Handling of Lithium-ion batteries

SfS Recommendation 050E/2022

SfS
Samarbeid for Sikkerhet

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1. Introduction

The installation and use of lithium-ion battery technologies has increased significantly in recent years, in order to meet environmental requirements for reduced emissions. Areas that have observed an increase in the application of these technologies typically include new energy, and various hybrid solutions within the shipping and petroleum industries. However, this increased use of lithium-ion batteries has led to several undesired incidents, especially in connection with the post-installation of battery packs. There is therefore a need for increased competence and the further development of regulations covering the design, construction and operation of the technologies, in addition to emergency preparedness and firefighting solutions.

One of the biggest challenges associated with lithium-ion batteries is the possibility of 'thermal runaway' – a sharp increase in temperature that may cause gases emitted by the battery to ignite. A fire may have consequences for personnel tasked with operating, monitoring and handling undesirable incidents where lithium-ion batteries are involved.

There are several lithium-ion battery chemistries (see Appendix 5), and these have different properties. Even though some chemistries are more resistant to thermal runaway than others, all of them may result in major problems with smoke and gas, which must be handled. Since the challenges relating to both fire and smoke/gas are different from those associated with ordinary fires, there is a need to increase the general competence in this area.

At the request of the PSA, DNV has prepared a comprehensive report,[1] which maps the risk factors associated with the use of lithium-ion batteries. The DNV report proposes measures to reduce risk, and should be thoroughly reviewed by anyone planning to use or who already uses such battery packs. The report also contains a review of the PSA's regulations, with proposals for improvements.

2. Purpose

The purpose of this recommendation is to contribute to increased competence surrounding issues relating to the safe installation and use of lithium-ion battery technologies in the petroleum and maritime industries.

The recommendation is generic for fires involving the most common types of lithium-ion batteries on the market at the time of the recommendation's publication. Furthermore, the recommendation does not distinguish between batteries in which each individual cell has passive fire protection and batteries in which only each module has passive fire protection. See Appendix 1.

3. Target group

The target group for this recommendation is anyone who plans, installs, organizes, is responsible for or performs work on or undertakes emergency response tasks relating to lithium-ion battery packs and larger energy storage solutions. This also includes personnel at onshore and offshore facilities, or on installations that do not have their own battery packs but interact with vessels / mobile facilities that have battery packs on board.

4. Background and challenges

As part of the green shift, an increasing trend has been the installation of lithium-ion batteries as an energy source for various purposes such as the propulsion and manoeuvring of vessels and battery back-up solutions on offshore installations. Such installations require expertise in several areas in order to be able to deliver safe operation and proper maintenance. Furthermore, competence in analysing and understanding data from normal operations and charging/discharging is required, so that undesired incidents can be prevented.

Appendix 1 shows the structure of a typical battery system.

The design and layout of the battery room must take a number of factors into account: humidity, salt, vibration, electromagnetic radiation and high voltage systems, cooling and ventilation during normal operations and in emergency mode. Furthermore, barriers to other hazardous loads/storage and the effect of high temperatures in the event of fire must be considered (may melt steel). These safety requirements also apply to retrofitted solutions.

It is crucial that the battery cells have been subjected to a recognized and quality-assured production process, where the (EMS) and battery management system (BMS) are tested and operated in a way that ensures that communication, surveillance and security systems remain operative at all times.

Larger battery systems are usually placed in dedicated battery rooms with the components and functions necessary to keep the battery system intact. The biggest risk associated with the most common lithium-ion battery chemistries is that they heat up, resulting in an exothermic reaction (thermal runaway) starting in the battery cells – if the control system fails, for example. This is a self-reinforcing effect that leads to a rapid rise in temperature and the release of gases.

A thermal runaway fire requires extensive analytical and technical expertise, especially with regard to temperature development, the emission of toxic gases, and the possibility of fire or explosion. The use of personal protective equipment and the presence of HVAC will be important factors, as will live working equipment, the proper types of extinguishing agents and capacity. Sufficient time and resources must be implemented for familiarization, overlap, and technical and emergency preparedness exercises.

