European Maritime Safety Agency

Guidance on the Safety of BESS on board ships

EMSA Guidance on the Safety of Battery Energy Storage Systems (BESS) on board ships

Version 1.0

Date: November 2023

EMSA

DISCLAIMER

None of the provisions within the EMSA Guidance are binding in nature and should be regarded as guidance for good practice. Adequate application of the recommendations within the EMSA Guidance should always be done in conjunction with the referenced industry standards on the design and installation of maritime battery energy storage systems.

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Introduction

The European Green Deal and the IMO initial and up-coming mid- and long-term Strategies for Greenhouse Gas reduction have sparked the development and implementation of technical solutions aiming at reducing the GHG emissions from shipping. The use of alternative zero carbon and sustainable fuels is increasing, as are solutions based on energy stored in batteries. Electrification brings advantages for the sector not only in terms of sustainability, by reducing emissions and energy consumption, but also in design and operations, reducing maintenance and allowing for more flexibility in the powertrain arrangements on board.

Battery Energy Storage Systems (BESS) installations on board ships have been increasing in number and installed power as the battery technology also develops. According to the Alternative Fuels Insight platform, there are more than 800 battery ships in operation, a figure that has more than tripled in the past five years. Out of those, around 60% are known to be operating in Europe, using batteries on board for propulsion either in pure electric or hybrid functions. At least 50% are hybrid or plug-in hybrid, and around 13% are pure electric.

The current low energy density of the available energy storage systems makes them a preferred option for short-distance voyages or services that require low-autonomy. For this reason, the ship record shows that the largest number of installations are in car and passenger ferries and ships dedicated to other activities than deep-sea commercial cargo transport.

Rapid technological development requires the implementation of technologies being made in a safe and uniform way across the sector based on well understood, simple and solid safety guidance.

At the moment, there is no regulatory instrument at international level on the safety aspects of using batteries in ships. This important scope has been left to and evolved through the requirements of class, industry standards and codes with limited requirements and experience from the side of flag states.

EMSA with the support of the European Commission, the Member States and the industry has drawn-up this non-mandatory Guidance to guide national administrations and industry, and which aims at a uniform implementation of the essential safety requirements for battery energy storage systems on board of ships.

The IMO GENERIC GUIDELINES FOR DEVELOPING IMO GOAL-BASED STANDARDS MSC.1/Circ.1394/Rev.2 were taken as the basis for drawing-up this Guidance.

Lithium-ion batteries are currently the most popular choice for ship operators. The main risks associated with this type of battery are fire and explosion due to thermal runaway and off-gas generation. Based on available literature shared by the group of experts and previous EMSA studies[1], functional requirements were developed using li-ion technology as a reference in view of the mitigation of the risks from design, installation, and operation of these systems.

This Guidance is structured as follows: Chapter 1 outlines the goals and functional requirements for the main components of the battery energy storage system. Chapter 2 deals with the goals and functional requirements of the system's arrangement across the different configurations and functions that the battery might have on board. Furthermore, Chapter 3 contains testing standards and procedures for maritime batteries and their installation. Chapter 4 includes operational, including maintenance, and training procedures and recommendations and is complemented by Annex B with a guidance for qualification of officers. Chapter 5 contains additional provisions by mode of operation of the battery system. Finally, Chapter 6 includes a generic safety assessment methodology for the cases for which this Guidance is not able to provide relevant technical provisions. For reference, Annex A includes a list of lithium-ion cell chemistries and expected off-gases.

[1] EMSA (2020), *Study on Electrical Energy Storage for Ships: Battery Systems for Maritime Applications – Technology, Sustainability and Safety,* DNV-GL 2020

Scope

This document addresses the hazards and measures to reduce the risks of Battery Energy Storage Systems (BESS) when installed on board ships, providing guidance on their design, installation, testing, operation, maintenance, and the training of those who manage their operation. This Guidance, aims at supporting a uniform assessment of the safety level of these installations by the Administrations in coherence with the safety goals in the International Conventions and the applicable EU legislation.

The Guidance should:

a. be supplementary to the applicable instruments[2] and only address Battery Energy Storage Systems matters as far as they are not addressed in the existing instruments; and

b. be goal based, non-mandatory and crafted in such a way as to facilitate its implementation.

Application

This non-mandatory Guidance applies to lithium-ion battery energy storage systems installations on board ships.

This non-mandatory Guidance refers to all ships engaged in international or domestic voyages, irrespective of their material of construction, for which a battery energy storage system based on lithium-ion technologies serves any of the following functions or their combination: main propulsion, auxiliary services, emergency propulsion, emergency services and/or other ancillary services.

CONTEXT

This non-mandatory Guidance addresses Battery Energy Storage Systems fulfilling functions such as:

- Fully electrical ships operation for which the BESS is the only source of power.
- Hybrid powering (peak shaving, backup/reserve, loads optimization) for which the BESS is an energy source.
- Emergency powering (e.g.it should entail primary and secondary essential services, as well as habitability services as per MSC.1/Circ.1572, and SOLAS regulations II-1/8-1, II-2/21 and II-2/22 (flooding and fire for the purpose of Safe Return to Port (SRtP), as applicable).
- Electrical services (e.g. it may entail primary and secondary essential services, as well as habitability services as per MSC.1/Circ.1572, SOLAS regulations II-1/8-1, II-2/21 and II-2/22 and/or also other non-essential services).
- Other ancillary services
- BESS as power source for embarked system, to fulfil a task of the ship.

[2] Applicable instruments depend on the ship's type, size and whether the voyage is domestic or international.

The abovementioned functions can be fulfilled by configurations such as:

1. All-electric propulsion
2. Battery hybrid propulsion
3. Battery hybrid propulsion with distributed batteries
4. Mechanical propulsion with battery hybrid electric power plant
5. Electrical/mechanical hybrid with DC and AC power distribution
6. Auxiliary power supply for other services

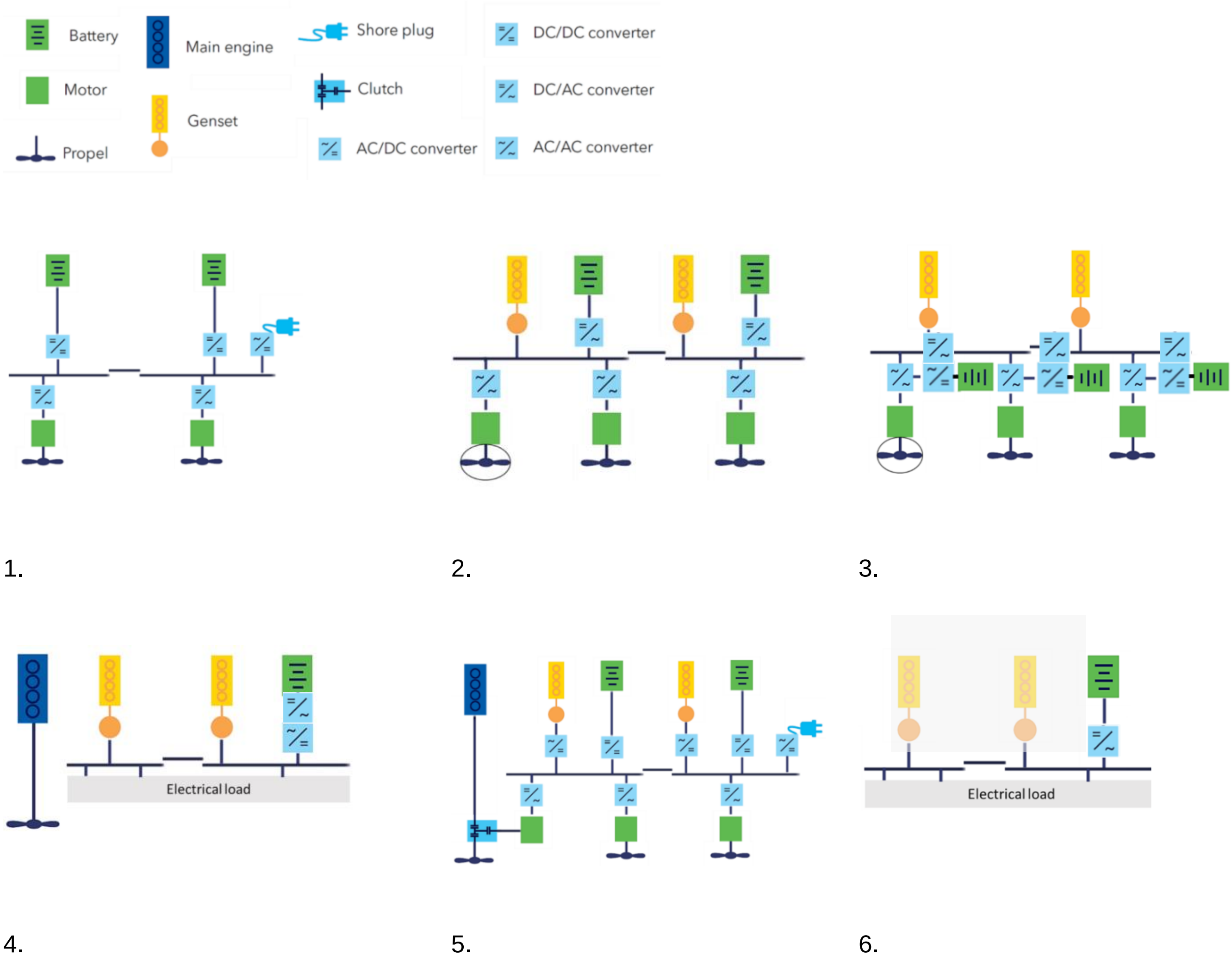

Figure 1.1 – BESS on-board power configurations.

This non-mandatory Guidance addresses the following topological configurations:

- Fixed (stationary) batteries installation
- Containerized batteries
- Distributed energy storage on-board

Exclusions

This non-mandatory Guidance is not applicable to installations of less than 5 kWh.

This non-mandatory Guidance does not refer to second life batteries. Second-life batteries may pose different safety concerns particularly related to aging, wear and tear and best practices for the safe and effective reuse are not consolidated at the stage of development of this Guidance.

Definitions

For the purpose of this Guidance, unless expressly provided otherwise, the terms used have the meanings defined in the following paragraphs. Terms used, but not defined in the Guidance, are to be interpreted as they are defined in the relevant European legislation and international conventions. In case of contradictory interpretations, the definitions as set in the international conventions shall prevail.

Term	Definition
Battery cell	The basic functional unit in a battery constituted by electrodes, electrolyte, active materials (such as lithium and cobalt), separators if applicable, container and terminals. A 'secondary battery cell' can receive, store, and deliver electrical energy through chemical energy storage within its internal components.
Battery Energy Storage System (BESS)	A rechargeable battery with internal storage specifically designed to store and deliver electric energy into the grid, which includes battery modules, packs, electrical interconnections, means of isolation, cooling system (as appropriate), battery management system and other safety features.
Battery Management System (BMS)	Electronic system that controls, manages, detects, calculates electric and thermal functions of the battery system and provides communication between the battery and upper-level control systems. It monitors the state of the battery and protects the battery from operating outside its safe operating area.
Battery module	An assembly of battery cells electrically connected which includes a monitoring circuitry and may include protective devices.
Battery pack	An energy storage device comprising one or more electrically connected cells or modules. The battery pack can include protective housing, protective devices and control and monitoring systems in communication with the battery management system. A battery pack can be used as stand-alone unit when a battery management system is integrated in the pack.
Battery room	Dedicated space where the Battery Energy Storage System is installed.
Battery space	A ship's space not exclusively dedicated to Battery Energy Storage System.
Battery string	A number of cells or modules connected in series with the same voltage level as the battery system.
Battery Thermal Management System (BTMS)	System that regulates the temperature of the batteries within the range specified by the manufacturer.

	Note: for the purpose of these guidelines BTMS has to be understood as the system built-in the battery case or rack and it should not to be confused with the ship-board HVAC system.
Cell balancing	Passive and/or active techniques that redistribute charges between battery cells to maintain equivalent state-of-charge of every cell.
Cell block	Group of cells connected in parallel or in series.
Energy Management System (EMS)	Integrated system that provides information and manages the flow of energy in a Power System looking to safety, function, and operating modes. It collects energy measurement data from the field and makes it available for information through graphics, online monitoring tools, and energy quality analysers.
Hazardous area	Means an area in which an explosive and/or toxic gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.
HVAC	Heating, ventilation and air conditioning of the battery space or room.
Lithium-ion cell	Cell where electrical energy is derived from the insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode.
Off-gas	The gas released by the battery cells during an abnormal incident, constituted by thermal runaway exhaust gas such as vaporised electrolyte.
Power Management System (PMS)	An electronic system to control the power production, distribution and load calculations of the ship ensuring that power capacity is line with demand at any time. The PMS integrates all sources of energy production and consumption and controls all associated sub-systems such as the electrical main distribution line, prime movers, energy storage systems, propulsion, and main consumers.
Rated capacity	The total number of ampere-hours (Ah) that can be withdrawn from a fully charged battery under specific conditions.
Rechargeable battery system	A battery system that is designed to be recharged.
State of charge (SoC)	A measurement of the amount of energy left available in a battery pack or system in a specific point in time expressed as a percentage of rated capacity. It provides information on how long the battery can perform before it needs to be charged or replaced.

State of health (SoH)	A measure of the general condition, including state of safety, and performance of a rechargeable battery compared to its initial condition.
Thermal runaway	The condition of accelerated increase of temperature by self-heating, where the rate of heat generation within a battery component, typically larger than >80 °C or 1 °C/s, exceeds its heat dissipation capacity.
Uninterruptible Power Supply (UPS)	A combination of convertors, switches, and energy storage devices (such as batteries) constituting a power system for maintaining continuity of load power supply in case of input power failure.
Venting	The operation of release of excessive internal pressure from a cell/battery as intended by design to prevent rupture of the case or explosions. or upon release of toxic gases or smoke.

General

Goals

This Guidance lays down goals and functional requirements for design, construction, installation, operation, including maintenance, of Battery Energy Storage Systems on board ships as source of power, ensuring the safety of the crew, passengers and the ship.

High-level functional requirements

- The safety, availability, reliability and maintainability of the Battery Energy Systems and its on-board arrangements and installation should be equivalent to that achieved with new and comparable conventionally fuelled main and auxiliary machinery.
- The probability and consequences of Battery Energy Storage System-related hazards should be limited to a minimum through design of the core equipment, the general on-board arrangement, their installation and operation on board. In the event of a failure of the risk reducing measures, necessary safety actions should be initiated.
- The safety level should not be impaired by a single failure in a technical system or component.
- The design philosophy should ensure that risk reducing measures and safety actions for the Battery Energy Storage System installation do not lead to an unacceptable loss of power (such as dead ship condition).
- Systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
- Suitable control, alarm, monitoring, disconnection and emergency shutdown systems should be provided to ensure safe and reliable operation.
- Commissioning, tests, trials and maintenance of the Battery Energy Storage System should satisfy the goal in terms of safety, availability and reliability.
- The technical documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used, and the principles related to safety, availability, maintainability and reliability.

