some point during the incident however, the system was most likely discharged due to the deflagration which either, activated the alarm or the pressure activated the break glass media trigger below the alarm panel.

The subsequent photographs/diagrams illustrate key compoenets of a BESS unit and the unit effected by fire during this incidnet. All illustartions compliment those used in the final FI.

Inside a BESS Unit[2]:



Note configuration of lithium ion banks, narrow access corridor and cooling vents fitted to ceiling.

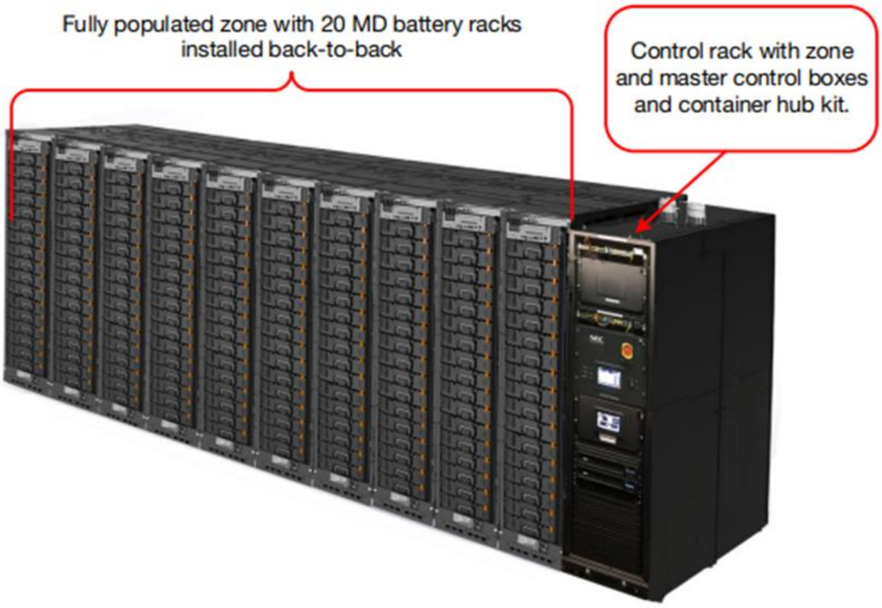


Figure 5: A populated array of 20 racks (two rows of 10, installed back to back) and a control rack

---

[2] NEC Energy Solutions, Inc (supplied to MFRS 3rd Feb 2022)

Affected BESS Unit:[3]

Image above: Exterior of unit with pressure damage to side.

Image below right: Internal view of modules.

Image below left: Fire damaged NOVEC 1230 unit.

[3] MFRS FI Photography post incident

7 RECOMMENDATIONS

Recommendations

The following recommendations are made to assist the industry in the management of BESS sites (or similar) and comprise a non-exhaustive list of suggestions based on the experience of MFRS. They should be considered in full by those responsible for the management and regulation of sites under their control, and prior to any future proposals. Fire & Rescue Services should make themselves aware of the recommendations when working with the persons responsible for the site(s) to ensure firefighter safety is a high priority and the risks are reduced to as low as reasonably practicable.

Information gathering

Fit a Gerda Box to the fence of the inner compound away from any blast risk. These are a secure access box called a Gerda Box that emergency responders can gain entry into in order to access and should contain:

- Plans of the building
- Description of the building and or site
- Information regarding the use of the site and significant risks
- Details of key personnel and emergency contact details
- Evacuation strategy within the local area
- Construction and layout including emergency access points and isolation systems
- Details of fire safety systems, alarms and suppression systems
- Any unusual features i.e. environmental protection plan

This would allow responders to gain information about the site and tactics for firefighting if their mobile data terminal (MDT) is down.

Emergency Contact Number:

Place signage on site that displays a direct 24-hour contact number for the monitoring station and provide this number to all Fire Service Control Rooms so they use this to gain information for example:

1. has the suppression system activated

2. Is the container on fire
3. Personnel receiving the call should be able to direct the call to a Subject Matter Expert who is familiar with the technology and Management System Information as well as assist the fire service during an emergency involving the site.

Installation Identification Number:

Add a number or other unique identifier that can be used by the BMS remote monitoring facility to identify the installation when speaking with fire service control rooms. Fire service personnel can then reference this when returning a call or making an initial call with the remote monitoring facility during an emergency.

External warning signs:

Place signs on the fence line warning about the hazards and risks present if an incident occurs. The fire responding fire appliance may not be from the local station and may not have knowledge of the site or the hazards posed.

Environmental Impact and Safety

Separators or a catchment system under the site to contain water run-off and or other contaminants. Fire and Rescue Services should be made aware of the potential contaminates that may be given off at an incident and remain present in the aftermath.

Smoke/Gas purge system:

Explore the options to fit a manually operated purge system designed to exhaust heat, smoke and toxic gases generated from the **Li-ion-ESS** during abnormal operating conditions.