It is important to be aware that there are lithium-ion batteries with a composition and chemistry (for example LFP batteries with passive fire protection at cell level – see Appendices 1 and 5) that do not result in a fire in the event of TRA under the test conditions defined in international standards (UL and IEC). Nevertheless, explosive and toxic gases and smoke must still be managed. Note that such batteries also contain flammable materials, and will burn if exposed to external flames.

Security personnel and firefighting teams must also be able to ensure their own safety.

5. Risk and contingency analysis

The responsible company must select technical, operational and organizational solutions that reduce the probability of damage, faults and hazardous situations. A basic requirement[3,6] when choosing new technical solutions, including the installation of battery packs, is that a comprehensive risk analysis of the design and construction is carried out. Such an analysis involves performing an FMEA. The analyses must be updated in the event of any changes that may affect the risk conditions, including software updates.

Contingency analyses shall be performed and included as part of the decision basis, including when defining danger and accident situations (DFUs). The installation of lithium-ion battery systems entails a risk of danger and accident situations that must be addressed through one or more DFU(s). All relevant situations that may arise in the battery system must be considered to ensure that appropriate measures can be implemented.

The risk and emergency preparedness analysis shall provide a basis for decision-making that ensures robust risk-reducing solutions are selected in order to reduce the risk and possible consequences in the event of an incident in a lithium-ion battery system. Preparedness must also be dimensioned and practised based on the results of the analysis. A central topic for such battery systems is which design criteria shall be used with regard to potential fire and explosion loads. It must also be ensured that the potential effect on the entire facility/ship in the event of an incident is manageable and that the risk of escalation is assessed. An example of other conditions that must be considered during the analysis is areas for ventilation from battery rooms, where it shall be ensured that there is a sufficient number of ventilation units, and that personnel avoid exposure to any gases / exhaust gases in a thermal runway situation.

Details of relevant regulations are provided in Appendix 3.

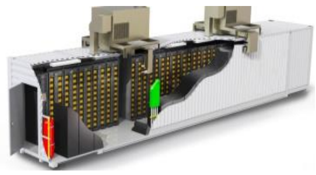
6. Handling of fires

The DNV report[1] proposes several technical and operational measures that can reduce both the probability and consequences of thermal runaway. Should an undesired incident nevertheless occur, it is important that all involved personnel have sufficient competence and training that enables them to handle the situation in a pre-established DFU which broadly outlines what to do – and what not to do – in such a situation.

To define the risk potential of fire in lithium-ion batteries more easily, we can divide this type of fire into four risk levels, from small battery fires to large complex battery fires. It is mainly the size of the battery pack/system and its placement that distinguishes the different risk levels. The greatest risk of a battery fire occurring is when gas from the batteries is given the opportunity to accumulate, thereby forming a toxic and explosive atmosphere. By using these risk levels, HRS, the emergency management team and the involved emergency response personnel can define and obtain a common understanding of the risks that are present and which measures should be implemented in order to limit or prevent the incident's development into a larger one.

6.1 Risk levels – battery fires

The figure below has been developed by Bergen Fire Department and OilComp AS, and shows the four risk levels in the event of a fire in lithium-ion batteries. These levels are also used in the DSP report.[9]

			
Level 1	**Level 2**	**Level 3**	**Level 4**
Fire in smaller lithium-ion batteries	**Fire in larger lithium-ion batteries**	**Fire in larger lithium-ion batteries in closed room** **ESS on deck**	**Fire in larger lithium-ion batteries integrated below deck on ship or facility**
〉 ***Cell phones*** 〉 ***PC*** 〉 ***Communication equipment*** 〉 ***E-bike/scooter***	〉 ***ROV*** 〉 ***Cranes*** 〉 ***Lifeboats*** 〉 ***Forklift trucks*** 〉 ***Diving bell*** 〉 ***UPS***	〉 ***Energy storage system (ESS)*** 〉 ***Larger UPS systems*** 〉 ***ROV and forklift truck, electric vehicle in garage***	〉 ***Buildings /installations with large battery bank systems*** 〉 ***All-electric or hybrid ve***
Low risk	**Low to medium risk**	**Medium to high risk**	**High risk**

There is a marked difference between risk level 2 and risk level 3, where we see that the risk and consequences of a battery fire increase significantly where un-combusted smoke and gases may accumulate. Level 2 fires, such as in lifeboats, cranes and forklift trucks, may also present challenges and will require training and handling that differs from those for 'ordinary' fires.