In order to achieve the goal above and fulfil the high-level functional requirements, this Guidance builds on the following general principles:

Availability of power supply

- Provide the availability of the essential systems after a flooding or fire casualty.
- Provide the availability of emergency services to support a ship's evacuation and abandonment after a fire casualty.
- Restore electrical power supply after malfunction.
- Provide sufficient power supply to the electrical loads in normal and emergency conditions.
- Provide measures to maintain the availability of the essential systems and support a ship's Safe Return to Port under its own propulsion after a fire casualty, as applicable for passengers ships under international regulations.

Fire safety

- Prevent battery fires.
- Provide fire detection, containment and suppression/extinction measures appropriate to the fire hazards concerned.
- Prevent unintended accumulation of explosive, flammable or toxic gas concentrations.

Safety of electrical installations

- Provide measures to prevent fire hazards originated in the battery system.
- Limit impact on the installations of conditions not originated by battery systems.
- Limit or mitigate the risk of disturbance to other main essential electrical systems.

Operational safety

- Provide measures for adequate personal protection and procedures for safety on board a ship with BESS.

Alternative design

This Guidance contains goals, functional requirements and specific requirements for all appliances and arrangements related to the usage of Battery Energy Storage Systems on board ships.

The goals and functional requirements set out in this guidance can be achieved by ensuring compliance with the prescriptive requirements in rules and standards specified in this guidance and/or by alternative design and arrangements which comply with MSC/Circ.1002 or MSC.1/Circ.1455.

Guidance review

This Guidance should be kept under review, gathering proposals for amendments from the stakeholders, as more experience is gained and as technology develops.

The review process should follow the same working method used to develop the first issue of this Guidance, with EMSA gathering the Group of Experts that originally engaged in the work to formulate proposals for amendments and suggestions for improvements.

The periodicity of the review process should be established on a need-to-act-basis, subject to EMSA’s assessment.

General requirements for the risk assessment

A risk assessment should be conducted to ensure that risks arising from the design, installation, overall ships' arrangement and operation of Battery Energy Storage System, affecting persons, environment, or the ship, are addressed. Electrical and fire safety, structural strength, and the integrity of the ship, as well as ventilation and venting, reliability, and availability of power, should in general be addressed in a risk-assessment. Consideration should be given to the hazards associated with physical layout, operation and maintenance following any potential failure, as well as human error.

The risk assessment would need only to be conducted where explicitly required by paragraphs of this Guidance and in all cases for which Alternative Design is applied.

The risks should be analysed using acceptable and recognized risk analysis techniques. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated, as necessary. Details of risks, and the means by which they are mitigated, should be documented to the satisfaction of the Administration.

Section 6 contains the main principles and high-level instructions on how to conduct a risk-assessment for the purpose of this Guidance.

Relevant standards:

ISO 31000:2018 Risk management – Guidelines

IEC/ISO 31010:2019 Risk management - Risk assessment techniques, with particular focus on section 7 (Selecting risk assessment techniques)

IEC 60812:2018 Failure modes and effects analysis (FMEA and FMECA)

IEC 61025:2007 Fault tree analysis (FTA)

IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems

1. Battery Energy Storage System (BESS)

This section addresses the Goals and Functional Requirements common to all functions that may be fulfilled by the BESS as specified in the 'Application' section. Function or technology specific provisions are addressed in section 5.

Hazards	H.1 Overall BESS design does not provide sufficient protection to prevent injuries. H.2 Energy stored in BESS is not sufficient, not readily available for the intended use in relation to the task of the ship and the functions assigned to the BESS and/or does not consider the ageing of the equipment. H.3 The BESS does not provide for redundancy, continuity of power supply in normal and in emergency operations, when it is the sole source of power, or when its functions provide energy for the essential services foreseen in MSC.1/Circ.1572 Annex 5. H.4 BESS is not designed for interfacing with other ship's systems, nor for being maintained and operated in marine environment, taking in duly considerations electrical hazards. H.5 BESS is not able to sustain large amplitude ship motions.
Goals	G.1 The BESS provides reliable electric energy for the specific needs of the ship, without posing any harm to the crew, passengers, property, environment, and avoiding any unscheduled interruption.
Functional Requirements	FR 1 → H.1, H.4 FR 2 to FR 4 → H.2 FR 5 and FR 6 → H.3 FR 7, FR 8, FR 10 to FR 14 → H.4 FR 9 → H.5

Functional requirements

Overall safety

FR 1 The BESS should be provided with means to minimize the possibility of fault conditions posing hazard to passengers, crew and the ship including other systems than and to the BESS itself.

Reliability of electrical energy supply

FR 2 The total required installed BESS capacity for its intended functions should be calculated, considering ageing – the decrease of capacity over time.

FR 3 The energy stored on-board in relation to the functions foreseen for the BESS should be made readily available upon request.

FR 4 The sub-systems should be designed and interfaced to enable the BESS to store and provide the required energy safely and continuously without any unscheduled interruption, during normal and foreseeable abnormal operations.

FR 5 The BESS should ensure that any single failure does not lead to any essential service being interrupted for more than the agreed restoration time.

FR 6 The same redundancy requirements applicable for the main and/or emergency sources of electrical power within existing regulations should be complied with when the BESS is fulfilling the functions expected from the main and/or emergency sources of electrical power.

Electrical interface

FR 7 The BESS should be capable of charging either from on-board power supply or at quay via shore supply.

FR 8 The interface parameters should be specified as compliant with existing standards.

FR 9 The maritime BESS should be designed and constructed to sustain marine environment exposure, including ship vibrations, motions and weather conditions, if applicable, while ensuring other safety performances (such as fire safety).

FR 10 The BESS system should be arranged to permit safe access for replacing components, inspecting, testing, replenishing, and cleaning if those actions are expected to be performed on board.

FR 11 Calculation of short circuit currents in different system's configurations should be conducted.

FR 12 Protection against overload and short circuits should be implemented. Selective tripping protection should be guaranteed. Protection against accidental contacts for earthing and short-circuits should also be ensured.

FR 13 Where a bi-directional flow of power may occur, the distribution system should be able to withstand the power variations being introduced. The level of bi-directional flow allowed should be specified by the system designer.

FR 14 An alarm should be provided at a manned control station in case of fault in the switching contactor or any major electrical fault requiring immediate intervention to prevent unsafe operation.

1.1 BESS description and boundaries

A Battery Energy Storage System (BESS) is an installation that reversibly converts chemical energy into other forms of energy, and which vice versa, stores energy internally in rechargeable batteries in the form of chemical energy.

Battery Energy Storage Systems include at least the following equipment and sub-systems:

- Batteries (cells and modules), battery packs, normally rack mounted which can be further organized in battery strings;
- Battery Management System (BMS);
- Communications protocols (DNP3, Modbus, et al) ;
- Operator control, monitoring and alarm system (able to report at least state of charge, voltage reading, state of health, temperature) (independent or incorporated in the ship main control and safety system);
- Power converters;
- UPS dedicated system (as safety feature part of the BESS), and
- Battery thermal management system (BTMS).

Battery energy storage system, depending on the function of the BESS, may interface with systems such as, but not limited to:

- Energy Management System;
- Charging station;
- Converters, Transformers;
- On-board distribution grid;
- On-board charging station;
- Switchboard, circuits breakers;
- Consumers;
- Emergency systems;
- Alarms and control systems;
- Battery space/room HVAC, as applicable;
- Ships Safety and Security Systems; Fire Detection Systems; Gas Detection Systems, and HV/LV Shore connection Systems.

1.1.1 Battery cells, modules and packs

Hazards	H.1 Internal cell failure causing thermal runaway. H.2 Temperature control for cells and modules is not adequate. H.3 Means to prevent or mitigate internal short circuits, mechanical and electrical hazards are not implemented. H.4 Means to manage the thermal runaway propagation are not provided.
Goals	G.1 Battery cells, modules and packs are constituted in sub-system assembly, capable of being safely charged, storing energy and provide it upon request (discharging); this assembly interfaces with other sub-systems of the BESS and/or other ship's support systems. G.2 Cells, modules and packs are protected against abuse and internal failures that are detected and contained.
Functional Requirements	FR 1 → H.1, H.2 FR 6 → H.2 FR 2, FR 3, FR 4 → H.3 FR 5 → H.1, H.4

Functional Requirements

To achieve the above-mentioned goals, the following functional requirements for the battery pack should be considered:

FR 1 Design should ensure that the battery assembly is maintained within the foreseen temperature range as given by the manufacturer by means of adequate thermal management systems.

FR 2 Design should minimize risk of short circuits and fault currents.

FR 3 The battery pack/assembly should be protected against over and under voltage and overcurrent.

FR 4 Mechanical and electrical solutions (including insulation degree) should be in relation to the foreseen on-board installation.

FR 5 Risk of thermal runaway propagation should be reduced by containing it within the smallest battery unit (cell or module).

FR 6 An alarm should be provided on-board in case of failure of the battery thermal management system.

Performance Requirements

In view of fulfilling the functional requirements, the following performance requirements could be taken into account:

Under FR 1 it is recommended that:

- Battery pack cooling is ensured either by the ventilation of the battery compartment or by direct ventilation and/or applicable cooling mediums (dedicated cooling circuit as part of the BTMS), or by the combination of the two.
- When a direct cooling is installed, the following alarms are provided, where applicable:
    - High temperature of the cooling air/medium of battery pack provided with forced ventilation.
    - Reduced flow of primary and secondary coolants of battery packs having a closed cooling system with a heat exchanger.
- The battery pack is provided with sensors connected with the Battery Management System for temperature control.
- Air based cooling includes filters for salty air if a direct air access is used.
- Humidity control

Under FR 2, FR 3 it is recommended that:

- Battery packs are constructed with rapid circuit breakers to prevent electric arc formation.
- Mechanical insulation and electrical protection between battery packs is provided, preferably by using a switchgear for safe isolation of the BESS system should be arranged. The switchgear should be able to be disconnected on both poles.
- Design considers creepage and clearance distances according to voltage levels. Creepage and clearance should consider potential cell swelling.
- Terminals are clearly marked, of size and conductive material fit for carrying the foreseen maximum currents.
- The battery system has means by which it can be electrically isolated for maintenance purposes. This isolation mechanism is independent of the emergency shutdown arrangement. The isolation mechanism allows for lock-out secured by a padlock or similar.
- The battery packs have means to be mechanically locked, prohibiting unauthorized action.
- The battery pack/assembly is protected against high temperature with disconnection device.
- The battery pack/assembly is protected against over and under voltage, with a disconnection device.
- For liquid cooled battery assembly, risk of leak of cooling liquid inside the modules is minimized by design to avoid creepage and currents/short circuit/arcing/ grounding faults. In addition, leak detection should be implemented.
- The battery pack/assembly is protected from ingress of water and other conductive particles (salt and dust).

Under FR 4 it is recommended that:

- The casing of a cell, module, battery pack, and battery systems is provided with a pressure-relief mechanism/arrangement to prevent rupture or explosion.
- Batteries are arranged such that those are suitably secured to move with the ship's motion.
- The battery casing, covering modules and cells, is made of a flame-retardant material.
- Enclosures have a degree of protection not lower than IP44. A degree of protection above IP44 could be considered in relation to the place of installation of the battery system and firefighting strategy (see also Section 2.2)

Under FR 5 it is recommended that:

- Battery cells are constructed and tested (see section 3) in accordance with the relevant industry standards.
- Battery packs are constructed and tested (see section 3) in accordance with the relevant industry standards.
- Battery cells and modules are designed for no fire propagation between cells within a module, whenever possible, or for no propagation between modules in a battery pack.
- Amount and composition of gases released during a cell thermal runaway should be known.

Under FR 6 it is recommended that:

- The alarm should be reported at a manned control station.

Relevant standards:

IEC 63462 IEC standard 63462-1 on Maritime battery system - Part 1: Secondary lithium cells and batteries - Safety requirements – under preparation[3]

IEC 62619:2022 Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Secondary Lithium Cells and Batteries, For Use in Industrial Applications

UL 9540A Test method for Evaluating Thermal Runaway Fire Propagation in Cell Energy Storage Systems

IEC 62620: Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Secondary Lithium Cells and Batteries for Use in Industrial Applications

IEC 62281:2019 Safety of primary and secondary lithium cells and batteries during transport (Similar to UN/DOT 38.3)

IEC 62133-2:2017 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems

[3] As the IEC 63462-1 standard will become available, parts of this Guidance will be reviewed to take in duly considerations the provisions of such standard.

1.1.2 Uninterruptible Power Supply (UPS)

Hazards	H.1 Loss of BESS safety functions due to loss of power. H.2 Configuration and available uninterruptible power supply is not able to maintain the functioning of the BESS's safety functions.
Goals	G.1 Uninterruptible Power Supply (UPS) maintains continuity of load power to the essential safety systems of the BESS at all times, except than for scheduled operations for the purpose of the safety of the operations.
Functional Requirements	FR 1, FR 2, FR 7 → H.1 FR 3 to FR 6 → H.2

Note: BESS safety functions for the purpose of this section include the Battery Management System, fire and explosion control systems and Battery Thermal Management System of the battery enclosure or HVAC of the BESS room or space.

BESS safety functions should be ensured regardless of whether such functions are integrated in a rack or not.

The UPS ensuring the BESS safety functions may be used also for ensuring continuity of power to other services.

Context

This section addresses the UPS that provide back-up power to the BESS essential safety functions.

However, for static Li-ion battery powered UPS above 5 kWh, the same rules as for the BESS should preferably apply.

Functional Requirements

To achieve those goals, the following functional requirements should be considered:

FR 1 During power failure, static and rotary UPS should provide the voltage output requested by the designated users to maintain continuity of the operations of the BESS safety functions.

FR 2 The energy storage system of the UPS should be at 100% SoC at all times and remain ready for use.

FR 3 The load power (DC or AC) the UPS provides should remain within the specified ratings (ranges and tolerances) of the UPS.

FR 5 UPS energy storage should be hardwired independent from the BESS for which it provides energy.

FR 6 UPS installation should ensure a grade of redundancy such that the power load of the BESS safety systems is maintained with half of the UPS in failure conditions.

FR 7 Containerized BESS should be provided with an UPS, installed in a segregated space,[4] and capable of communicating with the BESS and the ship's systems.

[4] The segregated space may be a ship's space adequate to host the UPS.

Relevant standards:

IEC 62040: Uninterruptible power systems (UPS):

- IEC/EN/BS 62040-1, General and safety requirements for UPS
- IEC/EN/BS 62040-2 Electromagnetic compatibility - Immunity category C3, Emission category C3
- IEC/EN 62040-3, class X, Voltage stability in transient state
- EN/IEC/BS 62040-4, Environmental aspects

1.1.3 Converters and inverters-chargers

Hazards	H.1 Converters and inverters-chargers do not operate as an integrated system, not providing for electrical protection and parameters within the range and tolerances of the BESS. H.2 Use out of operational tolerances and consequent system failures are not reported.
Goals	G.1 Semiconductor power converters are used for the conversion of electrical power, ensuring a reliable and safe charging and discharging of the batteries.
Functional Requirements	FR 1, FR 2 → H.1 FR 3, FR,4 → H.2

Functional Requirements

To achieve the above-mentioned goals, the following functional requirements should be considered:

FR 1 The electrical converter and BESS should operate as an integrated system, while preserving the BMS safety functions.

