財團法人驗船中心
CR CLASSIFICATION SOCIETY

# GUIDELINES FOR LITHIUM-ION BATTERIES APPLIED TO MARINE SYSTEM/EQUIPMENT

**CR CLASSIFICATION SOCIETY**

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# GUIDELINES FOR LITHIUM-ION BATTERIES APPLIED TO MARINE SYSTEM/EQUIPMENT

## CONTENTS

# Abbreviations

| | |
|---|---|
| BCS | Battery Charging System |
| BMS | Battery Management System |
| BSS | Battery Support System |
| CID | Current Interrupt Device |
| EDS | Emergency Disconnect System |
| ESD | Emergency Shutdown |
| FFES | Fixed Fire Extinguishing System |
| FMEA | Failure Mode and Effect Analysis |
| HAZID | Hazard Identification |
| HVAC | Heating, Ventilation, and Air Conditioning |
| IEC | International Electrotechnical Commission |
| LEL | Lower Explosive Limit |
| PCS | Power Conversion System |
| PMS | Power Management System |
| SOC | State of Charge |
| SOH | State of Health |
| SOLAS | Safety of Life at Sea |
| UL | Underwriters Laboratories |

# Chapter 1 General Requirements

## 1.1 Introduction

CR recognizes the increasing use of batteries in the marine and offshore industries and their benefits. The Guidelines for Lithium-ion Batteries Applied to Marine System/Equipment (hereinafter referred to as the Guidelines) have been developed to facilitate the effective installation and operation of lithium-ion batteries. The Guidelines are to be used in conjunction with and as a supplement to the CR Rules for the Construction and Classification of Steel Ships (hereinafter referred to as "the Rules") and the CR Guidelines for Hybrid Power Propulsion Systems as applicable. The basic safety principles contained in the Rules are to be followed in general (such as providing sufficient power generation/storage capacity, having adequate standby and emergency power sources, arrangements for continuity of supply in the event of a fault, general electrical safety such as proper cable sizing, appropriate insulation, and suitable equipment enclosure ratings). These specific requirements are not repeated in the Guidelines.

## 1.2 Application

The Guidelines are applicable to marine and offshore assets designed, constructed, or retrofitted with a lithium-ion battery system used as a source of electrical power with an energy of 20 kWh or greater. An optional notation **CLB** may be granted to those assets once the battery installation has complied with the requirements of the Guidelines. Where batteries are being used as the main source of power, the additional requirements set forth in Chapter 4 are to be met. Where batteries are being used as the emergency source of power, the additional requirements set forth in 2.2.15 are to be met.

The requirements contained in the Guidelines are mandatory, even if the optional notation is not selected.

Marine and offshore assets equipped with a lithium-ion battery system having an aggregated capacity less than 20 kWh shall comply with Chapter 6 of the Guidelines.

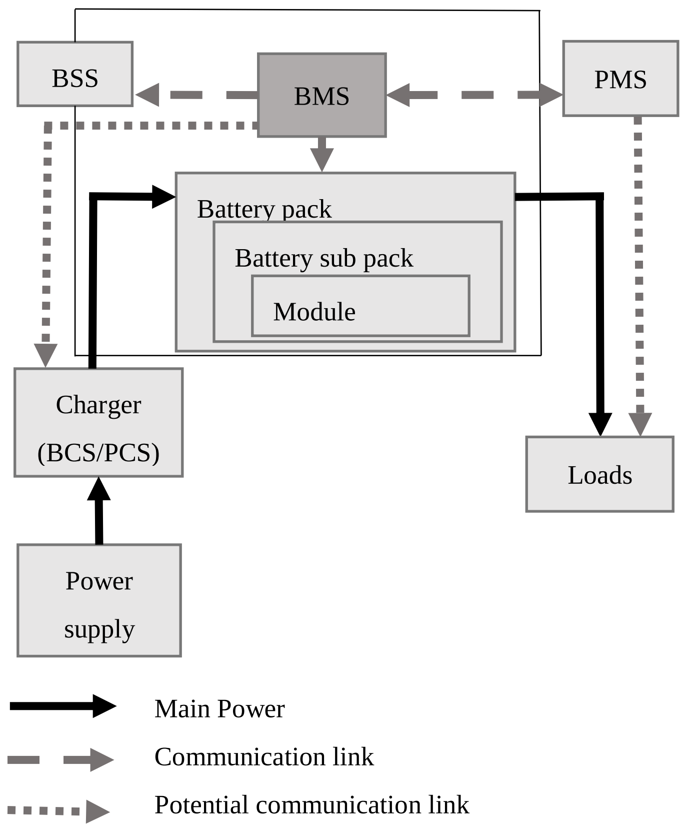
Where type approval of a lithium-ion battery system is requested, applicants should contact CR for the approval process. See Table 2-1 for certification details.