Battery fires in risk level 3 and risk level 4 require an additional understanding of how a fire will develop, and how to approach this kind of fire.

6.2 Handling of fires at level 1

Lithium-ion batteries may spontaneously give off large amounts of gas, and self-ignite without warning. In addition, they may burn for longer than ordinary materials. Inhalation of smoke and the risk of the fire spreading are therefore the two greatest risk elements in connection with fires at level 1.

Water is a suitable agent to use in extinguishing smaller battery fires. Because lithium-ion fires are difficult to put out, significant volumes of water must be used – or the battery placed in a container of water if possible. Salt water can be used in the container, since this both cools and discharges the battery. Other extinguishing methods such as foam, powder and fire blankets may also be used, but these will have a lower cooling effect.

6.3 Handling of fires at level 2

The challenges associated with fires at level 2 are largely the same as for level 1 fires. However, the size of the battery and the unit in which it is placed mean it is not easy to cover the battery using fire blankets or to lower it into a container of water. Larger volumes of gas and higher voltage must also be handled.

Lowering the relevant vehicle into an open container filled with water has proven to be the preferred solution for extinguishing fires in electric cars. Equivalent solutions, such as the temporary lowering/dropping of equipment into the sea for lithium-ion operated equipment on ships or other offshore installations must be assessed and be in accordance with emergency preparedness analyses. Where this is not possible, the use of special fire blankets and access to extinguishing/cooling using fresh water may be relevant.

For battery packs connected to external power supplies, charging should be interrupted in the event of a fire. If the external power supply is not disconnected, the fire shall be regarded as a fire in a live installation and the correct protective equipment (1,000-volt gloves) must be used. Also be aware that vehicles/units that have been exposed to fire or collision may self-ignite. If extinguishing the fire is not possible, letting it burn down, thereby discharging all the energy, must be considered. The high temperature that develops in the event of a lithium-ion fire dictates that one should cool down and remove/move the unit at least 10 metres away from other flammable materials in order to prevent the fire spreading.

In terms of personal protective equipment, complete respiratory protection may be necessary due to large volumes of gas. The use of fans to obtain control of smoke should also be assessed.

6.4 Handling of fires at levels 3 and 4

Outside a battery room in which a fire is burning, there may be few signs to suggest there may be an explosive atmosphere inside the battery room. Good knowledge of alarm systems, extinguishing systems, ventilation systems, sensors and ventilation options in the battery room is essential knowledge one must have before choosing to respond to a level 3 or 4 battery fire.

If you do not have this knowledge, it is not advisable to open the battery room to try and extinguish the fire. Furthermore, lack of competence can also deprive emergency personnel of the opportunity to perform firefighting work if the fire in the battery room is a ‘traditional’ one (e.g. fire in plastic or other combustible material in the battery room that has nothing to do with lithium-ion batteries).

The tables below list measures for fire and fire warnings at risk levels 3 and 4:

Recommended measures to **prevent fire**:

• Perform routine checks of the ventilation system in the battery and battery room. NB: Sufficient ventilation is the first priority in order to prevent explosion and fire in the battery room or container. Reference 2 provides recommendations for calculating the necessary ventilation capacity.
• Have good maintenance procedures, including for air filters in the battery room.
• Ensure that the battery room has an IP rating of greater than 44 and keep it clean and dry.
• Undertake regular practice drills for manual shutdown under various abnormal conditions as a natural part of emergency preparedness exercises.
• Use access control and perform safe job analysis (SJA) for maintenance work in the battery room.
• The operator must have knowledge of the parameters that are indicators of early thermal runaway. Examples include rising battery temperature, high voltage and current, and gas evolution.
• Operators must be familiar with the prerequisites for safe operation of the battery system. These may include:
  - Restrictions for power sources and characteristics of connected equipment
  - Amount and type of coolant
  - Ventilation inlets and outlets and dedicated ventilation from battery cabinets
• In the event of modifications, the risk analysis for the battery system must be reviewed to ensure that the assumptions and results are still valid.
• Do not leave battery room doors open for longer than is necessary.
• Do not store equipment in the battery room that could cause sparks, burn, or generate significant heat.
• Consider implementing lifting restrictions above and in the vicinity of battery rooms

