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 45°C 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:

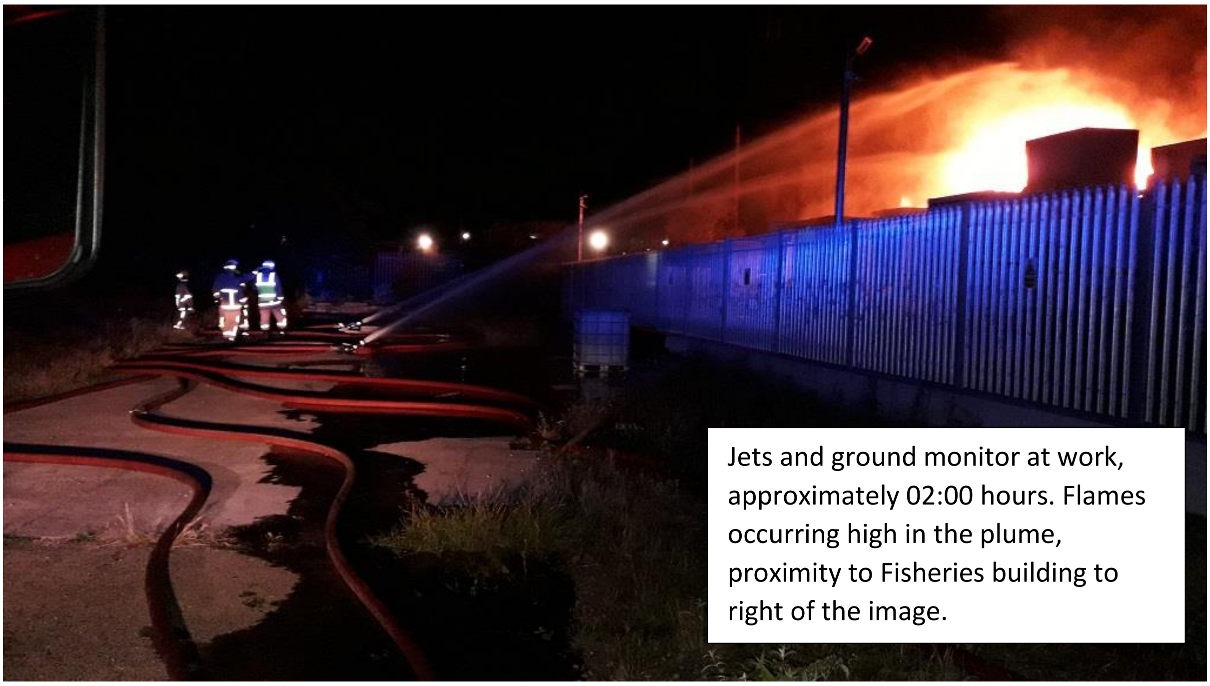
Time	Orsted Bess Incident (No. 018965) 15th September 2020
00:49	First call received by MFRS Fire Control.
00:52	Appliances mobilised to large explosion near the Fisheries, Lister Drive
00:54	Numerous calls received to large explosion with smoke and flames
00:57	First appliance, [redacted], in attendance
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

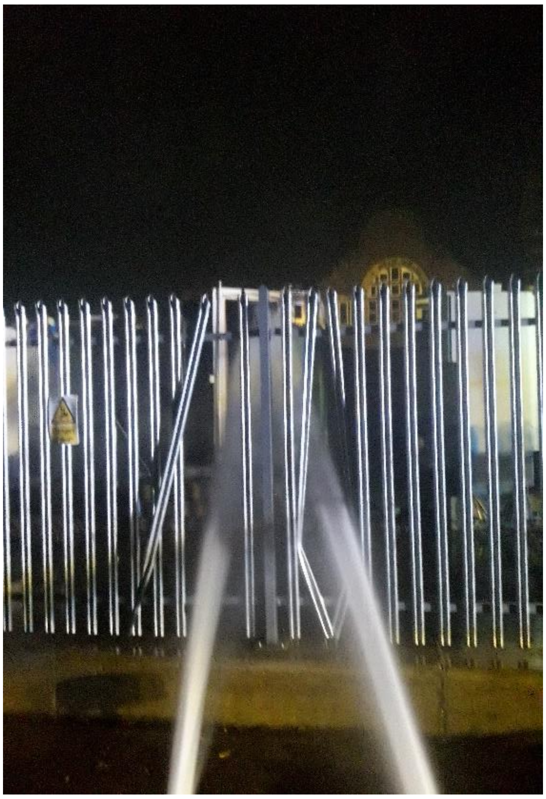
Foreword: Due to the unique nature of this incident, the areas for investigation will include details of the construction, hazards and issues presented by Li-Ion units when involved in fire

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.