The Guidelines were primarily written for ships that comply with the Rules. It may be applied to other ship types (HSC, Yachts, etc). In this case, the equivalent requirements from the Rule set applicable to the ship or unit are to be applied. Refer to Appendix 1 for special considerations related to ships that are not required to comply with the International Convention for the Safety of Life at Sea (SOLAS) regulations.

## 1.3 Battery System

A battery system is an energy storage device that includes cells, cell assemblies or battery pack(s), as well as electrical circuits and electronics (example of electronics: Battery Management System (BMS), Battery Support System (BSS), Cell electronics).

The battery system considered is summarized in Fig. 1-1.




This configuration shows only one battery pack. The battery pack may be duplicated inside the battery system.
BCS: Battery Charging System
BSS: Battery Support System
PCS: Power Conversion System
PMS: Power Management System
BMS: Battery Management System

**Fig. 1-1**
**Battery System Considered**

The battery storage system is illustrated as Fig 1-2.

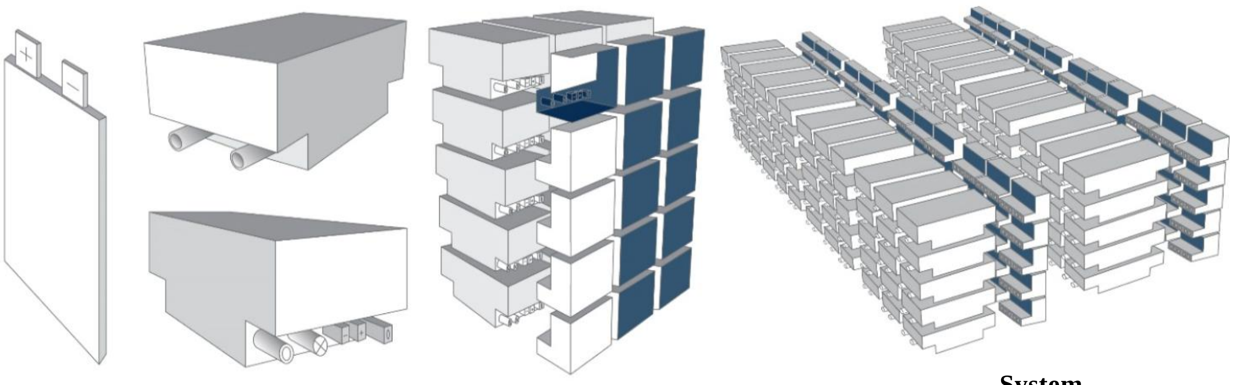



**Fig. 1-2**
**Battery Storage System**

## 1.4 Definitions and Terminology

Primary cell/battery
A cell or battery that can only be discharged once. It is not designed to be rechargeable and is usually protected from a charging current.

Secondary cell/battery
A cell or battery that is intended to be subjected to numerous charge and discharge cycles in accordance with manufacturer's recommendations.

Battery cell
The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, and terminals that creates electrical energy by insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode. It is ready for use only after it has been fitted with its final housing, terminal arrangement, and electronic control device(s). [*UL 1642*]

Battery module
A group of cells connected together in a series and/or parallel configuration with or without protective devices and monitoring circuitry. [*IEC 62620*]

Cell electronics
The electronic device that collects and possibly monitors thermal and electric data of cells or cell assemblies and contains electronics for cell balancing, if necessary, as well as over-current protection devices (e.g. fuse).