Recommended measures **in case of potential outbreaks of fire:**
• Leave the battery room and monitor the situation from the outside • Evacuate the area outside the ventilation outlet from the battery system and the battery room. • Monitor the situation and prepare for the release of extinguishing agent. • Always keep the battery room door closed. • Disconnect the battery system in case of failure of battery safety and auxiliary systems, ventilation and cooling (usually automatic). • Make sure that the battery cooling system is activated if it is not initially switched on. • Manual interventions to prevent the fire that involve the presence of personnel in the battery room are discouraged. • Do not re-enter the battery room until the exhaust gas has been vented. • In the event of an external fire or explosion, procedures must be followed for starting the external sprinkling system and internal liquid/air heat exchanger, and shutting down of the battery system to avoid further heating during use. The cooling system of the battery system must be maintained if possible.

Recommended measures **in case of fire:**
• Internal alarm and emergency notification to the relevant emergency preparedness centres. Obtain a floor plan and assess the risk of the fire spreading. • Activate emergency stop and extinguishing system.* • Obtain information from the monitoring system (battery management system – BMS). Look for changes in the battery system such as rising temperatures or sensor failure. (This provides information about whether there is an accelerating situation in the battery room, or whether there is a more stable situation – heat-affected batteries may spontaneously ignite). • Monitor other auxiliary systems such as video surveillance, gas or temperature sensors that may be located in the battery room. • Monitor the exhaust system from the battery room. Ensure that gases are not ventilated to areas containing personnel. • Monitor gas ventilation from the battery room. Is there a gas leak to adjacent rooms? Avoid supplying oxygen if the battery room is closed. • Monitor the spread of heat from the battery room. • Do not enter the battery room until you have a complete overview of the concentration of gas in the room. Always use complete protective equipment. • The use of salt water in the battery room and directly on batteries should be avoided. • Short circuits in the battery installation may occur even when using clean water (the water binds particles such as ash, soot, salts and metal particles which make it conductive, use large amounts of water).

* Note that the facility regulations state that extinguishing systems must be automatic, while the regulations for mobile facilities[8] facilitate both automatic and manual tripping based on assessments. (The Norwegian Maritime Authority sent out a separate clarification regarding this on 13.12.2019)

Recommended measures to **reduce the consequences of fire:**
• Situate the battery room on the vessel/installation/facility so that it will impact upon the facility's integrity to the least possible extent in the event of a fire or explosion. • Ensure that the ventilation is sufficiently robust, and preferably set up with a dedicated outlet, with particular focus on the placement of the supply air and outlets (also with regard to the mustering station). Ensure that light, flammable gases are ventilated out by situating outlets at high points, ceilings. The ventilation capacity should be sufficient to prevent the accumulation of a combustible atmosphere. • Consider equipping the battery room with CCTV in order to have the best possible grounds for not exposing emergency personnel in the event of an abnormal situation, be as well-prepared as possible for the situation that has arisen, and provide important info to those who shall handle the situation. • Set requirements regarding the production and product quality of battery packs[19, 20], including battery chemistry and waste gases. Along with quality control, these are important factors in preventing typical thermal runaway. • Set a requirement that the overheating of a lithium-ion battery cell shall not influence neighbouring cells (passive solution – avoid internal propagation/escalation of the incident). The battery supplier must document that thermal runaway tests have been conducted in a way that establishes that internal overheating within a battery cell shall not spread and influence neighbouring cells. • Consider setting fire cell requirements for the battery room (A60 or stricter), and in addition that the room shall not contain other types of equipment or be used in a way that may influence the outcome of or be able to start a battery incident/fire. • Consider installing a damper that ensures no vacuum or overpressure can be created within the battery room. • Consider the use of a water mist system in order to keep the battery room cool. • Ensure the battery room will not be affected in the event of an external fire.

7. Competence

An important factor in choosing a technical solution is the supplier's competence, including with regard to regulations, the environment, construction, design, and fire and evacuation systems.