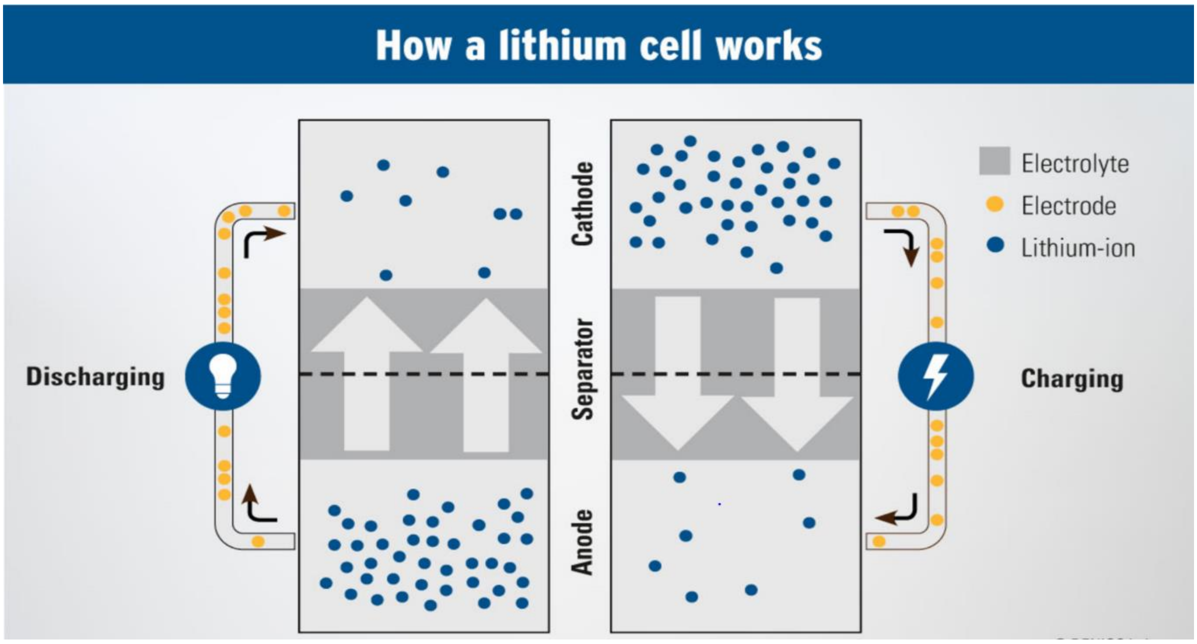
Action: The HMEPO role was crucial in this instance in preserving Firefighter safety. Fire Control action plans have been amended to mobilise a HMEPO if units of a similar nature are identified and involved in fire in future incidents.

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.