Battery pack
Energy storage device that is comprised of one or more cells or modules electrically connected. It has a monitoring circuitry that provides information to a battery system. [*IEC 62620*]

Battery system (array)
System comprised of one or more cells, modules, or battery packs. It has a battery management system to cut off in case of overcharge, overcurrent, over-discharge, and overheating.

Battery space (compartment)
The space in which the battery system is physically located.

Battery string
A number of battery cells or modules are connected in series to produce the same voltage level of the battery system.

Cell balancing
The technique of balancing and equalizing the voltages of the battery cells within a battery module to have identical voltages so as to improve the available capacity of a battery pack with multiple cells and increase each cell's longevity. Cell balancing is achieved by means of a balancing circuit, which is usually part of the battery management system. Without cell balancing, cells may become under-charged or overcharged, either of which can lead to a failure of the battery module.

Battery Management System (BMS)
Electronic system associated with a battery module/pack that has functions to cut off in case of overcharge, overcurrent, over-discharge, and overheating. It monitors and/or manages the battery's state, calculates secondary data, reports that data, and/or controls its environment to influence the battery’s safety, performance, and/or service life. [IEC 62619]

Battery Support System (BSS)
A battery support system is a group of interconnected and interactive parts that performs an essential task as a component of a battery system.
Note :
Such systems are, for example, electrolyte circulation pumps, cooling and heating devices or fire extinguishers.

Power Management System (PMS)
A complete switchboard and generator control system controls power generation and distribution including multiple switchboards and ring bus systems. The PMS on board a ship is responsible for functions such as load sharing among different power sources, load shedding when generated power is insufficient, etc.

Rated capacity
The capacity value of a cell or battery determined under specified conditions, determined and declared by the manufacturer. [*IEC 62620*] Capacity is usually measured in Ampere-hours (Ah).

State of Charge (SOC)
Available capacity in a battery expressed as a percentage of rated capacity. [*IEC 62660-1*]

State of Health (SOH)
An indication of the general condition of a battery compared to its ideal conditions (i.e., a new battery). The unit of SOH are percent points (100% = the battery’s conditions match the battery’s specifications).

Thermal runaway
The condition where the rate of heat generation within a battery component exceeds its heat dissipation capacity. Thermal runaway can have many causes, such as overcharging, and high ambient operating temperatures, ~~etc.,~~ and can lead to a catastrophic failure of the battery cell, including fire and explosion.

Transitional source of emergency electrical power
A battery suitably located for use in an emergency which can operate without recharging while maintaining the voltage

of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically for a specified period of time in the event of failure of either the main or emergency source of electrical power.

Abnormal conditions
Conditions that deviate from the normal operation of the battery system and that can lead to safety hazard such as gas release.

Control station
A location where controllers or actuators are fitted, with monitoring devices, as appropriate, for purposes of effecting desired operation of specific machinery.

Electrical load profile
The type and demand of electrical load versus time for the intended application.

Main source of electrical power
A source intended to supply electrical power to the main switchboard for distribution to all services necessary for maintaining the ship/unit in normal operational and habitable conditions.

Main switchboard
A switchboard which is directly supplied by the main source of electrical power and is intended to distribute electrical energy to the ship's/unit's services.

Emergency source of electrical power
A source of electrical power, intended to supply the emergency switchboard in the event of a failure of the supply from the main source of electrical power.

Emergency switchboard
A switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency power and is intended to distribute electrical energy to the emergency services.

Emergency disconnect system
A control system used for emergency electrical isolation of battery system.

Lower Explosive Limit (LEL)
LEL is to be taken as the same as the lower flammable limit and which is 4.0% vol. fraction for hydrogen.

Off-gas
Toxic and flammable gases released during abnormal conditions and thermal runaway events.

Safety system
A system comprising several components that work together to prevent damage to the battery and immediate surroundings. The components that make up the safety system for the battery system and space are BMS, thermal management system, electrical protection system, gas detection system, fire detection and suppression system, ventilation system, environmental control system and emergency disconnect system.