As a general rule, it will be necessary to strengthen internal competence when installing new battery packs, and it may be crucial that the supplier can provide training on the specific system being installed; see references 4 and 21.

Competence regarding the installation, operation and maintenance of battery systems is only included in the regulations' mandatory basic education for maritime and electrical engineering subjects to a limited extent.

The need for competence always arises as a result of new technology, and the gap between implementation, regulations and competence becomes a safety challenge which, based on existing overarching regulations, must be specifically addressed for the individual installation. These analysis will then form the basis – preferably in parallel with the 'green shift' – for common competence requirements. Until this happens, it is especially important that those who operate and maintain battery systems receive good basic training on battery systems, in addition to equipment-specific training for the facility/ship's equipment, provided by the system supplier. This will then form the basis for the establishment of a dedicated DFU, which broadly outlines the emergency preparedness training programme and the training of emergency response personnel.

The following areas must be covered in detail in the equipment-specific training:

Competence – Operation and maintenance of battery systems:

- Energy management system (EMS)
- Battery management system (BMS)
- Operation and maintenance of battery systems
- Digital information analysis
- Manual operation of critical components

Competence regarding operation, risk, safety and emergency preparedness

- The structure of battery modules – water-cooled and air-cooled
- Structure and function of control units and barriers
- Communication between switchboard, BMS, battery modules and control units
- Cell balance, min/max volts calculation/calibration, charge balance, and connection/disconnection
- Hazards associated with work on or near battery systems
- Understanding of risks in the event of thermal runaway and the subsequent processes involved in handling it
- Knowledge of how to handle a fire in a lithium-ion battery based on risk levels
- Knowledge of what distinguishes a lithium-ion battery fire from a conventional one
- BMS function, with monitoring, alarms and limit values

After basic and equipment-specific training, sufficient time for familiarization must be allocated and implemented. In addition to increased competence among those who shall operate and maintain the facility, it will be necessary to provide the necessary competence to search and rescue, because battery fires must be handled in an entirely different way than the fires they are traditionally trained to manage.

Furthermore, there will be a need for increased competence in the operation of more complex systems – battery packs often become an integral part of the total energy supply need for the installation or vessel. For larger battery energy systems, competence that will ensure the facility has adequate cybersecurity[18] must be taken into consideration during the design, training and operation phases.

Sample training plans are provided in Appendix 5. Courses that cover syllabi 1-3 are already commercially available, while courses that cover syllabi 4-5 will be available in the spring of 2022.

8. References and links

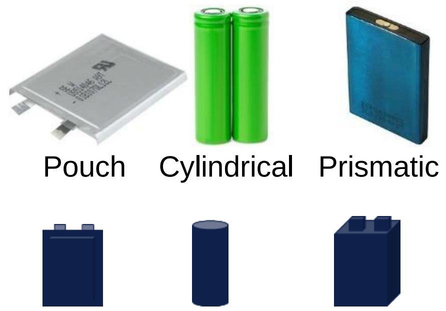
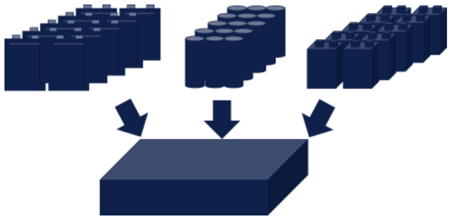
1. Safe use of Lithium-ion batteries in the Petroleum Industry, report no.: 2020-0778, Rev 1. DNV-GL
2. DNV MARITIME BATTERY SAFETY Technical Reference for Lithium-ion Battery Explosion Risk and Fire Suppression
3. PSA: The management regulations
4. PSA: The activities regulations
5. PSA: Technical and operational regulations
6. NMA: Risk analyses for mobile offshore units
7. NMA: Construction of mobile offshore units
8. NMA: Precautionary measures against fire and explosion on mobile offshore units
9. DSB Guide: Risk Assessment and handling of fire in Lithium-ion Batteries
10. NMA: Guidelines for chemical energy storage – maritime battery systems
11. NMA: Safety management system for Norwegian ships and offshore mobile units
12. Ship Safety and Security Act
13. NMA: Working environment, health and safety of persons working on board ships
14. NMA: Qualifications and certificates for seafarers
15. NMA: Operating arrangements on Norwegian ships
16. DSB Regulations relating to maritime electrical installations
17. Safety regulations when working in and operating electrical installations
18. ISM Resolution MSC.428(98) Maritime Cyber Risk Management in Safety Management Systems
19. IEC standard 62619 Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications
20. ULA 9540 A Testing the fire safety hazards associated with propagating thermal runaway within battery systems.
21. NMA: Guidelines for training requirements on chemical energy storage (maritime battery systems) on board Norwegian vessels