FR 2 These components should:

- regulate or adjust voltage interface with the BMS, maintain the frequency and avoid grid distortion, communicate with and operate within the limits given by the BMS in accordance with the capacity specified by the specific application.
- utilize independent voltage sensors from the BMS for voltage protection.
- maintain voltage, current within the limits specified for the battery cell by the battery manufacturer.
- sustain voltage, current and frequency variations foreseen in the plant/users they are servicing.
- ensure Bi-directional operations (charge and discharge).
- prevent ground potential differences or ground loops between the battery system and the rest of the ship.

- not be damaged by under load switching.
- be provided with means to protect the battery from reverse current and prevent a failing component from discharging the battery.
- initiate an alarm at manned control stations in case of charging and discharging failure.

FR 3 An alarm should be provided in case of inverter overload, over or under temperature.

FR 4 An alarm should be provided in case of power electronics fault.

Relevant standards:

IEC 60146-1-1:2009 Semiconductor converters - General requirements and line commutated converters - Part 1-1: Specification of basic requirements

IEC 60146-2:1999 Semiconductor converters - Part 2: Self-commutated semiconductor converters including direct d.c. converters

IEC 6100- series for Electromagnetic Compatibility (EMC)

IEC 62477 - Safety requirements of Power Electronics Converter System, as applicable

1.1.4 Battery Management System (BMS)

Hazards	H.1 Overcharge and over discharge are uncontrolled. H.2 High temperature during charging and discharging operations is not monitored and no measures implemented in case of overtemperature. H.3 BMS is not protected from unscheduled power interruptions.
Goals	G.1 The BMS monitors, protects, informs, controls, optimizes, and reports performances of a battery cells, modules, packs and strings, organized in a battery energy storage system (BESS) at all times to ensure the safety of the system on-board.
Functional Requirements	FR 2 → H.3 FR 1 and FR 3 → H.1 and H.2

Functional Requirements

FR 1 The battery system should have an integrated battery management system (BMS).

FR 2 The BMS should be functioning continuously, without any power interruption, including during emergency disconnection, installation, and decommissioning, except than for planned operations.

FR 3 BMS should be able to monitor, manage and inform on battery parameters, protect the system and diagnose internal faults according with the recommendations below:

MONITOR

- monitor and detect cell over charge and over discharge.
- continuously monitor the internal temperature of the battery.
- measuring and communicating battery voltage, battery current, battery balance and ground fault on module level.

MANAGE

- control of the charge current limits and action the switches between the pack and the load.
- adjust dynamic power limits.
- keep the balancing amongst the cells (active and passive).
- BMS should be able to monitor insulation.

ALERT/INFORM

- alert in case of over discharge.
- alert in case of loss of sensors.
- communicate the alerts to the relevant ships' alert system.
- allow for data transfer for ex-post analysis.

PROTECT

- cut-off charging and discharging in case of overcharging and over discharging.
- cut-off in case of overtemperature.
- protect from overcurrent, overvoltage and undervoltage.

DIAGNOSIS

- provide for faults diagnosis: an alarm should be raised in case of loss of main power supply.
- quantify of the remaining State of Charge (SoC) of the battery.
- present data for interfacing, management, and storage.
- assess the State of Health (SoH) based on the following parameters:
    - Remaining capacity,
    - Overall capacity fade,
    - Remaining power capability and power fade,

- Actual cooling demand,
- Evolution of self-discharging rates
- Ohmic resistance and/or electrochemical impedance.

FR 4 BMS should be able to validate the data which it monitors and a failure of the BMS (management, alert, alarm and protection functions) should raise an alarm at a manned control station.

Relevant standards:

IEEE 1679.1—IEEE Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications - Section 5.8 (active management requirement) describes BMS as active management for the battery system and defines its function (cell balancing, disconnect devices, thermal fault handling) and provides a BMS block diagram

IEC 62619:2022—Secondary cells and batteries containing alkaline or other non-acid electrolytes—Safety requirements for secondary lithium cells and batteries, for use in industrial applications – Section 8.2

IEC 60092-504 Electrical installations in ships - Part 504: Automation, control and instrumentation (relevant for BMS)

IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems

1.1.5 Other Components

1.1.5.1 Communication protocols for BESS and to external systems

Hazards	H.1 Communication protocol fails to deliver, where needed, alarms and alerts messages. H.2 Communication protocols are compromised for the failure of a single node of the network.
Goals	G.1 Communication protocols within the BESS and its interfaces ensure built-in error detection and containment, robustness to failure modes, speed and secure communications.
Functional Requirements	FR 1 → H.2 FR 2 → H.1 and H.2

Functional Requirements

FR 1 Communication protocol should ensure that:

- data consistency is maintained in the network of nodes,
- the information is broadcasted in more locations, as needed,
- the required bandwidth is available at all times and high priority/critical messages are always transmitted,

FR 2 Communication protocol should be in a way that:

- it is capable of error containment (i.e. faulty resistance which avoids that the failure of one node makes the network in-operative),
- vulnerability to failure modes is mitigated (by using electronic components (transceivers)), and
- is able to detect interruption (‘frozen’) of communication.

Relevant standards and communication protocols:

Controller Area Network (CAN bus) CAN Bus, CANOpen and CAN SAE J1939 - EN 50325/4, ISO-11898: 2003 - CAN2.0B

ModBUS – 1 – ModBus Organization Specs, Modbus TCP/IP

Profibus - EN 13321/1 (FMS), EN 50254/2, EN 50170/2, IEC 61158 Type 3

Foundation Fieldbus H1 - EN 50170, IEC 61158

DeviceNet - ISO 11898 &11519

Ethernet - ISO 8802.3- TCP/IP

ANSI/TIA-232-F-1997 (R2002) and ANSI/TIA/EIA-485-A-1998 (R2012) - RS232 and RS485

2. Battery on-board arrangements

2.1 Energy Management System

Hazards	H.1 Continuous assessment of power and energy available to the ship becomes unavailable. H.2 Alarms and alerts are not reported. H.3 Cyber resilience is not ensured.
Goals	G.1 The Energy Management System provides for the continuous assessment of the power, energy available and for the time needed for the completion of operations in normal and emergency scenarios, while ensuring resilience to cyber risks.
Functional Requirements	FR 1, FR 4 and FR 5 → H.1 FR 2 to FR 3 → H.2 FR 6 → H.3

Functional Requirements

In order to do so, the following functional requirements should be considered:

FR 1 The EMS should be independent from the BMS.

FR 2 The EMS should acknowledge and inform Operators of deviations from normal operational parameters of the BESS at all times, including in case of cyber threats.

FR 3 The EMS should be prepared to interface and synchronize with the BMS for the purpose of reporting alarms and warnings at least at module level, preferably also by replicating the BMS interface, information, and messages in the EMS on the bridge and engine control room (if applicable).

FR 4 The EMS should initiate immediate protective action on detection of abnormal energy flows between the sources, stores and consumers part of the electrical power system.

FR 5 The Energy Management System should provide a reliable measure of the available energy and power, taking into consideration the information provided by the BMS on SoH and SoC.

FR 6 The EMS components should be equipped with a suitable and up to date detection system for cyber risks if the operating system could be compromised in such a way.

Relevant standards and regulations:

IEC 60092:2023 Electrical installations in ships SER Series, with regard to:

- IEC 60092-201:2019 Electrical installations in ships - Part 201: System design - General
- IEC 60092-504:2016 Electrical installations in ships - Part 504: Automation, control, and instrumentation

IACS No. 166 Recommendation on Cyber Resilience

ISO/IEC 27001 standard on information technology – Security techniques – Information security management systems – Requirements.

2.2 Space(s) for Battery System

This section addresses the goals and functional requirements related to the arrangement of the BESS on-board.

The requirements in this section are recommended for all batteries and battery powered UPS units above 5 kWh. Where expressly specified specific requirements for BESS systems with energy content above 50 kWh are devised.

Throughout this section, the distinct definitions used for battery room and battery space should be carefully noted. The BESS is considered to be located in a battery room – one exclusively dedicated to the BESS – or in a battery space - not exclusively dedicated to the BESS. Container units housing the BESS are regarded as battery rooms unless stated otherwise.

Hazards	H.1 Mechanical impact damaging the battery space. H.2 Battery gassing, fire and/or explosion originating inside the battery space. H.3 Water ingress, leakages and condensation in the battery space. H.4 External factors to the BESS determining unsafe conditions inside the battery space (such as fires, outside temperature). H.5 Overall degradation of the system and its performances due to environmental conditions.
Goals	G.1 BESS are arranged in a room or space on-board that minimizes the danger to persons, damage to the ship, environment, surrounding spaces and equipment during its normal operation, maintenance, and emergency in the case of hazards. G.2 The BESS is housed and protected in a way that ensures that suitable operating conditions in terms of mechanical and structural protection, temperature, humidity, and other parameters that would impair performance or accelerate deterioration of the system are met.
Functional Requirements	FR 1, FR 2 → All H. FR 3, FR 6, FR 7, FR 9, FR 14 → H.4 FR 8, FR 10 → H.5 FR 5 → H.2, H.3 FR 4 → H.1, H.2, H.3 FR 1, FR 9, FR 11 → H.1 FR 12 to FR 15 → H.2

Functional requirements

FR 1 The battery room should only contain equipment associated with the BESS, minimizing the risk of increased temperature, fire, liquid leakages, condensation, dust and presence of other hazardous particles.

FR 2 The boundaries of the BESS room or space should not form part of the boundaries of spaces containing an emergency source of electrical power. [5]

FR 3 BESS should be located in spaces where they pose minimum risk of harm to crew and passengers in case of battery gassing, fire and/or explosion.

FR 4 BESS should have a pre-identified location on-board to allow for suitable design and testing of the space and ship safety systems.

FR 5 The safety and operational systems serving the space should be arranged to ensure that in case of detection of a hazard, the mitigation measures are effective and limit the damage from spreading to adjacent spaces and appliances.

FR 5.1 – Recommendations to mitigate the risk of explosion:

- The structural integrity of the hull and of the battery room or space should not be compromised in the case of battery fire and/or explosion.
- Toxic and explosive gases originated in the battery room or space should not spread inside the ship through ventilation, bilge or any other means.
- The BESS room or space should be provided with the means to prevent or mitigate explosions by using solutions such design/means to contain the energy or by releasing the energy in a controlled and safe way.
- Ventilation, extraction of gases and smoke should be continuous and coordinated with the firefighting strategy (i.e. with the deployment of inerting agents, extinguishing means and with the intervention of fire responders).
- BESS should not ventilate the off-gas directly into the room or space.
- For installation in enclosed spaces, the volume of the room/space should be suitable for the size and type of installation it houses, to allow for good air circulation and control of room temperature.

FR 5.2 - Recommendations to mitigate the risk of water ingress and BESS leakage:

- Bulkheads (and their penetrations) enclosing the battery room or space are watertight and constructed to be capable of preventing the passage of smoke and flame, with gastight doors and keeping the room or space at negative pressure.
- Pipes, cables, and ducts serving the equipment inside the space should be suitably protected in accordance with IMO MSC.1369 principles (SRtP)[6].
- Ingress protection for fluids, seawater spray, green-water, salt, objects and fire should be provided under normal operating conditions, including for BESS installed on open decks (e.g. IP67 or higher for installations on open decks).
- The battery space should not contain any tank with liquid other than drain tanks for possible leakages (of the battery liquid cooling system) dedicated to the systems inside the space.
- A bilge alarm to the space where the battery is installed should be provided at a manned control station.
- A system to mitigate leakages and manage the drainage should be provided.

[5] Not applicable if the BESS is used as transitional source of emergency power or as emergency source of electrical power.
[6] Regardless the applicability of MSC.1369.

FR 6 The battery space or room should not contain heat sources, flammable liquids, flammable gases, flammable metals, cooking oil and fats external to that of the battery system.[7]

FR 7 The batteries should not be located where exposed to sun and frost, unless ensured that the temperature exposure limits remain within the manufacturer specifications at all times.

FR 8 BESS and containerized BESS should be mechanically secured to the ship's structure. Fixings should be constructed to withstand the forces imparted from the batteries in design seagoing conditions.

FR 9 Deck space for the containerized BESS should be such to allow for safe loading and unloading operations of the container.

FR 10 The space should be arranged to permit safe access for maintenance, inspection and testing of the batteries rescue and fire-fighting purposes. In containerized BESS it might be admitted that the space does not permit on-board maintenance.

FR 11 The battery room or space should be located in areas on-board where collision probability is low, as far as practicable.

FR 12 The battery room or space should preferably[8] not be contiguous with machinery spaces of category A (cat (12)), spaces containing main source of electrical power, associated transforming equipment (if any) or the main switchboard, or other high fire risk spaces containing stowed flammable liquids (cat (14)).

FR 13 It should be possible to operate the essential BESS controls, from at least two locations with at least one out of the battery room or space.

FR 14 The battery room or space should be provided with one or more means of escape[9] appropriately marked, illuminated, protected against fire in the space and not capable of being cut off by it.

FR 15 The UPS serving the BESS essential safety functions should be installed in a separate room or space from BESS it is providing energy for.

Performance requirements

In view of fulfilling the functional requirements, it is further recommended that:

- The battery room contains only equipment associated with the BESS, including:
  - cell packs, racks, BMS, power control system (PCS) of the BESS and inherent safety systems (which includes BTMS and fire safety systems).
  - systems and servicing networks of the room such as pipes, ducts and cables essential for the operation of the BESS.
- BESS should be located outside accommodation spaces and control stations.

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[7] SOLAS II-2/Reg.9.2.2.3 / Cat(10) spaces (tanks, voids and auxiliary machinery spaces having little or no fire risk) may be appropriate for BESS installations below 50 kWh, while maintaining fire integrity as per Cat(11).

[8] Should not be possible because of space constrains (especially in small ships) refer to Section 2.2.3.2 Containment / List of performance requirements

[9] The battery room or space should be regarded as a machinery space for assessing the number of means of escape according to SOLAS II-2, Regulation 13.4.