## 1.5 Documents to be Submitted

The following drawings and data are to be submitted for review:

1.5.1 General drawing: Position of battery space relative to other spaces/items.

1.5.2 The main components drawing, including enclosures drawing, plate drawing, BMS principal block diagram.

1.5.3 BMS functional description and test reports.

1.5.4 Battery system technical specifications such as nominal voltage and operational limits (e.g., voltage, current, and temperature), safety devices, cell/batteries configuration, battery chemistry, method of activation, discharge and recharge rates for the batteries, etc.

1.5.5 Battery system capacity calculation for intended application.

1.5.6 Battery system electric drawing (including circuit diagrams comprised of batteries, BMS systems, and power distribution boards).

1.5.7 Battery system location and arrangement plan including structural fire protection details.

1.5.8 Battery system risk analysis document (i.e., Failure Modes and Effects Analysis (FMEA)).

1.5.9 Emergency Shutdown (ESD) arrangement (if applicable).

1.5.10 Calculation report: Documentation of the SOH and SOC calculation.

1.5.11 Ventilation system ducting diagram: Detailed arrangements of the ventilation ducts for battery spaces.

1.5.12 Justification for choice and arrangement of fire-extinguishing system.

1.5.13 Fire detection and alarm system arrangement.

1.5.14 Information about toxic products present or likely to be produced in the battery system.

1.5.15 Combustible gas detection and alarm system arrangement (if applicable).

1.5.16 A list of alarms and defaults: This list is to describe alarms and defaults directly connected to the battery system and interfaces with other systems of the ship, if any.

1.5.17 Operations and maintenance manual for battery system and BMS.

The battery system operations and maintenance manual is to be submitted and is to address normal and emergency operating procedures and maintenance procedures for the use of the battery system.

Recommendations on maintenance/servicing records are to be part of the maintenance manual.

Where methods for the verification of proper operation are provided (for example, SOH of battery system and software testing programs), the use of such methods are to be detailed.

The manual is to contain clearly defined, legible and complete instructions for the following, at a minimum:

(a) Instructions for disconnection, de-energizing and firefighting of the battery system depicting illustrations and locations of all relevant components.

(b) The maintenance procedure for the calibration of the BMS.

(c) Procedure for checking the SOH of the battery system as per 4.2.5.

(d) Specifications for the frequency of air filter change or cleaning and the dimensional size and type of filter for replacements. These instructions are to provide directions for removal and replacement of filters and pictorially illustrate and denote all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters.

(e) Instructions for examining the battery system installation to confirm.
- Any intake or exhaust openings are clear and free of obstructions.
- There are no obvious signs of physical deterioration of the battery system or its support (i.e., casing, frame, or rack).

(f) Periodic examination of the vent system, gas detection system, fire dampers, and related functional parts.

(g) Calibration of gas detectors.

The procedures and information are to include maintenance of electrical equipment installed in explosive hazardous areas. The inspection and maintenance of electrical installations in explosive hazardous spaces are to be performed in accordance with a recognized standard.

The inspection and maintenance covered by the Guidelines is to be carried out only by trained or experienced personnel. Documentation verifying compliance with this requirement are to be made available to the Surveyor upon request.

A battery system maintenance schedule is to be provided for review and maintained on board. Refer to 6.1.13 of Part VII of the Rules for requirements related to the maintenance schedule.

1.5.18 Battery system maintenance schedule.

1.5.19 Test plans

(a) Commisioning test plan

A test plan is to be submitted to CR at the start of the plan review process. The test plan is to identify all equipment and systems, listing performance tests or trials. Additionally, the control, monitoring and safety system are to be tested and verified according to Table 3-1, as applicable.

(b) Inspection/survey plan

An inspection/survey plan for the battery system is to be submitted for review and is to be approved by CR. The inspection/survey plan is to identify components/systems to be examined and/or validated during surveys throughout the battery system's life and, in particular, any necessary in-service inspections, maintenance and testing that was considered when selecting the battery chemistry system design parameters.