9. Abbreviations

DFU	Defined Danger and Accident Situation
DSB	Norwegian Directorate for Civil Protection
FMEA	Failure Mode & Effects Analysis
HRS	The main rescue centre
ILO	International Labour Organization
IMO	International Maritime Organization
ISM	The International Safety Management Code
ISPS	International Ship and Port Facility Security
MARPOL	The International Convention for the Prevention of Pollution from Ships
MLC	Maritime Labour Convention
PSA	Petroleum Safety Authority
ROV	Remotely operated vehicle
NMA	Norwegian Maritime Authority
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UPS	Uninterrupted power supply

Appendix 1 Battery systems

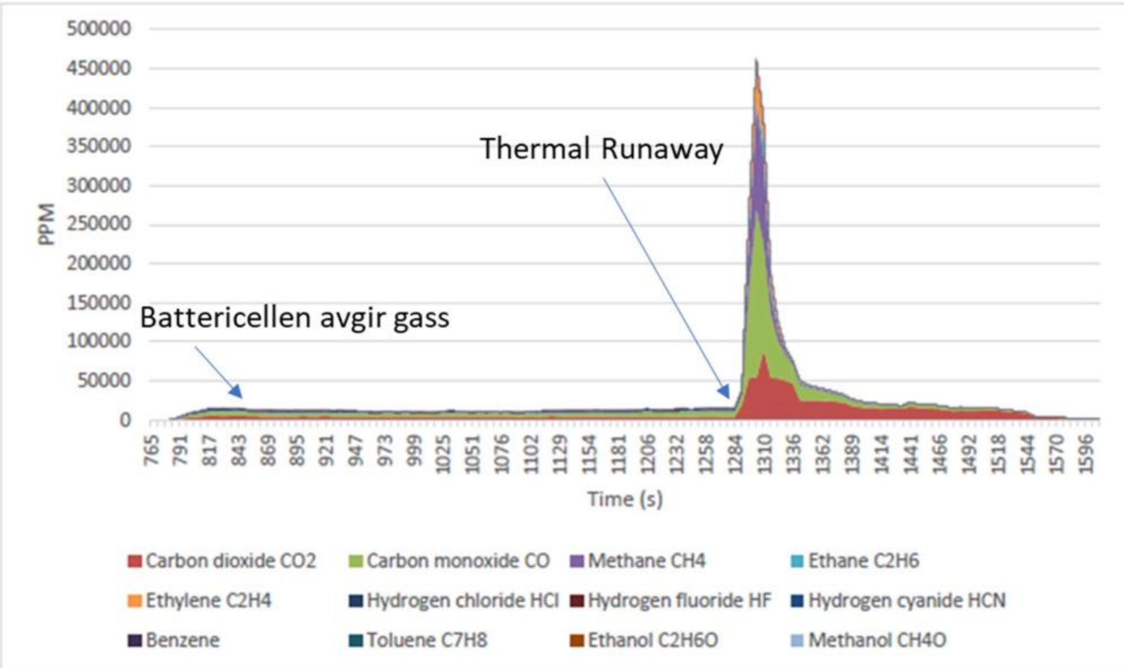
The figure below shows the typical structure of a battery system. The components in a battery system can be divided as shown below. Note that there are several types of lithium-ion batteries with different cell chemistries – and therefore different properties. There are also different compositions. Some battery systems have passive fire protection at cell level, while others only have fire protection at module level. In a battery with fire protection only at module level, a fire in one cell will be able to spread to the neighbouring cells.