Deflagration mitigation:

Consider retro fitting deflagration mitigation to allow internal pressure within containers to be released at the time of a deflagration.

Blast walls:

The responsible person for BESS should consider strategically placing concreate blast walls to provide protection against the blast risk for relevant persons and first responders. This would also limit the radiated heat and damage to other units. These would be placed in front of both doors as well as a line along both sides.

Example of a blast wall.

Detection and suppression

Explore the different interventions that could be used to remove the build-up and transfer of heat due to thermal runaway, leading to thermal propagation between cells. Without intervening in this cycle, cells may continue to get hot and release potentially flammable gas.

Automatic fire alarm system:

BESS site operators and the energy industry should review the automatic fire alarm system and consider a system that would detect the early stage of a cell in thermal runaway, giving early warning and activating any media fitted within the compartment. IE air sampling alarm systems that could pick up on a change in air quality.

Audible and visual warning:

External audible and visual warning devices linked to detection and suppression systems should be marked up to enable first responder to understand what the warning is in relation to. This will aid in their decision-making.

Suppression systems

1. **Testing:** The energy industry should conduct tests, to determine if the suppression systems, within the structure can extinguish any ignition once a cell has begun to fail.

2. **Remote activation**: Enable remote activation of the suppression system, to allow the monitoring station to deploy the media if deemed appropriate.

3. **Suppression system applicator**: Ensure that the siting of the suppression system applicator is in the correct position to be effective. As the gases and smoke being to be given off by a cell may cause turbulence, which in turn may prevent the firefighting media from penetrating the rack, module or cell.

4. **Dry misting system**: Fit a dry misting system that first responders and plug their fire appliance in to and apply water internally to the affected container without entering the risk area.

5. **Suppression Systems.** Some ESS design validations have included pre-engineered inert or clean agent fire suppression systems for fire protection. These system installations were often approved without validation based on large-scale fire testing by nationally recognized testing laboratories. Evidence-based data is needed to ensure ESS designers specify appropriate fire protection systems based on the material involved and physical design characteristics.

Several early research papers from multiple organizations, including NFPA's Fire Protection Research Foundation, and third-party engineering groups have shown that fires involving lithium-ion cells must be cooled to terminate the thermal runaway process. Water is the agent of choice, yet system cabinet design could pose a significant barrier to the efficient application of water while simultaneously allowing the free movement of fire and combustion gases.

Fire fighting

- **External markings:** Markings should be placed externally (similar to those found on aircrafts) to denote where a lance or stinger can penetrate without damaging any cells.

- **Fire and Rescue Services Act 2004 7 (2) (d):**

  The responsible person for each BESS site operator in the UK should actively engage with the local Fire and Rescue Services Act 2004; section 7 (2) (d) of the Fire and Rescue Service Act 2004 access, for the purposes of gaining up to date risk information, training and exercising that will help to ensure safe and effective response to any future fire emergency.

Post Incident

- **Information sharing:** Any occurrence of a cell, system failure or recall should be shared with the United Kingdom Association of Fire Investigators and National Fire Chiefs Council for learning and informing first responders of possible hazards and risks.

Testing:

The industry should conduct testing and research with a suitable reputable body, for example the Building Research Establishment **(**BRE) or the Health and Safety Laboratory (HSE).

This is to establish:

1. The different issues that could cause BESS cells to fail whilst held in a module
2. The gases and chemicals being given off when in thermal runaway or when involved in fire directly or through radiated heat
3. Learning from a reconstruction of a BESS container fire and initiate a failure to establish timescales, how long it takes for a power cell to dissipate and to identify any residual chemical left on scene.
4. Identify firefighting media and best practice for extinction.

8 Debrief Module - Organisational/Team/Individual Learning

A local MFRS debrief was created for the incident on the OSHENS electronic recording database, utilised by Merseyside operational staff, inviting attending officers to provide a response, following discussions with attending crews. 18 invites to debrief were sent, including the attending GM, SMs, WMs and Fire Control Watch Officer.

The debrief is;
Inc. 018965 18/9/20 [redacted], was issued and received a number of responses aligning to themes which are presented below. All returns were analysed by OAT and

for manageability of the document, responses relating to similar issues are grouped together.