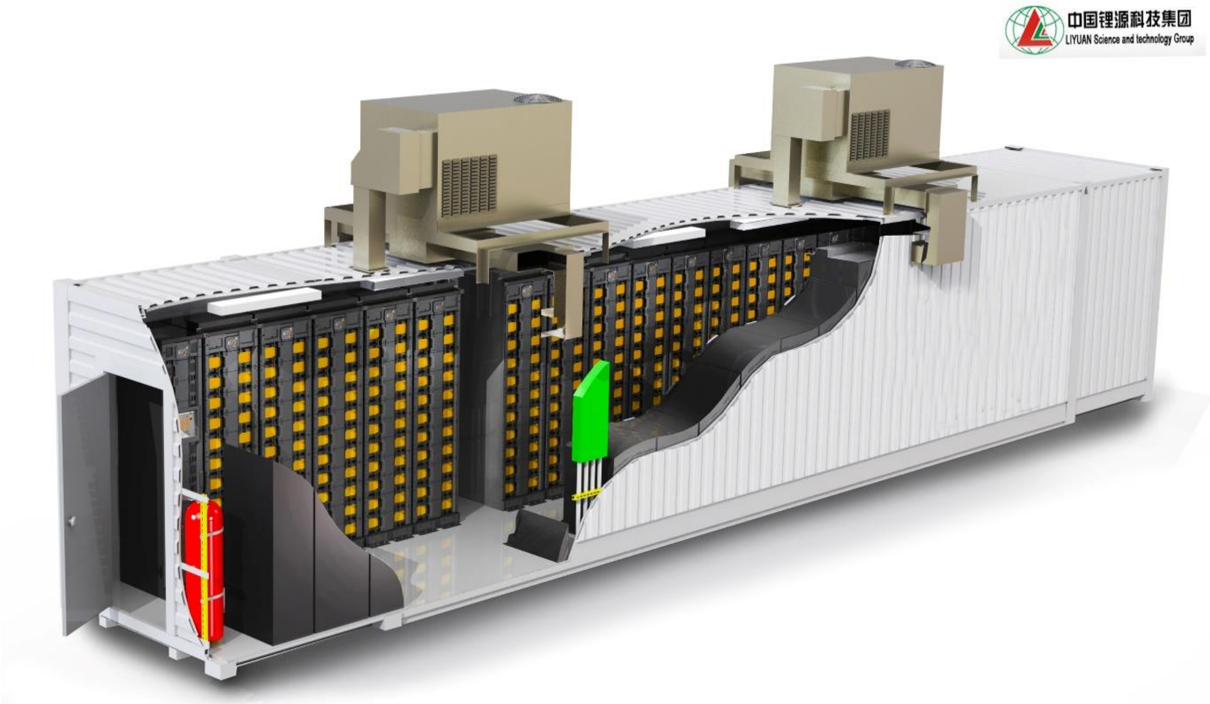
The most likely scenario is that HF conversion is part of the gas evolution during thermal runaway. The liquid electrolyte rarely escapes as liquid and HF would more be gaseous pollutant that is entrained by firewater or deposited on surfaces by the gases.

Li-Ion BESS unit construction:

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:

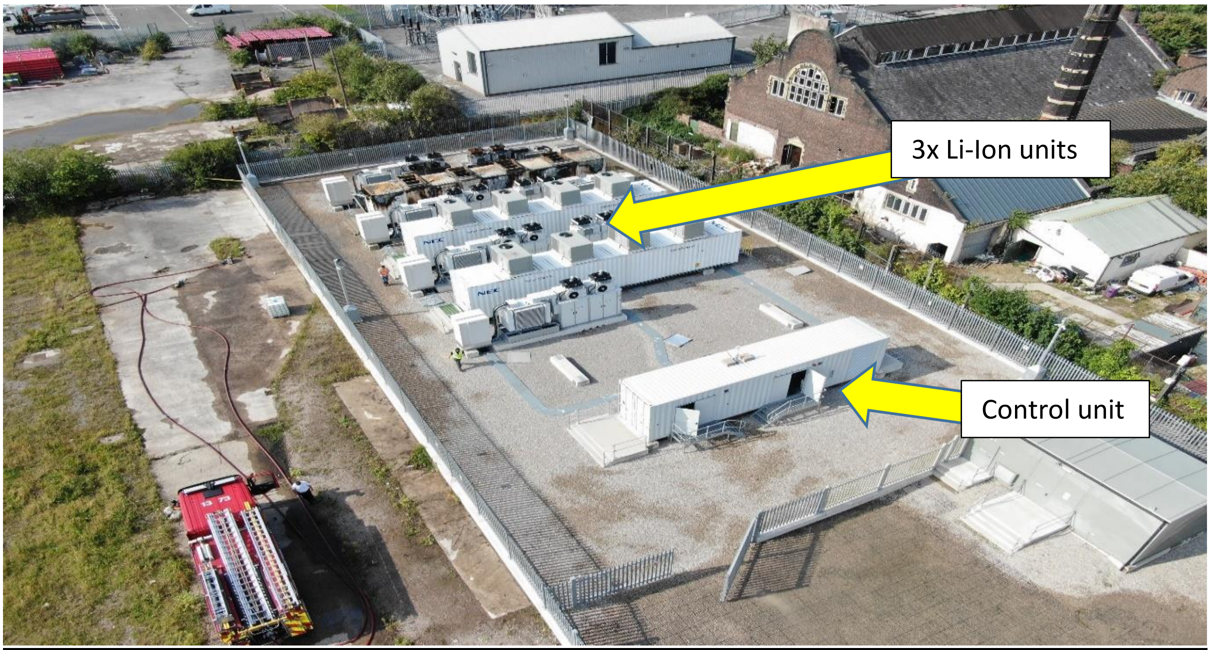
Industry guidance on extinguishing fires involving Li-Ion cells states that the combustion process liberates oxygen and as such, a fire involving a BESS unit should be identified as a "Class D" metal fire and extinguished using a proprietary powder or granular agent.