- Areas on open deck within 1.5 m of inlet or exhaust openings of BESS spaces/cabinets are classified as hazardous areas.
- Regardless of the explosion mitigation measures implemented, all equipment located at ceiling level in the BESS room or space is suitable for hazardous area including firefighting, air conditioning and exhaust extraction equipment.
- Any metallic component of the fuel system passing within 300 mm above the battery top is electrically insulated.
- Water level alarms and (bilge) pumps are installed to serve each battery space or room and may be used in the fire-fighting/ventilation coordinated strategy. High water level alarms are reported on the bridge. Water level sensors are powered by electrical sources external of the battery room or space they serve.
- Means to lift the batteries are installed.
- Foundations of the battery racks are in steel.
- The battery space or room is located aft of the collision bulkhead.
- For ships not required to have a collision bulkhead the battery space or room is not located forward of 0.05L from the forward perpendicular where L is the overall length of the ship.
- Batteries are not installed directly above or below a fuel tank or fuel filter.
- Access to the battery room is through normally closed gas-tight doors with alarm at a normally manned location or self-closing gas-tight doors with no holdback arrangement.
- If the installation of pipes cannot be avoided inside the battery space those do not have any flanged or screwed connections potentially leaking to the space wherever technically possible.
- Permeability coefficients of the BESS room or space are provided for damaged stability calculations.

Relevant standards and references:

IEC 60079-10-1:2020 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres, with particular regard to section 4.4.2 Zone of negligible extent

IEC 60079-13 Equipment protection by pressurized room ‘p’ and artificially ventilated room ‘v’

IMO MSC.1/Circ.1369 Interim Explanatory Notes for the Assessment of Passenger Ship Systems' Capabilities After a Fire or Flooding Casualty (SRtP principles)

2.2.1 Fire safety

Definitions for the purpose of this section:

- **Place of Safety** means a place where a ship in need of assistance can take action to enable it to to stabilize its condition and reduce the hazards to navigation, and to protect human life and the environment. At a place of safety passengers and crew can be safely evacuated as foreseen by the applicable regulations. Places of safety should be established to the satisfaction of the Administrations.

- **Load bearing function** is the ability of a structure or of a part of it, to sustain specified design loads during the relevant fire event, according to defined criteria.

- **Integrity** is the ability of a separating ship's boundary, when exposed to fire on one side, to prevent the passage through it of smoke, flames and hot gases and to prevent the occurrence of flames on the unexposed side.

- **Unsafe conditions** are those conditions generated by a fire (internal and external) to the battery room or space (normally excessive heat by radiation) for which the BESS is not operating within the functioning parameters as specified by the manufacturer (opposite to safe conditions).

Relevant standards:

ISO 13943:2017 Fire Safety - Vocabulary

Hazards	Battery spaces **external** and **internal** fires are addressed in the following sections. H.1 For fires external to the battery room or space(s), the rise in temperature inside the battery room or space (by radiating effect or by conduction) is such that it causes increase of internal temperature of the BESS with loss of functionalities in the BMS and BTM, leading to thermal runaway (due to loss of cell voltage measurement or the electrolyte evaporation or melting separator). H.2 For fires internal to the battery room or space(s) the main hazards are: • H.2.1 Fires generated in the battery space/room, other than those electrical generated fires from battery cells/module/packs/strings. • H.2.2 BESS generated fires due to thermal runaway: ○ Electrical fire – overcharging/discharging or low temperature causing dendritic growth, lithium plating causing short circuits (leading to thermal runaway and fire). ○ Thermal fire – over temperature causing the electrolyte decomposition or melting separator (leading to thermal runaway and fire). ○ Mechanical fire – events that can lead to penetration of the enclosure of the battery/cell (such as drop of objects, ship's collision, grounding, maintenance errors) causing short circuits, (leading to thermal runaway and fire). ○ Internal short circuit – failure of the separator due manufacturing fault or any of the above conditions.

Goals	G.1 The goal of this chapter to ensure that systems for fire detection, containment and suppression[10]/extinguishment of battery room and space fires and for fires external to the battery room, are effective and operable under hazardous conditions and that suitable means of escape are provided for passengers and crew in case of fire. G.2 Fires and re-ignition of the batteries are managed taking into consideration the ship's concept of operations: G.2.1 Fire is **extinguished**, and the **re-ignition** of the batteries is **prevented**. G.2.2 Fire is **extinguished**, and **re-ignition** of the batteries is **suppressed**, within the time provided by the fire insulation of the battery space. G.2.3 **Fire and re-ignition** of the batteries is **contained and mitigated** (as opposed to suppressed), until the BESS, the battery room or space(s) and the ship are brought to safe conditions and/or the ship is at a place of safety.
Functional Requirements	FR 1→ H.2 FR 2 → H.1 FR 3 and FR 4 → H.1 and H.2

A fire risk assessment should be provided to the satisfaction of the administration (see Chapter 6) to address the ship's concept of operations, taking into consideration the Goals, Functional Requirements and where applicable, recommended Performance Requirements, as provided in the following sections (General, Detection, Containment and Firefighting).

Functional requirements

To achieve the above-mentioned goals, the following functional requirements are embodied in this section:

FR 1 There should be means to detect, contain and for firefighting (suppress and/or extinguish) any fire originating from the battery room or space.

FR 2 Protection of the battery room or space from external fires should be ensured by implementing safety measures appropriate for the contiguous spaces avoiding unsafe conditions inside the battery room/space.

FR 3 Fire safety equipment and strategy should be suitable for the concept of operation of the ship, and for the specific BESS arrangements.

FR 4 Fire protection of means of escape and ensured access for firefighting should be provided.

[10] Suppression of the fire can be only temporary as the fire could still re-ignite.

2.2.1.1 Detection

Hazards	H.1 Thermal runaway is not detected at early stage and no consequential fire safety measures are taken. H.2 Detection technology is not able to detect fire inception from the relevant active conditions (e.g. High air speed impairing detection capabilities).
Goals	G.1 To ensure that the thermal runaway is detected, treated as early as possible and contained at the lowest practicable level avoiding propagation to other battery modules. G.2 To provide measures for early and effective detection of gassing and fires arising from: - electrical fires (short circuits other than those arising from internal cell mechanisms), - thermal fires, - mechanical fires, - internal short circuits fires, and/or - any other active conditions in the battery space (such as thermal gradient for an active fire outside the battery space(s)) and provide alarms for safe escape and effective firefighting. G.3 Firefighting sequence is initiated upon a detection event alerts and alarms.
Functional Requirements	FR 1, FR 2 to FR 6, FR 8 to FR 10 → H.1 FR 2, FR 7 → H.2

Context

Recalling the scope of this non-mandatory Guidance, it is re-confirmed that:

- Relevant provisions of SOLAS Chapter II-2 Part C – Suppression of Fire, Regulation 7 Detection and alarm, remain applicable.

- Relevant provisions of Directive 2009/45/EC as amended and of HSC Code 7.7.1 and 7.7.2 remain applicable.

- Relevant provisions of FSS -Fire Safety Systems Code Chapter 9 Fixed fire detection and fire alarm systems and Chapter 10 Sample extraction smoke detection system, remain applicable.

Functional requirements

To achieve that, the following requirements should be fulfilled:

Measures for the battery room or space(s):

FR 1 Detectors should be installed in the room or space at least in the air extraction ducts[11] and be capable of off-gas (of invisible and vapour electrolyte release such as methyl ethyl carbonate, carbon monoxide, methane, hydrogen *et al*), heat and smoke detection (or a combination thereof). The detectors should be provided in number and positions adequate with the topology of the installation.

FR 2 The components of the detection system installed inside the battery space should be certified for use in explosive atmospheres.

FR 3 Ambient temperature monitoring with alarms should be available from a manned location.

FR 4 The temperature increase rate beyond which an alarm should be initiated should be defined.

FR 5 Detection system should interface with the BMS for shutdown operation and isolation of the battery pack/module/rack and should be independent from the BESS built-in system.

Detection built-in the battery racks (see also section 1.2.1 of this Guidance):

FR 6 Off-gas and temperature detectors should be installed in the racks where the batteries are contained in a number and positions (such as exhaust ducts) sufficient to ensure early detection.

FR 7 Gas detection of invisible and vapour electrolyte release should be implemented in the rack in a number and positions (such as the rack-exhaust-ducts) to guarantee early detection (see in combination with FR 1).

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FR 8 The following detected abnormal conditions inside the space should initiate an alarm at a manned control station:

- High ambient temperature,
- Low ambient temperature,
- Gas, heat and smoke detection, and/or
- Failure of the temperature and gas detection systems.

FR 9 Controls should be provided to de-energize electrical equipment upon gas detection.

FR 10 Containerized BESS should be provided with a detection system that is independent from the ship and should be able to communicate with the ship's system. Such detection system should fulfil FR 1 to FR 10.

[11] This detection system is not part of the racks mounted batteries detection system that can still be installed and connected with the ship's system(s) as appropriate.

Relevant standards:

IEC 61000-4 – Electromagnetic compatibility (EMC standards)

IEC 60079-29-2 Gas detectors – selection, installation, use and maintenance of detectors for flammable gases and oxygen

IEC/UL/ANSI 61010 - Safety requirements for electrical equipment for measurement, control, and laboratory use

2.2.1.2 Containment

Hazards	H.1 Smoke and fire from outside the battery space determines unsafe conditions inside the battery space. H.2 Structural integrity is endangered by loss of containment.
Goals	**Depending on the concept of operations of the ship:** G.1 The fire is contained, within the battery space until the fire is extinguished, while maintaining the structural integrity of the battery space and of the ship. OR G.2 Structural integrity is maintained until passengers, crew and the ship are at place of safety. * * * G.3 The fire is contained, outside the battery space until the fire is extinguished, without raising the temperature inside the battery space to conditions such that the BESS functionalities are impaired as specified by the manufacturer.
Functional Requirements	FR 1, FR 2 → H.1 FR 3 → H.2

Context

Recalling the Scope of this non-mandatory Guidance, it is re-confirmed that in particular:

- Relevant provisions of SOLAS Chapter II-2 Part C – in particular, Definitions Regulation 3, Control of smoke spread Regulation 8, and Containment of Fire, Regulation 9, remain applicable.
- Relevant provisions of Directive 2009/45/EC as amended and as applicable.
- Relevant provisions of HSC Code (areas of major fire hazard - fire category A).

Note*: For ships engaged in short coastal voyages in regular service, the fire safety strategy can take into consideration the evacuation of crew and passengers at the place of safety and the firefighting function being carried out in full or partially by onshore firefighting brigades on the basis of the evaluation carried out by the relevant administration on the availability and preparedness of onshore firefighting services. In cases where the onshore firefighting services are part of the fire safety strategy, coordination with the ship should be provided also when the ship is at berth unattended by the crew.*

Functional requirements

To achieve these goals, the following functional requirements should be fulfilled:

FR 1 Fire integrity of the battery room or space should ensure containment of the fire in the space protection for the time necessary to bring the space back to safe conditions.

FR 2 Fire integrity of the battery room or space boundaries, including openings and penetrations, should be able to protect the room or space from external fire.

FR 3 Battery room or space should be of gas-tight type.

PERFORMANCE REQUIREMENTS

In view of fulfilling the functional requirements, the following performance requirements should be considered:

Depending on the concept of operations of the ship:

For FR 1 and FR 2 it is recommended that:

- For fires breaking out from inside the battery space(s) - Integrity (as the one required for machinery spaces of category A) – A60 insulation of the internal boundaries of the battery room or space on all surfaces.

  Boundaries between category A machinery space (cat(12))12 and battery room or space are to have a A-60 fire insulation.

  > Explanatory note*: A60 protection secures containment for 60 minutes (when exposed to the standard fire test) that should be sufficient for the ship to reach a place of safety where evacuation can take place and the firefighting function can be conducted by rescue services (upon evaluation of the relevant administration).*

- For fires breaking out from inside the battery room or space – structural integrity, load bearing capacity and insulation performances are maintained until the fire is extinguished.

  Boundaries between category A machinery space (cat(12)) and battery room or space are to have a A-60 fire insulation.

  > Explanatory note:* it implies that the fire is contained within battery room or space without losing structural integrity, load bearing capacity and insulation which can be achieved by a combination of the containment and the firefighting capabilities. It should be demonstrated that a certain fire protection*

[12] See SOLAS II-2/Reg. 9.2.2

combined with a firefighting technical solution maintain the room or space within the required integrity. (See section 2.2.1.3 for more details).

- Containerized BESS are built according to ISO 1496-1 as minimum standard and should maintain structural integrity during a fire event and be classified as machinery spaces of category A. A risk-assessment (see Chapter 6) should validate the arrangements.

2.2.1.3 Extinguishment

Hazards	H.1 Re-ignition of the fire in the battery space. H.2 Extinguishing means are not able to reach the fire. H.3 Extinguishing means generate explosive, toxic and/or corrosive chemical compounds.
Goals	**Depending on the concept of operations of the ship:** G.1 To contain and suppress the fire as early as practicable and not later than time for which fire protection is ensured by the passive insulation of the battery room or space, to **control** and **manage** re-ignition. *Explanatory note: The firefighting solution should be sufficient for the ship to reach a place of safety where evacuation can take place and where the firefighting function can be conducted by rescue services. e.g. A60 containment capability combined with one release of inerting gas should extend the time to a possible reignition sufficiently for the ship to reach a place of safety within 60 min.* G.2 To contain the fire within the room or space and extinguish the fire as early as practicable and **deny re-ignition**, while maintaining structural integrity, load bearing capacity (and insulation performances) until the fire is **extinguished**. *Explanatory note: This requirement implies that the fire is contained within battery room or space without losing structural integrity, load bearing capacity and insulation which can be achieved by a combination of the containment and the firefighting capabilities. It should be demonstrated that a certain fire protection combined with a firefighting technical solution maintains the room or space within the required integrity, regardless the amount of energy stored in the batteries.* * * * G.3 Controlling and managing the production of harmful chemical compounds (solid, liquid and gaseous) during a fire event.

Functional Requirements	FR 1, FR 2 → H.1 FR 3 → H.2, H.3 FR 4, FR 5 → H.1 to H.3 FR 11 to FR 13 → H.2 FR 6 to FR 10 → H.3

Context

Recalling the Scope of this non-mandatory Guidance, it is re-confirmed that in particular:

- Relevant provisions of SOLAS Chapter II-2 Part C – Firefighting Regulation 10, remains applicable.
- MSC/Circ.1165, as amended

Functional requirements

To achieve that, the following functional requirements should be fulfilled:

FR 1 **For > 50 kWh should be in a dedicated battery room** defined as category A machinery space (cat (12)[13]) and depending on the concept of operations of the ship, the fire extinguishing system should provide for:

a) extinguishment and re-ignition **management** to prevent loss of the structure integrity and its load bearing capacity for the time needed by the ship to reach a place of safety.

or/and

b) extinguishment and re-ignition **denial** to prevent loss of the structure integrity and its load bearing capacity.

FR 2 **For < 50 kWh** installation in a machinery space other than a category A machinery space[14]), and depending on the concept of operations of the ship, the firefighting system should:

a) prevent loss of smoke tightness, loss of fire containment, loss of structural integrity and loss of load bearing capacity of the structure, for the time needed by the ship to reach a place of safety.

or/and

b) prevent loss of smoke tightness, loss of fire containment, loss of structural integrity and loss of load bearing capacity of the structure until the fire is extinguished.

[13] It refers to SOLAS II-2/Reg.9.2.2.3 Fire integrity of bulkheads and decks in ships carrying more than 36 passengers – made applicable to all ships.
[14] Cat(10) spaces (tanks, voids and auxiliary machinery spaces having little or no fire risk) may be appropriate, while maintaining fire integrity as per Cat(11).