## 1.6 Scope

Lithium-ion battery types covered by the Guidelines include the following battery types:

- lithium-ion cobalt oxide
- lithium-ion manganese oxide
- lithium-ion nickel manganese cobalt oxide
- lithium-ion nickel cobalt aluminum oxide
- lithium-ion iron phosphate
- lithium-ion titanate

For requirements related to conventional battery types, refer to Chapter 6 of Part VII of the Rules.

Battery chemistries and designs are continuously evolving. Alternative battery technologies and arrangements may be considered provided it can be shown, through either satisfactory service experience or a systematic analysis based on sound engineering principles, to meet the overall safety standards of the Guidelines and the Rules.

## 1.7 Alternative Standards

Battery systems for which there are specific requirements in the Guidelines, may comply with the requirements of an alternative standard, in lieu of the requirements in the Guidelines, if the standard is determined by CR as being not less effective than the requirements provided in the Guidelines. Where applicable, requirements may be imposed by CR in addition to those contained in the alternative standard to meet the intent of the Guidelines. In all cases, the battery system is subject to design review, survey during construction, tests, and trials, as applicable, by CR for purposes of verification of its compliance with the alternative standard.

# Chapter 2 Battery System Design

## 2.1 Battery System Design and Construction

The provisions of this Chapter apply to ship battery energy storage systems. These systems are intended to complement the electric propulsion, the main electrical power sources, and the emergency power sources.

The provisions of this Chapter address battery systems fulfilling functions such as:

- Operation of all-electric ships for which the battery energy storage system is the source of power
- Hybrid powering (peak shaving, backup/reserve, loads optimization) for which the battery system is an energy source
- Emergency and transitional powering (for example, essential services as per 1.3 of Part IV of the Rules)
- Electrical services and other ancillary services for non-essential services

**Table 2-1**
**Certification Details – Battery System Components**

| Battery System Components | Requirements Reference |
|---|---|
| 1. Cells and Modules | 2.2.3, 3.1 |
| 2. Pipe, Valves and Fitting | Part VI of the Rules |
| 3. Cooling System | 2.2.4 |
| 4. Electrical Equipment | Part VII of the Rules |
| 5. Battery Chargers | 2.4, 3.1 |
| 6. Battery Management Systems | 2.3, 3.1 |
| 7. Battery Control and Monitoring System | 2.2.13, 3.1 |

2.1.1 Environmental conditions

The battery systems are to be suitable for proper operations under the inclination and environmental conditions as shown in 1.3 and 1.4 of Part VII of the Rules and the IEC 60092-101.

The requirements of Chapter 1 & 2 of Part VIII, as appropriate, of the Rules, are also applicable to all ships with equipment for control, monitoring and safety systems associated with the battery systems. The equipment is to be designed to withstand the test conditions stipulated in Table VIII 2-2 of the Rules, as applicable.

## 2.2 The Design of Battery System

2.2.1 General

(a) The battery system enclosures installed in a battery space are to have a degree of protection not lower than IP44. For battery system enclosures installed on an open deck an IP67 rating is required.

(b) Accessible parts of the battery system are to have no sharp edges, sharp angles or rough surfaces likely to cause injury.

(c) The exposed parts of battery system are to be designed and constructed to prevent slipping, tripping, or falling hazards.

(d) The battery systems are to be designed, constructed and/or equipped to mitigate risks due to the release of gases, liquids, combustion products or vapors during abnormal conditions, electrical shock or maintenance. Refer to requirements in 2.2.2 to 2.2.16 and 3.3 and 3.4.

(e) The battery system and components are to be designed and constructed with sufficient stability that under operating conditions, they are not at risk of overturning or tipping. Refer to the requirement 2.1.1. Appropriate means of anchorage are to be incorporated and indicated in the installation manual. Refer also to 3.4.1.

(f) All parts are to be securely mounted or attached and rigidly supported.

(g) The battery system is to be fitted with an emergency disconnect mechanism adjacent to, but outside of the battery space. If the battery system is used to provide power for propulsion of the asset, there should be an additional emergency disconnect arrangement on the navigation bridge and the centralized control station or enclosed operating station. All emergency disconnect circuits are to be hardwired and independent of any control, monitoring, and alarm system circuits.