Battery cell – the smallest electrochemical component in the battery system. The cells may vary in both shape and size. The most common in larger systems are 'pouch cells', 'cylindrical cells' or 'prismatic cells'.	Rated voltage: 2.4VDC – 3.6VDC, depending on cell chemistry. Energy: 7Wh – 640Wh. The most common size is 230Wh	
Battery module – A collection of cells including some control and monitoring. The smallest unit that can be electrically isolated in a battery system.	Rated voltage: 10 – 60VDC. The most common is around 50VDC Energy: 3kWh – 6kWh	
Battery string / battery rack – A collection of modules that is connected in series. A battery string has the same voltage as the system voltage.	Rated voltage: 300VDC – 1200VDC Energy: 70-150 kWh The most common is approx. 120 kWh	
Battery system – One or more strings/racks including control and monitoring electronics	Rated voltage: 300VDC – 1200VDC (Equal string/rack voltage) Energy: 200kWh - 30MW Trend is increasing amount of energy	

Appendix 2 Thermal runaway – gas evolution

Many of the gases that develop during a battery fire are explosive, corrosive and toxic, and it is therefore extremely important that those who are to fight battery fires take the necessary precautions to protect themselves against such gases. The figure below[1] shows how quickly gases may be formed, and which gases are released in the event of thermal runaway (TRA). The battery cells start to emit gases at as low as approx. 50 degrees, with a sharp increase in gas production when TRA occurs at 80-90 degrees and the temperature increases to over 500 degrees.

Before TRA occurs there may be a pre-heating process. If this is detected via the BMS or other systems, full TRA may in some cases be avoided.



In addition to the listed gases, hydrogen will also be produced.

Hydrofluoric acid (Hydrogen fluoride – HF) gas from a fire in lithium-ion batteries can be extremely dangerous:

Skin hazard	Absorbed through skin. Causes nerve, bone and organ damage. Can be fatal.
Eye hazard	High risk of blindness.
Inhalation hazard	Toxic, lethal at concentrations> 200ppm, non-lethal doses may cause pulmonary oedema.
Ingestion hazard	Toxic, often fatal.

Given this risk, one should keep a good distance from and <u>not enter</u> areas where one may be exposed to hydrofluoric acid. Also be aware that filter masks and ordinary fire protection clothing do not provide protection against this acid – and that glass in masks and instruments will blacken when exposed to hydrofluoric acid.

Only chemical suits will provide protection against hydrofluoric acid. But with the necessary competence ‘splash suits’ may be used after a fire, for example in the event of an investigation.

Appendix 3 Regulations

The Norwegian Petroleum Safety Authority's (PSA) regulations apply to offshore facilities, mobile facilities that operate on the Norwegian shelf and onshore facilities in the petroleum industry. The PSA has a functional set of regulations, and there will be several regulations and sections relating to technical, operational and organizational matters that may be relevant to battery packs.

<u>Relevant PSA regulations:</u>

- The management regulations
- The activities regulations
- Technical and operational regulations

For mobile facilities registered in a national ship register and which follow a maritime operating concept, relevant technical requirements in the Norwegian Maritime Authority's regulations for mobile facilities with additional class rules given by a class institution, or international flag state rules with additional class rules with the same safety level, may, with the clarifications and restrictions that follow from section 1 of the Facility Regulations, be used instead of the technical requirements given in and pursuant to the Petroleum Act. The maritime regulations that are chosen to be followed must be followed in their entirety.

<u>Some laws and NMA regulations that are relevant to battery packs on mobile offshore units:</u>

- Ship Safety and Security Act
- Requirements for risk analysis:
    - Regulations on risk analysis for mobile offshore units
    - Regarding the post-installation of battery systems, it is particularly important to note section 7 (Revision of the risk analysis) and section 8 (Qualification requirements)
- General requirements for fire/explosion protection and other technical design elements:
    - Regulations on precautionary safety measures against fire and explosion on mobile offshore units
    - Regulations on the construction of mobile offshore units sections 6, 6a, 6b, 11, 18 and 21
- Requirements for safety management system and qualifications:
    - Regulations on safety management systems for Norwegian ships and mobile offshore units
    - Regulations on qualifications and certificates for seafarers
    - Regulations on the working environment, health and safety for persons working on board ships

<u>On ships, the following regulations are relevant:</u>

- Ship Safety Act
- Regulations on the working environment, health and safety for persons working on board ships
- Regulations on safety management systems for Norwegian ships and mobile offshore units
- Regulations on qualifications and certificates for seafarers
- Regulations on operating arrangements on Norwegian ships
- Regulations on maritime electrical installations
- Regulations on safety when working in and operating electrical installations
- Regulations on rescue equipment on ships
- Standard NEK 410 also covers electrical systems on ships (based on IEC 60092). A standard for specifications for battery systems (NEK 411) is also being prepared.