Organisational Learning		
Issue	Actions	Outcomes
Current SOP for electrical installations has highlighted a gap for the emerging hazards and risks associated with Li-Ion battery installations.	• Review action at incident against [redacted] Electrical Installations for Gap Analysis. • Report to NOL to inform NOG.	Submission to NOL – 9/10/20 SOP reviewed by OA team with recommendations for [redacted] Electrical Installations 1/10/20
SSRI for site incomplete; contained survey information but completing crews had not fully referenced hazards when involved in fire.	• Station 16 to update the SSRI, local crews to familiarise.	Station 16 completed SSRi with CAD plans c/o FI Officer.
No Operational Response Plan (ORP) for site.	• Ops Planning to liaise with site to produce ORP and distribute locally.	ORP discussed with Ops Planning, TBC on submission of SSRI.
600mm main and hydrants defunct Green Lane	• Station Manager to report to Water Section and feedback results. Potential failure due to current road works.	Water Section responded to confirm that United Utilities had recently decommissioned hydrants in this area. Walk and records updated and communicated.
Initial attendance stated that the units highly resemble refrigeration plant and contained lack of external signage.	• Incident Note highlighting unit image distributed to MFRS all operational staff.	Incident Note completed – learning provided to NOL

Notable Good Practice		
Issue	Actions	Outcomes
Early and continuous deployment of Water has prevented spread to second unit and potentially	• Potential for unit failure and injury risk to crews to be reinforced as soon as is practicable.	Incident Note sent to all MFRS 17th/9/20 with hazard and site details.

prevented injury or failure of a further unit.		Site Specific Risk Information reviewed by local crew in conjunction with Orsted.
First attending Station Manager had a basic understanding of key hazards and risks at time of incident and was able to advise crews accordingly until arrival of HMEPO.	• Station Manager to contribute knowledge to report and SOP review.	SM interviewed as part of fact finding prior to SIR compilation.

9 Next Steps:

MFRS are committed to supporting the process of learning for the Fire Sector on a local, national and international scale in respect to new incident types or emerging Firefighter hazards. This process includes support of NOL, which forms part of the maintenance process for the NOG products and will be a vital element of NOG in today's society. NOL outcomes will be one of the factors considered when changes are made to guidance and will ensure the review of NOG is as effective as possible.

MFRS initially set a number of actions following the incident through Operational Assurance and the associated mechanisms for information and change. These are detailed below:

Internal Actions	
IA.1	Produce and distribute a local Incident Note for crews detailing the attendance and hazards encountered.
IA.2	Produce a briefing note for MFRS Principal Officers consideration.
IA.3	Collate all submitted debrief returns for review and action.
IA.4	Interview all MFRS attending parties (Officers/Watch Managers) to gain accurate and concise information.
IA.5	Create a Significant Incident Report (SIR) for internal learning and further distribution to the UKFRS Sector.
IA.6	Local station to attend site and review/update current risk information (SSRI)
IA.7	Review [redacted] Electrical Installations and advise Operational Planning through gap analysis.
IA.8	Review internal electronic learning packages for accuracy relating to lithium ion battery storage sites.

IA.9	Produce a case study to promote internal and external learning.
IA.10	Complete risk information gathering regarding other sites in Merseyside – in operation, development or proposed.
External Actions	
EA.1	Inform National Fire Chiefs Council (NFCC)/NOL of the incident and provide sufficient information in an effective format to the UKFRS Sector.
EA.2	Continue to liaise with NOL to ensure that NOG are aware and sighted on creating a response.
EA.3	Inform the UKFRS Sector via Workplace.
EA.4	Work with industry professionals to establish best firefighting practice.
EA.5	Promote learning regionally at the North West Region OA quarterly meetings.

10 GLOSSARY:

°C	Degrees Centigrade
AIG	American International Group
Appliance	Fire and Rescue Appliance, (pump) crewed by 4 or 5 operational staff.
BESS	Battery Energy Storage System
BV	Bureau Veritas, MFRS third party Scientific Adviser
CCTV	Closed Circuit Television
CHEMET	Chemical Meteorology service
FF	Firefighter
FI	Fire Investigation
French drain	A trench filled with aggregate, that allows surface water to drain
GM	Group Manager
GMFRS	Greater Manchester Fire and Rescue Service
HazMat	Hazardous Materials
HF	Hydrofluoric acid
HMEPO	Hazardous Materials Environmental Protection Officer
HVP	High Volume Pump
IC	Incident Commander
kV	Kilo Volt
Li-Ion	Lithium Ion
Main Jet / Main Branch	A jet of water from a hose line branch of between 45 to 70 mm diameter.
MFRS	Merseyside Fire and Rescue Service
NFCC	National Fire Chief's Council
NOG	National Operational Guidance
NOL	National Operational Learning
mW	Mega Watt
OA	Operational Assurance
pH	A measure of acid / alkaline in water on a range from 0 to 14: 7 = neutral; < 7 = acidity; > 7 = base.
Pump	Fire and Rescue Appliance, crewed by 4 or 5 operational staff. Sometimes referred to as an appliance.
Scottish Power	Utility company who manage the local electrical grid
SM	Station Manager
SOP	Standard Operating Procedure
SSRI	Site Specific Risk Information
UKFRS	United Kingdom Fire and Rescue Services
WM	Watch Manager