For FR 1 and FR 2 the following should be applicable:

Fire dynamic simulations, including heat transfer analysis, should be performed to determine the time before the structure loses smoke tightness, fire containment capability, and to estimate the time to collapse. On the basis of these results, determine the firefighting strategy and capabilities of the system to avoid loss of smoke tightness, fire containment, collapse.

Fire simulations can be realized by using fire simulation CFD models and/or by testing to the satisfaction of the administration.

The ventilation function of the battery room/ space should be coordinated with the chosen firefighting strategy to control and manage formation of dangerous chemicals while ensuring the effectiveness of the firefighting operations.

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FR 3 **For < 50 kWh** installation in a ship service space, which is not a category A space, nor a machinery space, the BESS should be of rack-type modular mounted systems, with a design that prevents outward expansion of flames, integrated cooling system, detection system (gas, heat and smoke) and firefighting system. Off-gas and smoke extraction of the integrated in the mounted BESS should be connected to the ship extraction and venting system to prevent the spread into ship's spaces.

In addition, means should be provided in the space to control and mitigate the effects of radiated heat, to prevent damages to other ship's equipment and structure.

FR 4 **For < 50 kWh** where the installation is housed in a gastight, watertight, smoke tight A60 enclosure made of steel with a built-in fire detection system, fire extinguishing system, alert and alarm capabilities, temperature control and a gastight extraction system to a safe space on open deck, the requirement for risk-assessment may be waived to the satisfaction of the administration.

FR 5 **For deck mounted (cat (5) space) BESS** (regardless the concept of operations) the BESS should be containerized or be of rack-type modular mounted systems, with a design that prevents outward expansion of flames, integrating cooling system, detection system and firefighting system.

Smoke extraction of the mounted BESS should vent away from manned or accommodation spaces. Protection grades recommended are greater than IP55 and preferably IP67 for open deck installations. Corrosion protection grades C5 or CX are recommended.

Containerized BESS fire suppression and extinguishment system should interface with the ship's systems for the purpose of activation and control.

The battery enclosure or container should be prepared for breaching of firefighting means.

Hazardous atmosphere

FR 6 A combination of inerting agents and water-based solutions can be used depending on the battery room or space configurations.

FR 7 Extinguishing means should be released in the event of fire confirmed by more than one sensor. Manual release of the fire extinguishing should be possible from outside the battery room or space(s), a control station and from the bridge.

FR 8 In case inerting gases are used, upon release of inerting agents fire and smoke dampers, fire doors, should be actuated (opened and closed) by the control system to prevent damages of over or under pressure. The room or space should be gastight. Recommendations on the release mechanism are provided in MSC/Circ.550.

FR 9 On release of the extinguishing agent (other than inerting gas – such as water) ventilation should be activated to avoid the formation of acids and/or explosive atmosphere and building up of over pressure.

Other

FR 10 Portable fire extinguishers should be located outside the room or space(s) at or near the entrance(s).

FR 11 For BESS integrating BMS, thermal management, power control and fire detection functions, the chosen extinguishing agent should be able to penetrate the battery system at least at module level when released.

FR 12 Trunks to BESS room or spaces should be protected by a fixed fire-fighting system.

FR 13 The fire-fighting control system should be located outside the battery space.

<u>Additional recommendations</u>

- Where an inerting agent is used, the capacity of the inerting system should be such that the concentration is sufficient for inerting the space. The agent concentration for nitrogen for class high hazard risks should be used (i.e. oxygen concentration of 11.3 % or lower which corresponds to 45.2 % extinguishing agent concentration) should be achieved for non-metallic lithium-based batteries (ref. to IMO/Circ.848 and MSC/Circ.1165). Depending on the electrolyte used, higher design concentrations may be necessary. Where a CO_2 system is used, it should be compliant with FSS Code, Ch.5.

- Where a water-based system is used (sprinklers, water mist, deluge or total flooding), the system should use for the first discharge fresh-water (for a discharge of minimum 30 min, but preferably of 60 min); should the discharge of fresh water not be sufficient, discharge could be followed by salt-water. The flowrate and duration of the discharge of freshwater should be established on the basis of the fire dynamics simulation. An alert upon commencement of the discharge and upon the switch between fresh and salt water should be sent to the control station and to the bridge, to coordinate with the exhaust ventilation system to avoid the building-up of explosive atmosphere.

- Combinations of the abovementioned extinguishing agents are admitted.

Relevant standards and regulations:

ISO 12944 Paints and varnishes – corrosion protection of steel structure by protective paint systems

IEC 60529 Degrees of protection provided by enclosures (IP Code)

EN15004 Fixed firefighting systems - Gas extinguishing systems - Part 1: Design, installation, and maintenance for the calculation of the concentration of inerting agent and EN15004 series as per relevant means of extinguishment

IMO Circ.848 Guidelines for the approval of equivalent fixed gas fire-extinguishing systems as referred to in SOLAS 74, for machinery spaces and cargo pump-rooms, as amended by MSC.1/Circ.1267

IMO MSC.1/Circ.1165, as amended by MSC.1/Cric.1269 and MSC.1/Circ.1386 for the approval of water-based fire-extinguishing systems for machinery spaces and cargo pump-rooms

2.2.2 Ventilation / HVAC

This section is addressing ventilation, air conditioning, for temperature and humidity control, by taking into consideration the built-in BTMS (Battery Thermal Management System).

Hazards	H.1 Overtemperature. H.2 Accumulation of toxic and explosive off-gases. H.3 Accumulation of smoke due to a fire. H.4 High level of humidity and condensation.
Goals	G.1 Continuous ventilation, cooling, venting, air conditioning systems are to provide overall thermal, humidity/condensation and air quality management of the battery space(s) maintaining these parameters within the specified ranges for the safe and efficient functioning of the BESS. G.2 During an emergency (such as release of gases or a fire) the ventilation/ extraction/suction system is to prevent the accumulation of toxic and explosive gases and to extract smoke and gases to safe locations to open air under specified conditions. G.3 Ventilation is to be coordinated with the fire safety strategy.
Functional Requirements	FR 1 → H.2, H.3 FR 2 → H.1, H.3 FR 3 → H.2, H.3 FR 4 → H.1 - H.4 FR 5 → H.2, H.3 FR 6 → H.1

Note: Applicable to air and liquid-cooled BESS.

Functional requirements

Note 1: for BESS below 50 kWh with ventilation and extraction system integrated in the racks the battery space may not be required to install venting and ventilation systems, provided that the system of the battery rack is connected to the ship's systems (air take-in, extraction, exhaust) and complies with the Functional Requirements listed below.

Note 2: for BESS above 50 kWh shipborne systems (air take-in, extraction, exhaust) should be provided in the battery space/room in addition to the ventilation and extraction system integrated in the racks. The shipborne systems should function when the fire event is beyond the capacity of the rack-integrated system.

In order to fulfil these goals, the following functional requirements should be considered:

FR 1 Ventilation of gases and smoke:

- Maximum ventilation capacity should be calculated according to expected gas release within of the BESS room or space.
- Ventilation ducts are to be made of steel.
- Exhaust ventilation system for the battery space should be independent from other ventilation systems of the ship.
- Location of the ventilation outlet should be arranged so that toxic and explosive gases do not enter other ventilation system or endanger the persons on-board.
- Extraction system embedded in the battery racks should be sufficient to extract thermal runaway off-gases, upon their detection.

FR 2 Performances of the systems:

- Ventilation, extractions devices (dampers et al.), should be of a non-sparking and explosion proof type.
- Air conditioning system should be able to maintain temperature and humidity within the parameter specified by the BESS manufacturer. Air conditioning system may be used in combination with ventilators aiming at a homogeneous temperature distribution in the battery space (to reduce the risk on condensation on surfaces with different temperatures).
- Air conditioning system should be provided with backflow prevention should the ventilation and extraction system fail to work.
- Air intakes during the air changes should be done maintaining control on the humidity that may lead to condensations and electrical arching (especially critical in air cooled battery systems).
- For BESS of 50 kWh or more in normal conditions, not less than 6 air changes per hour of the battery room should be foreseen
- Exhaust ventilation system should be activated automatically on gas and/or temperature sensing.
- In coordination with the fire safety strategy, air intake and exhaust systems should be capable of maintaining negative pressure of the battery room, at least when unattended. Negative pressure conditions should be monitored. During a fire alarm extraction at full capacity should be activated.

- Gas detection inside the BESS room or space should be monitored. Gas detection monitoring system should be independent from the BESS being monitored.
- Position of ventilation and exhausting ducts relative to gas detectors should not affect the detection of gas.
- Temperature inside the BESS room or space should be monitored. Temperature monitoring system should be independent from the BESS being monitored.
- Temperature activated battery module and battery rack built-in ventilation should be provided (as built-in battery thermal management).

FR 3 Ventilation system arrangements:

- In case inerting gases are used, inlets and outlets ventilation ducts should be provided with a fire damper preferably automatically operated.
- Inlets and outlets ventilation ducts should be gastight and watertight and fitted with non-return valves.
- Battery room or space ventilators are to be fitted with a means of closing from outside the room or space (SOLAS II-2/5.2.1.1 IACS UI/SC240). An alert should be provided at the moment of acting the closing device.
- Inside the battery room or space, the ventilation exhaust should be located at ground level, as well as, as close as practicable to the ceiling to avoid accumulation of off-gases.
- Air extraction pipes from ventilation should not go through accommodation spaces, service spaces or control spaces.
- Outside ventilation openings should be arranged to prevent ingress of water (rain, snow and green seas).
- Ventilation inlets in the battery space should be positioned in such way that water does not drip on battery racks.
- Ventilation inlets and exhaust from battery spaces should be evacuated directly to open air, away from any ignition sources and areas where toxic gases produced by the battery may endanger crew or passengers.
- Arrangements should be made to avoid accumulation of hydrogen caused by water reaching the batteries resulting in electrolysis.
- Areas on open deck in the proximity of the exhaust opening of the space off-gas ventilation ducts are to be considered as hazardous areas.
- Ventilation ducts inlets and outlets should (preferably) not be placed in proximity of life saving appliances or muster stations even if equipped with fire and smoke dampers.

FR 4 Controls:

- Manual control of the ventilation should be possible from outside the space upon any failure in the remote or automatic control system.
- Detection systems should be able to monitor negative room pressure, ventilation air flow, explosive or inflammable gas concentration and position of the ventilation circuit valves.

- BESS ventilation system should be powered by two sources of power, one for normal and one for emergency operations.

FR 5 Emergency and explosion:

- Emergency exhaust suction capability should be provided in coordination with the chosen firefighting system to avoid the formation of explosive mixtures while preserving the efficiency and effectiveness of the firefighting systems. Functioning strategy should be part of the risk assessment.
- Emergency suction capability should activate automatically on sensing off-gas from batteries. Manual activation should also be possible from remote and from outside the battery space.
- Explosion proof ducts and, if applicable, explosion proof extraction fans, should be used.
- All fans, motors, electrical equipment and their wiring should preferably be non-sparking type and certified to be used in explosive atmospheres.

FR 6 Cooling:

- Liquid cooled BESS system should be designed such that the risk of leakage of the internal cooling liquid in the BESS is minimized and do not lead to hazardous creeping currents, electrolysis, short circuit, electric arcing, earth faults or other hazards. Internal leakage detection should be arranged and initiate an alarm at a manned control station.
- Liquid used for cooling purposes should be protected from undesirable particles and bacterial growth. Filtering, deionizing and conductivity measurement should be in place.

Relevant existing regulations:

SOLAS Chapter II-2 Regulation 4

SOLAS Chapter II-2 Regulation 8

MSC.1/Circ.1434

SOLAS Chapter II-2 Regulations 5.2, 19.3, 20.3

SOLAS Chapter II-2 Regulation 5.2.1.1

IACS UI/SC240

2.2.3 Electrical arrangements

Hazards	H.1 External short circuits (high temperature, high humidity, others). H.2 Arc-flash. H.3 Faulty electrical protection of the system (over current, over and under voltage) and network. H.4. Earth fault. H.5. Electromagnetic incompatibility. H.6. Harmonic distortion. H.7 Mechanical impact (vibration levels exceeded, others).
Goals	G.1 To ensure safety and integrity of the electrical components and connections and within the BESS and its boundaries when placed inside or in the vicinity of the battery space, in the engine control station or bridge.
Functional Requirements	FR 1, FR 3, FR 6 to FR 9 → H.3 FR 2, FR 4, FR 10 → H.1, H.2 FR 5 → H.7 FR 6 → H.2 FR 11 → H.4 FR 12 → H.5 FR 13 → H.6

Functional requirements

FR 1 Electrical protective devices (breakers or switches) should be used to isolate the battery system from the ship's network to prevent damage to other electrical equipment in case of battery failure and to allow safe disconnection for maintenance.

FR 2 Cables within the battery space are to be suitable for hazardous area operation.

Where cables which are installed in hazardous areas introduce the risk of fire or explosion in the event of an electrical fault in such areas, special precautions against such risks should be taken to the satisfaction of the Administration. (SOLAS II-1 Reg.45)

FR 3 Means for protection from electrical faults of the battery circuits should be provided. Circuits between poles as well as circuits from poles to protective devices should be "short-circuit proof" – e.g. by means of double insulated cables.

FR 4 Electrical equipment in the battery space should be suitable for use in the vapours or gases likely to be encountered.

FR 5 Electrical equipment in the battery space should be able to withstand the mechanical stress caused by on-board installation.

FR 6 Hard-wired means to disconnect the battery system from power distribution in case of emergency should be provided.

FR 7 Electrical arrangements used for emergency isolation of the BESS system should be hardwired circuitry separated from components and cables used for control, monitoring and alarm functions.

FR 8 Means for isolating the battery system for maintenance purposes should be provided, independently of the emergency shutdown arrangement.

FR 9 An emergency shutdown system should be installed and capable of disconnecting the battery system in an emergency.

FR 10 Batteries should be so installed that battery poles are covered/protected such that a short circuit is prevented in case of falling objects or other incidents.

FR 11 Means for monitoring and detection of earth fault should be provided and capable of providing an alarm at a manned control station.

FR 12 Electrical installation should be protected against EMC related disturbance. BESS and related systems should be controlled and documented in accordance with the IEC 60533:2015 or equivalence standard.

FR 13 Electrical installation should be protected against harmonic distortion. BESS and related systems should be controlled and documented in accordance with the IEEE 519-2014 or equivalence standard.