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:

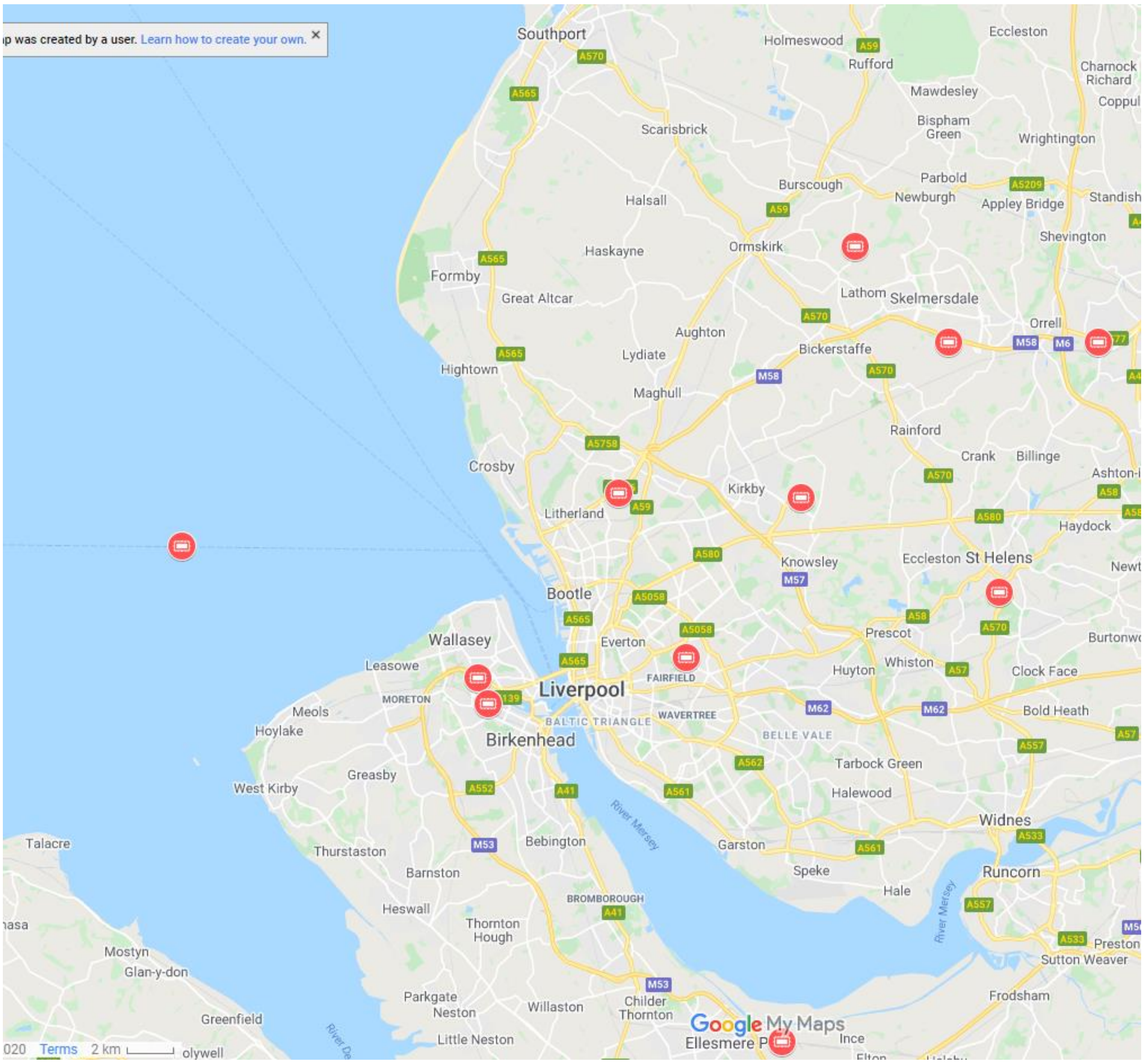
https://www.destentor.nl/apeldoorn/dak-in-apeldoorn-mag-rommelig-als-het-duurzaam-wordt~a55b4d3b/?referrer=https%3A%2F%2Fwww.google.nl%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3D%26esrc%3Ds%26source%3Dweb%26cd%3D%26ved%3D2ahUKEwixxLKv5-_rAhWKMewKHZPVC1AQFjACegQIChAB%26url%3Dhttps%253A%252F%252Fwww.destentor.nl%252Fapeldoorn%252Fdak-in-apeldoorn-mag-rommelig-als-het-duurzaam-wordt%7Ea55b4d3b%252F%26usg%3DAOvVaw0DGdV3ILwzQ9m_-9T6JcKS

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:

http://www.mygridgb.co.uk/map/.