All shipping is subject to international rules laid down by the IMO and ILO, ratified and implemented in Norwegian law and regulations. The four safety pillars in the shipping industry are SOLAS, MARPOL, STCW and MLC. Requirements for risk analysis are described in ISM Code 1.2.2: *'provide for safe practices in ship operation and a safe working environment; establish safeguards against all identified risks; and continuously improve safety management skills of personnel ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection.'*

In addition, sections 8-12 of the Staffing Regulations, and ISM code 6.2, which refers to IMO A.1047 (27), are relevant. Responsibility and competence requirements for individual positions can be found in the Regulations on qualifications and certificates for seafarers (STCW).

Appendix 4 Training curriculum

Sample training curriculum* for Lithium-ion batteries.
NB: These plans do not cover necessary equipment-specific training.

Course	Content	Target Group	Duration
Intro-ductory course	Describe lithium-ion battery structure, causes of fire, demo battery fire, extinguishing methods and hazards	Everyone who works in areas with battery systems	Adapted to target group
Basic course	Basic electrical understanding, basic understanding of batteries, extinguishing systems, regulations and hazards. Should be adapted to the relevant battery solution	Fire teams, technical personnel emergency management, HSE	½ day
Advanced course for operative technical personnel and fire teams	Comprehensive understanding of what a lithium-ion fire is and what distinguishes these fires from other fires. The course shall provide students with a thorough understanding of risk and fact-based knowledge, enabling them to undertake risk assessments in the best possible way and to understand which measures may be implemented.	Machinists, electricians, constructors, engineers, fire brigade, HSE	1 day
Practical training	General understanding of what a lithium-ion fire is and what differentiates these fires from other fires. The course uses a combination of classroom-based teaching and practical demonstrations to provide students with a thorough understanding of risk and fact-based knowledge, enabling them to undertake risk assessments in the best possible way and to understand which measures may be implemented.	Fire teams and on-site managers	1 day
Manage-ment and strategy	Participants are given an introduction to risk, scope of damage, factors that increase/decrease the risks in connection with a lithium-ion battery fire in risk classes 3 & 4. Using a dedicated plan, participants must be able to lead different scenarios on board (without immediate external help) and interact with rescue resources (HRS, RITS etc.) through various exercise scenarios. Be able to handle larger numbers (passengers/employees on board.	Emergency management	1 day

* Reproduced with permission from OilComp AS

Appendix 5 Different lithium-ion battery chemistries

LTO (Lithium titanium oxide): Charges more quickly than other lithium-ion batteries. High safety with low energy density (see figure below). Used in some electric vehicles and e-bikes.

LFP (Lithium ferro phosphate): High safety, low toxicity, long lifetime and low price. Used in some electric vehicles, including Tesla, and several Chinese brands. Also used in UPS/power backup systems.

LMO (Lithium manganese oxide): High safety, low price and rapid charging, but short lifetime.

NMC (Lithium manganese cobalt oxide): High power-to-weight ratio. Used in most electric vehicles (Audi, BMW, Chevrolet, Hyundai, Jaguar, Nissan, VW etc.). Also common in mobile phones / smart phones and larger battery packs (e.g. 30 MW facility installed in Australia in 2018).

LCO (Lithium cobalt oxide): Good energy density, but poor thermal safety; vulnerable to thermal runaway in the event of overcharging.

NCA (Lithium nickel cobalt aluminium oxides): Extremely high energy density. Often used in smaller batteries (e.g. Panasonic). Relatively expensive, with lifetime (number of charge cycles) only half that of LFP batteries.

Energy density for various battery chemistries (all orange columns are lithium-ion batteries). In general, the lower the energy density, the safer the battery chemistry.