Relevant standards and regulations:

SOLAS II-1 Regulation 45 Protections against shock, fire and other hazards of electrical origin

IEC 62477-1:2022 – Safety requirements for power electronic converter systems and equipment – Part 1: General

IEC 60068 Environmental testing of electrotechnical products:

- Part 2-6: Tests – Test Fc: Vibration (sinusoidal)
- 2-10 Test J and guidance: Mould growth
- 2-30 Test Db: Damp heat, cyclic (12h + 12h cycle)
- 2-52 Test Kb: Salt mist, cyclic (sodium chloride solution)

IEC 60092-101 Electrical installations in ships – Definitions and general requirements

IEC 60332 series – Tests on electric and optical fibre cables under fire conditions (flame propagation and flame-retardant properties)

IEC 60331 Fire-resisting characteristics of electric cables (in accordance with IEC 60332-1)

IEC 60533:2015 Electrical and electronic installations in ships – Electromagnetic compatibility (EMC) – Ships with a metallic hull

IEC 62742:2021 Electrical and electronic installations in ships – Electromagnetic compatibility (EMC) – Ships with a non-metallic hull

IEEE 519-2022 Standard for harmonic control in electric power systems

IEEE 1547:2018 Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEC 61000-4 – Electromagnetic compatibility (EMC)

IEC 60945-9 – Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results

CISPR16-2-1 – EMC Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

IEC 60529: Specification for classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 Kv

2.3 Other battery support spaces

Other battery support spaces are spaces to house the battery support systems, including cooling and heating devices and fire extinguishers. These spaces should:

- Provide for fire insulation in way of the battery space.
- If adjacent to the battery space, keep the boundaries at normal temperature levels not to rise the temperature in the battery space.

2.4 Alerts and Indicators

Shipboard alerts and indicators as required by international instruments, and others further mentioned throughout this Guidance, should comply with the IMO Code on Alerts and Indicators, 2009.

Alert systems should be provided which announce at a manned control position, by visual and audible means, over malfunctions or unsafe conditions on the BESS.

An alarm should be provided at a manned control station in case of:

- *Earth fault detection.*
- *High – Low Battery voltage*
- *High – Low Battery temperature*
- *High charge current*
- *Communication failure between battery management system and external charge controller system*
- *Failure of the Battery management system*
- *Failure of the battery temperature sensors*
- *Failure of the Voltage sensor*
- *Low insulation resistance*

An emergency alarm should be provided in case of total loss of electrical supply – including by emergency shutdown, - thermal runaway or activation of a fire-detection system.

An alert should be provided on-board to indicate a failure in the battery charger.

An alert should be provided at a manned control station in case of fault in the switching contactor.

An alert should be provided in case of inverter overload, over or under temperature.

Alerts should be provided on-board in case of failure of the battery thermal management system (see section 1.3.1.3).

An alert should be provided at the moment of acting the closing device of the battery room ventilators.

When a direct cooling is installed, the following alarms are provided, where applicable:

- *High temperature of the cooling air of battery pack provided with forced ventilation.*
- *Reduced flow of primary and secondary coolants of battery packs having a closed cooling system with a heat exchanger.*
- *An alert should be provided upon low pressure in the closed-circuit cooling system (for early leakage detection)*

An indicator should be mounted in a suitable place on the bridge, main control room, the main switchboard and at control stations to indicate when batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged. (SOLAS II-1 42.5.3 and 43.5.3)

During firefighting, where a water-based system is used, it is recommended that an alarm is sent to the control station and to the bridge upon commencement of the discharge and upon the switch between fresh and salt water (see section 2.2.3.3).

In addition, the following information should be permanently displayed on the bridge, at the main machinery control room:

- Active operating mode of the BESS (such as load smoothing mode, peak shaving mode, enhanced dynamic performance mode, power back up mode, zero emission mode when temporarily solely supplying power to the ship)
- Charging/discharging status of the BESS as main or auxiliary source of power
- State of charge of the BESS
- Remaining autonomy at standard conditions defined to the satisfaction of the Administration (e.g. at design speed, design displacement, sea state 3/calm water)).
- State of health of the BESS
- Values of current/voltage of the BESS
- Active power delivered

Relevant standards and regulations:

IEC 60092-504:2016 installations in ships - Part 504: Automation, control and instrumentation

ISO 24060:2021 Ships and marine technology — Ship software logging system for operational technology

IEC 63462 IEC standard 63462-1 on Maritime battery system - Part 1: Secondary lithium cells and batteries - Safety requirements – under preparation[15]

SOLAS II-1/50 Communication and SOLAS II-1/51 Alarm System

[15] As the IEC 63462-1 standard will become available, parts of this Guidance will be reviewed to take in duly considerations the provisions of such standard.

3. Testing

While testing standards and procedures for BESS are based on international standards (such as ISO and IEC), additional testing may be required to ascertain performances for installations on board ships.

Goals

G.1 To ensure that the BESS testing is harmonised against the relevant testing standards and procedures for installation on board ships.

G.2 To ensure that the procedures for testing of the installation of the BESS provide information on the suitability of the design of the battery space and associated safety systems for fire extinguishing, explosion relief and ventilation in a maritime environment.

Functional Requirements

- Battery cells and system should be constructed and tested in accordance with the relevant IEC standards as specified below under Testing Protocols.
- Testing protocols should ensure that the specific performance requirements for use on board ships are complied with.
- The installation of the BESS on-board should be tested following the recommendations of this Guidance as a complement to already existent requirements from classification societies.
- Test ambient conditions should be maintained within the range of atmospheric conditions expected during normal operation.
- The test reports and related documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines and design standards used for manufacture and installation on-board.

3.1.1 Requirements for organizations verifying conformity

Third-party verification by a conformity assessment body should be independent of the organisation of the equipment manufacturer which it assesses.

The personnel responsible of the conformity assessment should be qualified, capable and have at its disposal the means to carry-on the conformity assessment as appropriate.

Conformity assessment bodies should meet the requirements of standard EN ISO/IEC 17065:2012 or any Recognised Organisation (RO) by the Administration.

Conformity assessment bodies/RO should ensure that testing laboratories and/or testing laboratories established at the manufacturer's facilities used for conformity assessment purposes meet the principles (preferably comply with the requirements of standard) EN ISO/IEC 17025:2017.

3.1.2 Testing protocols

The manufacturer should demonstrate that they have a quality management system in place, for example, certified by ISO 9001.

The third-party verification should address both the product and the production process.

Tests addressing the BESS should be performed at cell, cell block or system level as indicated in the table below.

The test unit (cell, cell block or system) should be clearly stated for each test by the manufacturer – tests in Table 3.1 – and by the responsible for verifying on-board installation – for tests in Table 3.2.

For tests that allow the test unit to be either cell or cell block, if the smallest test unit (cell) cannot be chosen a justification should be provided.

Alternative equivalent test standards to the referenced in Table 3.1 and Table 3.2 may be used to the satisfaction of the Administration.

Table 3.1 – Tests on lithium cells, cell block and battery system.

Battery verification					
	Test	Methodology/ References	Cell level	Cell block	System level
1	External short-circuit test	IEC 62619 7.2.1	x	x	x
2	Impact test	IEC 62619 7.2.2	x		
3	Thermal abuse test	IEC 62619 7.2.4	x		
4	Forced discharge test	IEC 62619 7.2.6	x		
5	Vibration	IEC 62281			x
6	Drop test	IEC 62619 7.2.3			x[16]
7	Overcharge test	IEC 62619 7.2.5	x	x	x
8	Internal short-circuit test	IEC 62619 7.3.2	x	x	

[16] Drop test should be performed at module/packs level if those can be used as replaceable units.

9	Propagation test	IEC 62619 7.3.3 IEC 63462-1			x
10	Hipot testing - *Dielectric Strength Test* - *Insulation resistance*	IEC 60092-303 IEC 63462, when available			x
11	Overcharge control of voltage	IEC 62619 8.2.2			x
12	Overcharge control of current	IEC 62619 8.2.3			x
13	Overheating control	IEC 62619 8.2.4			x
14	Charging procedure for test purposes	IEC 62620 6.2			x
15	Discharge performance (rated capacity check) Capacity validation Discharge at low temperature High-rate permissible current	IEC 62620 6.3 IEC 62620 6.3.1 IEC 62620 6.3.2 IEC 62620 6.3.3	x	x	
16	Capacity retention and recovery (self-discharge)	IEC 62620 6.4	x	x	
17	Cell balancing functional test	IEC 62933-2-2			x
18	Internal resistance test	IEC 62620 6.5	x	x	
19	Gas Analysis Including cell vent gas composition test	UL 9540A – Section 7.4	x		
20	Environmental testing (Cold test, dry heat, damp heat, salt mist)	IEC 60068-2-2			x
21	HVIL (High Voltage Interlock Loop)	UL 9540A			x

Table 3.2 – On-board installation verification tests

On-board installation verification		
	Test Type	Protocol/Reference
22	Functional test of the system and BMS, including of other integrated safety functions and alarms	IEC 62619 6.7.4
23	Functional test of alarms in the battery room or space	TBD[17]
24	Emergency disconnection test of function	TBD
25	Simulation of sensor failures in the battery room or space	TBD
26	Simulation of communication failure (e.g. with battery charger)	TBD
27	Functional test of safety systems in the battery room or space (e.g. ventilation strategy, liquid cooling, gas detection, fire detection and firefighting)	TBD (e.g. verification of thermal management under service conditions during sea trials)
28	SOC validation test	TBD
29	SOH indication test	TBD
30	Functional test of the EMS	Including Total Harmonic Distortion test
31	Test of independent temperature and or voltage-based disconnection (not required for battery with cells with current interrupt device)	TBD
32	Pressure test of coolant piping/hoses	IEEE 1679.1
33	Interface Testing - General	IEC 61439-1, 5.1
34	Interface Testing - Voltage ratings	IEC 60092-302-2, 5.2

[17] To be defined

35	Interface Testing - Rated voltage	IEC 61439-1, 5.2.1
36	Interface Testing - Current ratings	IEC 61439-1, 5.3
37	Electromagnetic compatibility test - Storm test included	TBD
38	Overvoltage protection test (of battery converter)	TBD
39	Under-voltage protection test (of battery converter)	TBD

3.1.2.1 Functional test of the BESS including integrated safety functions and alarms

Testing should verify that at least the following conditions or events related to the function of the BESS and integrated safety functions, as applicable, initiate an alarm at a local control panel and in a continuously manned control position:

- safety intervention of the BMS of the battery system, including loss of data connection,
- cell voltage unbalance, high cell temperature, opening of cell safety venting device, high pressure in the battery cell,
- high and low ambient temperature (out of range of normal operating conditions),
- failure of cooling system or leakage of liquid cooling system, if applicable,
- low ventilation flow,
- gas detection,
- overvoltage and undervoltage,
- charging failure,
- black out recovery,
- activation of integrated fire containment and firefighting functions.

3.1.2.2 Propagation test

A propagation test should be always conducted and modified from the reference standard in line with the below.

This test is designed to evaluate the damage potential of a possible thermal runaway event originating in one cell in the battery system installed on-board.

Auxiliary systems which are integrated in the battery pack to prevent propagation, and which are operative when the battery is in use, should also be tested.

Tests should be witnessed by an inspector from or designated by the administration.

Test set-up as recommended:

- All operative modules in the test should have a 100% State of Charge at the start of the test.
- Conducted in an enclosed space, as similar as possible to the manufacturer's recommendation for battery spaces. The temperature of the space should be equivalent to the maximum operating temperature for the battery system (+/-5°C) as defined by the manufacturer and not less than 45°C.
- The test module should be randomly selected from a production batch and should not be altered expect for instrumentation.
- The test module should be surrounded by other modules and be installed in a rack system similar to the one used on-board ships. The modules in the least favourable positions with regard to fire propagation from the tested module should be operative modules.
- The internal structure of the modules should not be changed. The remaining may be dummy modules as long as they have the same heat capacity, heat reflective properties and conductivity as the actual modules.
- The trigger cell should have the least favourable position in the module with regard to propagation.
- The method used to initiate thermal runaway in the trigger cell should be described and documented in the test report. Overcharging or cell heating should be preferred to nail penetration as method to initiate thermal runaway.
- Propagation tests should use nail penetration as a last resort only, where overcharging or cell heating is not possible. If it is necessary to use this test method, all elements of risk associated with thermal runaway in a cell must be correctly presented, i.e. a nail penetration test should give rise to the same response as a heating test. The module should not be modified so that the direction of the flames is altered.
- The safety functions of the battery management system (BMS) are deactivated during testing.
- The test is instrumented to continuously record relevant data. Voltage and temperatures of the tested module and the other operative modules are logged as a function of time. The temperature of the dummy modules should be logged in the same way. The temperature sensors are to be placed on the surface closest to the module where the thermal event is initiated.
- Modules in the test set-up should be continuously monitored and the result registered until the temperature is back to ambient temperature, and as a minimum for 8 hours after the thermal event occurred.
- The test is conducted without use of active external safety functions at the space level such as fire extinguishing system and ventilation.

<u>Acceptance criteria 1 (recommended):</u>

- Confirmed thermal runaway in initiating cell.
- No module case rupture.
- No propagation occurs between cells in three witnessed tests.
- The temperature in neighbouring cells should not exceed 80°C during thermal runaway and show measurable voltage at all times.
- No external fire from the battery system is created.

<u>Acceptance criteria 2:</u>

- Confirmed thermal runaway in initiating cell.
- No module case rupture.
- No propagation occurs between modules, and it is demonstrated through risk assessment that off-gas from the cells that can be affected from the trigger cell within the module (cell block or all cells in module) is safely ventilated according with section 2.2.4.
- No external fire from the battery system is created.

3.1.2.3 Gas and explosion analysis

The test should be conducted in an inter atmosphere by controlled heating of a single cell until the cell reaches thermal runaway. The cell should be randomly selected and should have a 100% State of Charge at the start of the test.

The resulting atmosphere should be analysed for identification of the maximum gas generation and gas composition.

Explosion analysis should be prepared for a ship-specific battery space. Requirements for explosion protection may depend on the potential for a deflagration involving the off-gassing or flammable gases during thermal runaway.

If the module has passed the propagation test described before and is designed so that a thermal runaway event in a cell will not spread to all cells in the module, the analysis may be prepared based on the gas generation from the affected cell only.

If cell-to-cell propagation is allowed by the acceptance criteria of the propagation test, then the analysis should be performed with off-gas from cell block or all cells in an entire battery module.

The analysis should include the estimated course of an explosion and the management of explosion pressure.

3.1.2.4 Others

The development of specific test methodologies, as needed, for the tests listed in Tables 3.1 and 3.2 is noted out for further work under the scope of this Guidance.

Checklist for periodical surveys:

1. Visual inspection of the battery room or space and exposed BESS and their openings.
2. Functional tests on fire detector, fire extinction and ventilations.
3. Operating instructions.
4. Test of battery (charge/discharge) and electric power convertor.
5. Interface between BMS and EMS.
6. Interface between PMS and EMS.
7. Emergency shutdown device.
8. Overcharge and overvoltage protection devices test.

3.1.3 Test Report and Documentation

Battery tests summary reports should be provided in accordance with Table 3.1 and made available by the manufacturer to the Administration.

The battery functional description and operational limitations of the BESS arrangements should be documented and include at minimum:

- Cell lower limit discharge voltage
- Cell upper limit charge voltage
- Cell charge/discharge current limits
- Cell temperature limits
- Cell balancing
- Rated operating current region
- Rated operating temperature region
- Rated capacity
- Charge/discharge instructions
- Behaviour in case of malfunction
- Firefighting agent(s)
- Gas detection system
- Type of ventilation and extraction system

4. Operations and trainings

Goal

To assist in defining procedures for the normal and emergency operational scenarios of the BESS.