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'

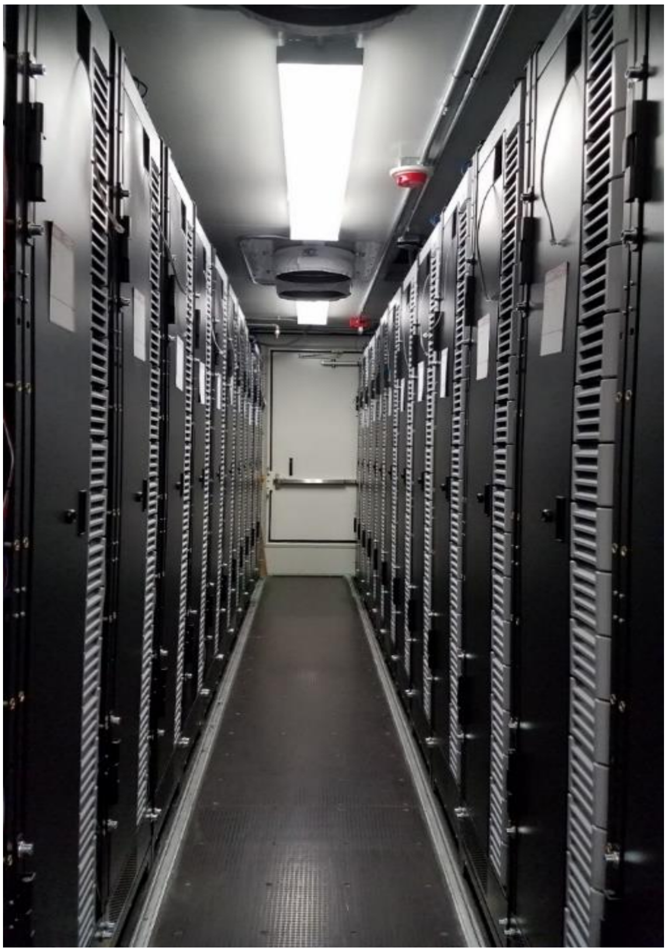
The initial suspected cause was deemed by the FI as:

'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.

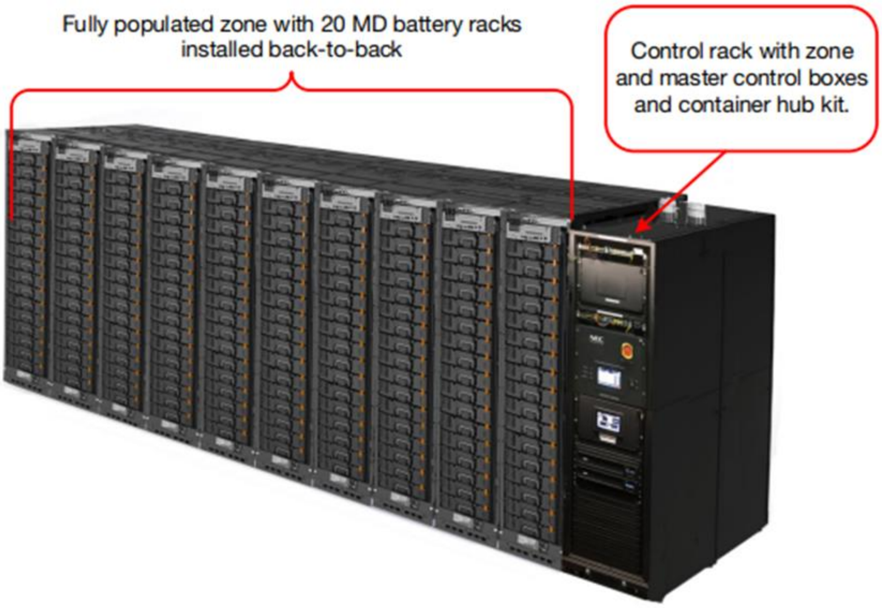


Figure 5: A populated array of 20 racks (two rows of 10, installed back to back) and a control rack

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[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 17^{th}/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:

ºC	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