To suggest minimum training and competences of crew to ensure safe operation of the BESS and ensure that loss of the battery system functionalities does not affect the safety of the ship or its operations.

4.1 Operational procedures

Goal

G.1 To ensure that the BESS is used on board within the design parameters and that procedures for safe operation in normal and emergency situations are described and followed.

G.2 To ensure that the management of BESS hazardous events are dealt by crew trained for the specific situations related with the installed system type and supporting systems.

General requirements

- Lithium-ion batteries, high voltage equipment, battery systems and battery compartments should be adequately labelled using internationally agreed symbols where available. Emergency systems should be appropriately labelled and be clearly visible.
- It is recommended that a BESS (e-)logbook[18] is kept on board to record the stats and history of event occurring to the battery and its equipment; the BESS logbook should be made available after an incident and accident.
- It is recommended to implement the (e-)logbook in electronic format.
- The BESS and protective systems are to be accompanied by instructions for safe:
    - putting into service,
    - use, including functional testing procedure and their periodicity,
    - maintenance,
    - management of malfunctions, troubleshooting and instructions on the management of hazardous scenarios (such as a fire or electric fault).
- The existence of the BESS on-board, changing the risk profile of the ship, personnel and the environment, may require additional lines in the Safety Management System of the ship particularly in relation to operational procedures, emergency procedures, reporting of accidents, maintenance records and documentation. If recommended by the administration through MSC.1/Circ.1371, or through National measures, the provisions in this Guidance should be ensured by the safety and management system according to the ISM Code.
- The root cause of warnings, alarms or fault indicators should always be identified, addressed and reported in the (e-)logbook.
- The access to the battery should be prohibited to unauthorized persons.
- Personal protective equipment to be worn at all times while working on batteries.

[18] Electronic logbook would be recommended.

4.1.1 Normal operational procedures

Goal

To define the procedures related to the normal operation of the BESS and ensure that the system is never operated outside of its design envelope and limitations.

Functional requirements

- Procedures for the use of PPE should be drawn-up and the PPE made available on-board with the appropriate quality and quantity.
- Charging procedures of fixed batteries installations should be drawn-up and kept on-board.
- For containerized batteries, mounting procedures should be drawn-up and kept on-board.
- Conditions and procedures to prepare the BESS for extended period of standby be drawn-up and should be kept on-board.
- Procedures for electrical safety in general and high voltage operation in BESS spaces should be drawn-up and kept on-board.
- A contact person should be made available on a 24/7 basis.

PERFORMANCE REQUIREMENTS

The following information should be permanently displayed on the bridge and at the main machinery control room:

- Active operating mode of the BESS (load smoothing mode, peak shaving mode, enhanced dynamic performance mode, power back up mode, zero emission mode when temporarily solely supplying power to the ship)
- Charging/discharging status of the BESS
- State of charge of the BESS
- Remaining autonomy at standard conditions defined to the satisfaction of the Administration, (e.g. at design speed, design displacement, sea state 3/calm water).
- State of health of the BESS
- Active power delivered

The battery (e-)logbook should include at least:

- Equipment serial numbers and dates of manufacture/installation/testing/expiry
- Location
- Equipment and/or systems served
- Maintenance records
- On-board in-service test results, as applicable
- Defects
- Summary of the battery charge/discharge cycles

Relevant standards and regulations:

IMO RESOLUTION MEPC.312(74) GUIDELINES FOR THE USE OF ELECTRONIC RECORD BOOKS UNDER MARPOL

ISO/DIS 21745 Electronic record books for ships — Technical specification and operational requirements

4.1.1.1 Shore-side battery charging

Reference to EMSA Guidance on Shore-Side Electricity to Port Authorities and Administrations – Part 2: Planning, Operations and Safety for information on different charging methods and equipment.

General requirements

- Electrical shore connection charging must be done outside hazardous areas with respect to the presence of flammable materials and/or explosive atmospheres.
- Fast charging only recommended when necessary for operational reasons, to maximize the battery lifetime.
- Charging is stopped immediately if there is a temperature rise to outside the limits set by the manufacturer in the charging profile.
- Contact of the charging equipment with the human operator should be minimized as possible to limit exposure to shock hazard.

Relevant standards:

IEC/IEEE 80005-1:2019 Utility connections in port — Part 1: High voltage shore connection (HVSC) systems — General requirements

IEC/IEEE 80005-2:2016 Utility connections in port — Part 2: High and low voltage shore connection systems — Data communication for monitoring and control

IEC/IEEE DIS 80005-3 Utility connections in port — Part 3: Low Voltage Shore Connection (LVSC) Systems — General requirements *(Under development)*

4.1.2 Emergency operational procedures

Goal

G.1 To identify the emergency scenarios related to BESS operation and installation on-board and ensure that emergency procedures are defined for those scenarios.

G.2 To provide information to the first responders, crew, and on-shore based fire brigades with emergency response plans.

G.3 During a fire, fire fighters should not enter the battery room or space until explosion risk is eliminated

Functional requirements

- Separate procedures, exercises, documentation, should be prepared for managing different emergency situations that can have origin in the battery system and space.
- Separate procedures, exercises, documentation, shall be prepared for managing different emergency situations that can have origin in the battery system and space, such as, but not limited to, fire alarm, gas detection alarm and cooling system failure do not endanger the BESS.
- Emergency procedures should be developed for external emergency scenarios, such as, but not limited to, fire in other compartments or collision to the BESS for which consequences can be worsened if the BESS is affected.
- The role of all stakeholders, including emergency services and salvage teams, during the emergency should be defined in the emergency procedures.

- Emergency drills should be routinely conducted for all emergency scenarios.
- Instructions for emergency operation should be kept on-board.
- A procedure for the communication with on-shore fire fighters brigades should be established and activated after the decision to call into a port has been taken.

Operational requirements

Emergency procedures should be developed at least for the following emergency scenarios:

- Activation of detection of the off-gas device. The following elements should be taken into consideration:
  - amongst first gases produced CO is always present which makes this gas good for early detection,
  - mechanical, electrical, thermal abuse and, fabrication defects of the cells cause cells' short circuits,
  - upon short circuits, BMS system to shut down BESS or part of it, however temperature may have already started to increase causing transformation of the electrolyte in gas. (Electrolyte may be made of (1) Solvent = Ethylene Carbonate (EC), Dimethyl Carbonate (DMC) + (2) Salt = Lithium Hexafluorophosphate ($LiPF_6$)),
  - violent cell venting - Off-gassing of electrolyte of cells with relief valves of the cell opening at around 130 deg.
  - loss of BMS functionalities may not activate the shutdown procedure,
  - thermal runaway inception may then occur (typically between 150 and 180 degrees),

- Activation of a fire detection device. The following elements should be taken into consideration:
  - smoke with no flames,
  - low visibility inside the space,
  - up to 30 min delay between gas detection and smoke detection – smoke with no flames indicate that in the space there is presence of explosive gases,
  - inert the space before ventilating – however if continuous ventilation is provided reaching the LEL can be avoided,
  - aiming at modules and packs rather than cells for fire-fighting
  - the action of inerting agent is to block the thermal runaway propagation keeping the temperature of neighbouring cells below well below 180 °C,
  - inerting agent should be effective also on non-flaming fires.
  - battery localised high temperature (cells burns at around 900 °C with presence of jet flames)

- Firefighting – early extinguishing proportional fire-fighting strategy and sequence of operations procedures for the specific ship and fire safety strategy,

- Medical scenarios and first aid (electrical shocks, toxic atmosphere hazards, *et al.*),

- Water ingress, flooding events.

- For each of the alarms specified in Section 2.4 a procedure should be developed.

Additional operational requirements for firefighting

Due to the possible presence of hydrogen fluorite acid (HF – see Annex A): firefighting outfit, breathing apparatus, gloves and boots should be provided according to:

- the up to date Implementing Regulation of the Marine Equipment Directive 2014/90/EU, as amended supplemented by,
- protective clothing to ensure proper protection against HF (inspired to ISO 17491-4),
- acid resistance gloves (made of materials such as nitrile, neoprene, butyl rubber – inspired to ISO 374-5)
- respiratory protection with self-contained breathing apparatus with appropriate acid-resistant canister and cartridge (inspired to ISO 16900-3),
- eye and face protection acid resistant mask and googles,
- HF decontamination procedure should be established,
- IR portable cameras should be provided to first responders.

A maximum smoke-gas exposure time (recommended 40 minutes) should be implemented with no re-entry allowed in the space.

For enclosed BESS <50 kWh first responders to be equipped also with fire suppressant means suitable for lithium battery fires.

Post-fire recommendations

A strategy for post-fire handling of a damaged battery, module or cell should be drawn-up and consider:
How to safely access the battery room or space (toxic and explosive atmosphere);
How to safely disconnect the damaged unit;
Use of adequate PPE;
Storage conditions for transport of the damaged battery unit onboard;
Possible removal of stranded energy;
Risk mitigation measures in case of temperature increase, smoke release, short circuit/arcing during transport.

4.1.2.1 Reporting of accidents

- Warnings, alarms and fault indication should be noted in the logbook, together with the analysis of the root cause and the measures taken to clear them.
- Accidents and incidents caused by a BESS failure, damage, fire, explosion, resulting in loss of functionality of the BESS system, immobilisation of the ship and consequent loss of manoeuvrability should be reported to the relevant administration.
- Occupational accidents and incidents with BESS should be reported in the logbook and reported to the relevant administration[19].

[19] IMO Res. MSC.333(90) as amended, laying down Voyage Data Recorders (VDRs) performance standards, should be considered for maintain access to relevant BESS data in case of the logbook or e-logbook becomes unavailable.

4.1.3 Maintenance

Goal

G.1 To ensure reliable, safe operation and that the overall safety of the BESS is maintained during the ships life cycle.

G.2 To ensure that maintenance schedules and instructions are available for the crew to perform maintenance activities safely either for preventing or correcting failures in the operation of the system.

Functional requirements[20]

- On-board maintenance and inspection manual should be provided by the system integrator / manufacturer.
- Inspections and maintenance should be in accordance with manufacturer's recommendations and operated under lockout tagout principle.
- Routine inspections may check for any signs of potential decrease in the safety level of the battery such as presence of salts, condensation, humidity, electrical connections, insulation, activation of breakers, overall status of the space and equipment, physical damage, cleanliness, signs of arcing or increased temperature, correct operation of ventilation and battery protection systems and similar. In particular capability to assess presence of salt or moisture in the battery room/space should be provided and the BESS regularly inspected for these specific hazards.
- BESS area arrangement shall be of appropriate dimensions for conducting inspections and maintenance.
- Lifting devices may be arranged to allow maintenance, as appropriate.
- The organisation and arrangement of the systems used during the battery installation or maintenance are to minimize the risk of short circuit or damage to the cells.
- Li-ion batteries should be safely handled, not exposed to fire or high temperatures, water, strong oxidisers or mechanical shock.
- Li-ion batteries should not be stored unmonitored or uncontrolled (BMS function should be active at all times).
- Maintenance and replacement should be planned in the ship's maintenance schedule.
- Continuously update the maintenance program based on the experience from ship's operation.

PERFORMANCE REQUIREMENTS[20]

- Lock out /Tag out (LOTO) procedure should be in place to ensure that BESS is properly shut off and locked safely before any maintenance operation takes place on the system.
- If salt of moisture is traced in the battery room, the battery supplier must be contacted to assess the condition of the batteries.
- Work surfaces should be clean and free of sharp objects that could puncture a cell.
- Batteries waste disposal must be in accordance with Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators.

[20] Some of the functional and performance requirements of this section maybe used for inclusion in the ship's ISM.

- Maintenance plan, based on SoH functionalities, upon indication of the manufacturer, should include the review of the parameters for determining the expected lifetime of batteries such as:
  1. The dates of manufacturing of the battery and putting into service
  2. Energy throughput
  3. Capacity throughput

Applicable to UPS

- Torquing of terminals and set-up of the battery management system by a trained service engineer. Configuration files should be saved for future reference.
- Refresh charge to ensure all batteries in each string are properly voltage-balanced and within limits.
- Test discharge for time, at one or preferably two different UPS load levels while verifying for temperature and voltage anomalies.
- Verification of automatic disconnection devices.

4.2 Training

A specific certificate released by the Flag State as BESS Technical Operator (BESS-TO) (which may include inter-alia DC high voltage section) may be drawn up and suggested for ships engaged in international voyages.

For ships operating in sea area D, defined as per Directive 2009/45/EU as amended, carrying less than 36 passengers, of < 24 m in length, may be sufficient the crew receiving main elements on the safe operation of BESS in normal, emergency conditions and for basic maintenance operations, to the satisfaction of the administration.

Aiming at creating a safety culture on BESS installation on board of ships, providing structured trainings programs for ships' operating crew, establishing cooperation routes along the value chain (from the manufacturers, integrators to the users and regulators).

Goal

G.1 To ensure that the crew is able to safely operate and maintain a ship supplied with a BESS and manage any emergency events in relation to the BESS on-board.

Functional requirements

- For ships engaged in international voyages, the crew operating and maintaining the BESS should withhold a valid certificate of competence as foreseen by the SCTW Conventions for ETOs.
- For ships engaged in domestic voyages, the crew in charge of the BESS may hold certification as electro-technical officer as per STCW or an equivalent certification to the satisfaction of the Administration.
- The crew should have a basic knowledge of the principles of operation of the BESS in its functions on-board and should understand safety information, symbols, signs and alarms related to the BESS.
- The crew should be aware of the main risks associated with batteries, the effect of external hazards, the importance of early extinguishing and what to do during an incident.
- All crew should be aware of the emergency procedures concerning the battery and should be aware of the implications of any alarms as per the manufacturer's specifications.
- Literature describing the systems must not contradict the instructions with regard to safety aspects.
- Minimum training in fire-fighting should include competences in relation to battery fires.

- Training should include the correct use and choice of personal protective equipment when entering a battery compartment during or after an accident.
- Monthly battery safety drills should be implemented for the crew.
- Visual inspections should be regularly conducted to verify at least the status of insulation, presence of salt crystals deposits, condensation, leakage of coolant liquid (for liquid cooled BESS) drainage water, presence of humidity and condensation on colder surfaces.

Operational requirements

- At no time there should be fewer than two persons on board who are adequately trained and experienced in battery equipment and procedures.

Relevant regulations and provisions:

- STCW Code Part A / Section III/6 – Mandatory minimum requirements for certification of electro-technical officers
- STCW Code Part A Section VI/3 - Mandatory minimum training in advanced fire fighting
- STW 44/3/1 – Model course – Electro-Technical Officer – ETO

5. Specific provisions

Li-ion batteries below 5 kWh may be installed in accommodations spaces and corridors (cat (3) and (6)), provided that those conform with the requirements of Chapter 1.3 of this Guidance.

Full electric

When the main source of power is based on BESS only, the main sources of power should consist of at least two independent BESS systems located in two separate room or spaces.

The two independent battery systems should not be connected to the same switchboard. If impracticable, the two independent battery systems might be connected to the same switchboard on two different control panels.

When only batteries are used as a main source of electrical power, one of the battery systems should be located in a battery space within the machinery space of the main switchboard.

Emergency

If the battery system is part of the emergency source of power, it is not to be installed in the same space as the emergency switchboard.

Where the battery is used as emergency source of electrical power in passenger ships, it should comply with the requirements of SOLAS Chapter II-1 Reg. 42.

Where the battery is used as emergency source of electrical power in cargo ships, it should comply with the requirements of SOLAS Chapter II-1 Reg. 43.

6. Safety Assessment

As battery technologies (as well as on-board configurations and functions of BESS) evolve rapidly, and new technical solutions become available for implementation, it is deemed necessary to provide for a safety assessment methodology to be used in all such cases for which this Guidance does not stipulate relevant technical provisions.

The primary objective of the risk assessment is to identify technical and operational hazards (HAZID and HAZOP) and consequent risk assessment associated with the proposed battery energy storage system technology, its integration on board a ship and to provide for mitigation measures of the identified risks.

A specific hazard identification should be conducted in all such cases for which this Guidance is not deemed sufficient for the purpose of a safe installation and operation of a BESS on board a ship, beyond the scope of this Guidance as specified in Section General – Alternative Design.

The risk assessment is to demonstrate that the overall ship safety, safety of passengers, crew and transported goods is ensured for the specific proposed technical solutions for systems departing from the baseline identified in the Guidance.

The risk assessment should cover all potential hazards represented by the specific type of BESS as well as the arrangement of the BESS spaces on-board and those arising from its operation.

The risk assessment should document the safety principles of the BESS technology and its arrangement in the ship's spaces.

The principle that a single failure should not lead to loss of function should be considered in the risk-assessment; the single failure of a battery module should not lead to the loss of the continuity of power supply.

The following hazards are to be covered, as appropriate in relation to the energy storage system chemistry, function, and general arrangements:

- internal short-circuit (such as induced by leakage of cell electrolyte)
- external short-circuit (such as induced by mechanical impact)
- earth faults
- sensor failure (voltage, temperature, gas sensor…)
- high impedance (cell, connectors, …)
- leakage (electrolyte, cooling system)
- failure of BMS (error on manoeuvring breakers, overloading, over discharge …)
- over temperature and mechanical stress
- loss of cooling
- loss of communication between battery packs and power management system
- thermal runaway
- emission of combustion gases (gas volume, release rate and gas composition)
- rupture of the casing of cell, battery module, pack, or system with exposure of internal components
- overpressure
- fire
- explosion
- venting out flammable, corrosive and toxic gases
- chemicals used and chemical fire to be considered
- external ingress (fire, fluid leakage, ingress of water into the battery space from cooling system leak, flooding of the battery space as consequence of an accident, fire suppression system release and/or adjacent areas)
- structural integrity (in relation to fire hazards)
- water event, flooding
- collision

Furthermore, the Safety Assessment should give due consideration to hazards arising from BESS for the following:

- Life Saving Appliances
- Embarkation stations
- Evacuation routes
- Evacuation of the ship
- Routing and protection of cables
- Firefighting procedures and methods

The following mitigation measures should be considered in the analysis, as applicable in relation to the specific technological solutions to be implemented:

- Thermal management of the battery space to prevent the possibility of thermal runaway of the battery modules, including the criticality of any cooling systems required to ensure reliable operation.
- Electrical protections (over current, over voltage and under voltage).
- Protection against creeping current, electrical arcing and electrolysis due to external leakage or pollution.
- Safe charging/discharging characteristics.
- Inherently safer design implemented (usually by the BMS) for the safe operation of the battery.
- Appropriate measures taken to isolate the battery pack in the event of a loss of communication with the BMS and/or EMS.
- Appropriate alarms and shutdown should be described.
- Necessary detection, monitoring and alarm systems in place and ventilation handling in case of off-gas release and/or fire.
- Adequation of fire-extinguishing system to battery type should be documented.
- Fire and explosion analysis.
- System, redundancies in place and communication protocols used.
- Prevention measures for temperature and voltage measurement sensor failure.

Hazards, risks, and mitigation measures considered in the risk-assessment should be described and documented in the risk-assessment report.

The following non-exhaustive list of different concepts with the corresponding design variations may be investigated in the safety assessment, by putting in relation the design variations with the relevant hazards:

1. The battery system is designed without module fire propagation protection.
2. The battery is located in a room with other essential equipment in the same redundancy group.
3. The battery system is connected to a DC bus with a converter.
4. Single cell propagation protection (compared to module).
5. The battery has solid state battery cells.
6. The battery has lithium-ion capacitors.
7. The battery system is containerized on deck.
8. The battery system has integrated off-gas ventilation in the cabinet.
9. The battery system has production of off-gas during normal operation.

The risk-assessment should be comprehensive, should include all relevant functions of the BESS and its equipment, systems, and arrangement on-board needed for the execution of the specific function. The comprehensive risk-assessment can be composed of risk-assessments made for specific equipment and systems (e.g. the comprehensive risk-assessment done by the system integrator/shipyard, could include the risk-assessment conducted by the OEM for the battery system).

Relevant standards and references:

IEC 60812:2018 Failure modes and effects analysis (FMEA and FMECA)

IMO MSC.1/Circ.1455 GUIDELINES FOR THE APPROVAL OF ALTERNATIVES AND EQUIVALENTS AS PROVIDED FOR IN VARIOUS IMO INSTRUMENTS

MSC/Circ.1002, GUIDELINES ON ALTERNATIVE DESIGN AND ARRANGEMENTS FOR FIRE SAFETY

MSC.1/Circ.1212-Rev.1 REVISED GUIDELINES ON ALTERNATIVE DESIGN AND ARRANGEMENTS FOR SOLAS CHAPTERS II-1 AND III

IEC 61508-1:2010: Functional Safety General Requirements IEC

IEC 61025:2007 Fault tree analysis (FTA)

ISO 31000:2018 Risk management - Guidelines

IEC 31010:2019 Risk management - Risk assessment techniques

Annex A – Li-ion batteries chemistry

Lithium-ion batteries chemistry

Sample of lithium-ion batteries and their typical nominal cell voltages:

1. Lithium cobalt oxide ($LiCoO_2$) - 3.6 V
2. Lithium manganese oxide ($LiMn_2O_4$) - 3.7 V
3. Lithium iron phosphate ($LiFePO_4$) - 3.2 V
4. Lithium nickel cobalt aluminium oxide ($LiNiCoAlO_2$) - 3.7V
5. Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$) - 3.7 V
6. Lithium titanate ($Li_4Ti_5O_{12}$) - 2.4 V
7. Lithium-sulphur (Li-S) - 2.2V to 2.6 V

Lithium-ion batteries - compounds produced during a fire event

Non-exhaustive indicative list of chemical compounds produced during a fire of lithium-ion batteries.

1. Carbon dioxide (CO_2): a colourless and odourless gas that is a by-product of the combustion process.
2. Carbon monoxide (CO): a toxic gas that can cause headaches, dizziness, nausea, and even death in high concentrations.
3. Hydrogen fluoride (HF): a toxic gas that can cause severe burns and lung damage.
4. Hydrogen chloride (HCl): a corrosive gas that can cause irritation to the eyes, nose, throat, and lungs.
5. Ethylene carbonate (EC) a flammable liquid (Class II) that can vaporize and produce toxic fumes when heated.
6. Dimethyl carbonate (DMC) a flammable liquid (Class II) that can produce toxic fumes when heated.
7. Lithium oxide (Li_2O): a solid residue that can be left behind after a lithium-ion battery burns.
8. Manganese oxide (MnO) a solid residue that can be left behind after a lithium-ion battery burns (for manganese lithium batteries).
9. Nickel oxide (NiO) a solid residue that can be left behind after a lithium-ion battery burns (for nickel cobalt lithium batteries).
10. Cobalt oxide (Co_3O_4) a solid residue that can be left behind after a lithium-ion nickel cobalt battery burns (Additionally, the water can react with the nickel and cobalt in the battery, producing toxic gases such as nickel oxide (NiO) and
11. Cobalt oxide (CoO)) a toxic gas that can be produced when a nickel-cobalt lithium-ion battery burns, and it is extinguished by water.
12. Lithium hydroxide (LiOH). a white, odourless, and hygroscopic solid that is soluble in water. It is a corrosive substance that can cause skin and eye irritation.

13. Cyanide (HCN) a highly toxic chemical compound that contains a carbon atom triple-bonded to a nitrogen atom, in its pure form or in high concentrations, cyanide can be deadly. The most common forms of cyanide are solid or liquid compounds, such as hydrogen cyanide (HCN) and sodium cyanide (NaCN), which can produce toxic gases when they react with acids or water. Hydrogen cyanide is a colourless gas with a bitter almond odour.
14. Benzene (C_6H_6) a colourless and highly flammable liquid with a sweet odour. Benzene exposure is harmful to human health.
15. Toluene (C_7H_8) a clear, colourless liquid with a sweet, aromatic odour. It can be harmful to human health when inhaled or ingested and can cause a range of health effects.
16. Methane (CH_4)
17. Hydrogen (H_2)

The chemical compounds produced during a fire depends on the battery chemistry and materials as well as on the fire extinguishing mean and on the materials of the various components which constitute the battery cell, module, or rack.

Annex B – Guidance for Officer's qualification

Guidance for officer's qualification
Recommended for BESS Technical Officers (BESS TO)

Recommended pre-requisites – STCW ETO Certification.

Main Elements

Training at the battery manufacturer premises, shipyard or facilities licensed by the battery manufacturer.

Training should provide knowledge in the following areas:

- Types of long duration batteries
- Different battery chemistry characteristics
- Safety hazards to consider
- Components in a Battery Energy Storage System (BESS)
- Different battery system functions on-board
- Battery system use cases on board ships
- AC/DC coupled systems
- End of life options for batteries

Training should foresee:

- Battery chemistry
    - Characteristics
    - Charge rates
        - Max charge
        - Discharge
    - Chemistries and Potential failure mechanisms
- Lithium-ion BESS
    - Principles
    - BESS safety
- Notions on other batteries technologies
    - Redux
    - Plating
    - Organic and others
- Design considerations
    - Common characteristics
        - Sizing, roundtrip efficiency
    - Projected life
    - Performance
- Safety
    - Battery scorecards
    - Relevant BESS Standards such as:**)**
        - NEC 855 **Standard for the Installation of Stationary Energy Storage Systems (relevant chapters)**
        - UL9540 and 9540A Energy Storage Systems and Equipment
        - IEC relevant standards as specific in this Guidance
    - Fire protection and ventilation systems
    - Relevant safety standards

- Major components in a BESS
    - Batteries
    - Fire suppression
    - Inverters
    - Step-up Transformers
    - Secondary containment
    - Controllers
    - Housings
    - Battery management system
    - Energy management systems
    - Substation
    - Other systems (HVAC, BMTS.)

- Operations & maintenance

System Resiliency

- Redundancy
- Backup Power/UPS

AC/DC Coupled Systems

- DC systems
- DC coupled to generation
- DC coupled to DC loads
- High Voltage DC principles, design, operations and maintenance

Design Considerations

- Li-ion batteries

Operational Risks

Inspections and Maintenance

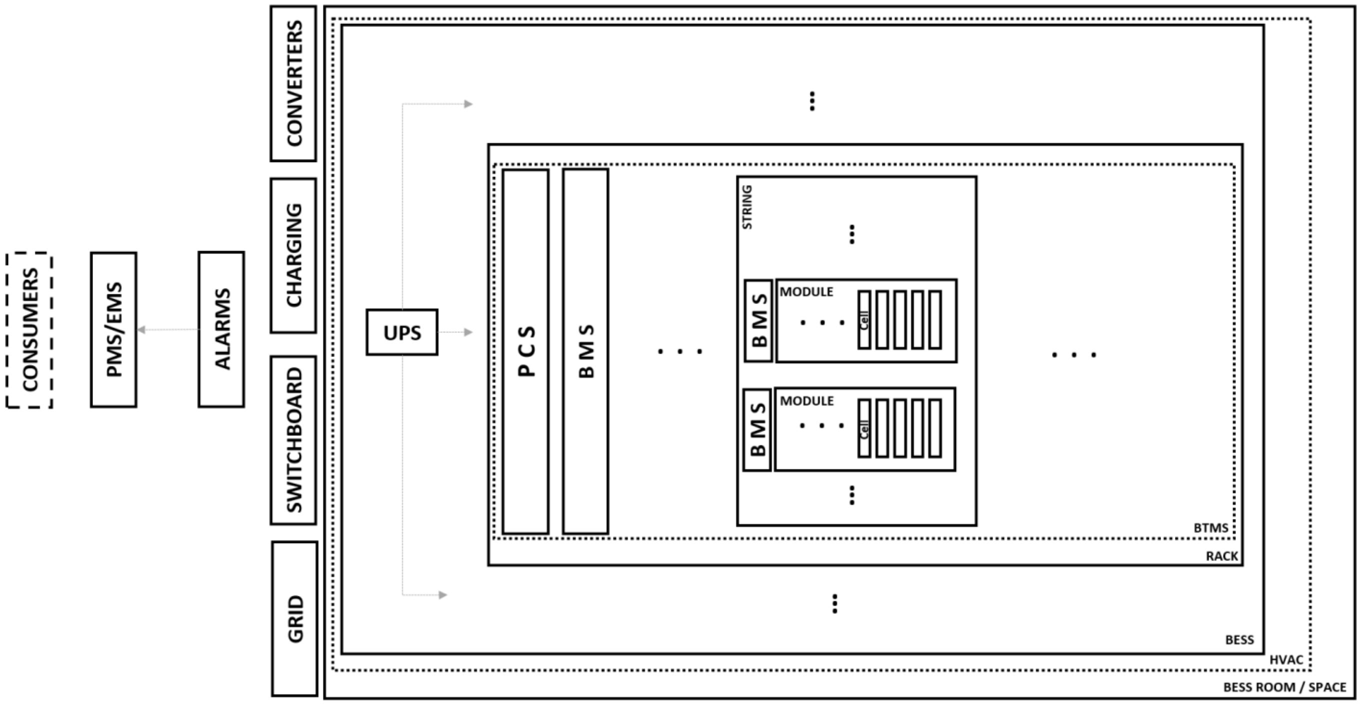
- Service agreements
- O&M agreement challenges

Decommissioning

- Recycling
    - The process
    - Li-ion decommissioning
    - Planning for disposal
- Environmental considerations
    - Recyclability
    - Regulatory framework
    - Decommissioning

Annex C - Infographics

Schematics of BESS boundaries



European Maritime Safety Agency
Praça Europa 4
1249-206 Lisbon, Portugal
Tel +351 21 1209 200
Fax +351 21 1209 210
emsa.europa.eu