(h) If the battery system is to be used as part of the emergency source of electrical power, it is not to be installed in the same space as the emergency switchboard. If the battery bank is used in conjunction with an emergency power source (e.g., emergency diesel generator), it should not be located in same space as the emergency power source. Both spaces are to be readily accessible and as near as practical.

(i) All outgoing circuits of the battery system are to be protected against overload and short-circuit, excluding the emergency batteries used for engine starting.

### 2.2.2 Materials

(a) Materials in general are to comply with the requirements of Part XI and XII of the Rules.

(b) The exposed battery casing (for cells and modules) is to be constructed of durable, non-combustible, moisture resistant materials, which are not subject to deterioration in the marine environment.

(c) The materials used within the battery space such as the battery casing, rack or frame and piping system are to be suitable for the intended application.

(d) The use of combustible materials inside the battery space is to be minimized. However, the use of combustible materials may be acceptable for sealing purposes subject to CR review and approval.

(e) The battery system and associated cables as applicable are to be made of a flame-retardant material and tested in accordance with Chapter 8 of Part VII of the Rules or IEC Publications 60092-101. Other recognized standards such as IEC 60695-11-10/20 and UL93 may be accepted. Refer to the requirements for environmental test in Table VIII 2-2 of the Rules.

### 2.2.3 Battery cell and module

(a) The battery cell and module are to be designed, type tested, and/or routine tested, and certified by a competent independent testing laboratory for compliance with IEC 62619 and 62620 or other recognized standards accepted by CR. Refer to Table 3-1. In addition, the module is to comply with appropriate requirements for installation in marine environment as documented in 2.1.1.

(b) Battery cells of different physical characteristics, chemistries, and electrical parameters are not to be used in the same electrical circuit.

(c) Cell swelling within a module is not to result in insulation breakdown or any other hazard.

(d) The casing of a cell, module, battery pack, and battery systems are to be provided with a pressure-relief mechanism/arrangement to prevent rupture or explosion. The individual modules are also to have arrangements to prevent release of electrolyte.

(e) As applicable, battery and/or module terminals are to be easily accessible, clearly marked and protected against mechanical damage and accidental contact for earthing, short-circuit.

(f) The module design is to prevent propagation of a thermal runaway from one cell to another cell. Alternatively, as a minimum, the system is to be designed such that a thermal runaway in one cell can spread within that module but will not propagate to another module. The type and level of insulation in the module to prevent thermal runaway propagation is to be based on the heat released per cell and the total number of cells per module and is to be verified through type test as per Table 3-1. The manufacturer's simulation model may be used where it has been validated through a previous type test on similar model.

(g) The battery modules are to be equipped with an independent overcurrent protection other than the BMS and the switchgear. The requirement for independent overcurrent protection is not applicable for battery systems with cells provided with CID or similar safety devices.

2.2.4 Piping systems

(a) Piping systems, cooling systems and auxiliaries are to be designed, constructed, installed, inspected, tested and surveyed in accordance with the requirements for piping systems provided in Part VI, Part XI and Part XII of the Rules, except as modified below.

(b) The minimum thickness of pipes and tubes is to comply with Part VI of the Rules or recognized standard.

(c) For pipes made of materials other than steel, the allowable stress will be specially considered by CR provided that a recognized standard has been used.

(d) Pipes other than those serving the battery system are not to pass through or enter the battery space. Exception to this requirement for existing ships or retrofit installations may be considered on a case-by-case basis

(e) The drainage system is to have a capacity at least equal to that of the water-based fire extinguishing system. Where the water is discharged by means of a pump operating directly from a bilge well or dedicated tank, the capacity of the bilge pump is to be at least 125% of the combined capacity of the water-spraying system pumps.

(f) Battery systems arranged with liquid cooling systems for cooling of the battery cells and/or modules are to comply with the following requirements:
- Where water cooling is used, the cooling system is to be arranged to avoid water ingress into the battery cell or module due to internal or external leakage from the cooling system.
- For liquid cooled battery systems, the cooling system piping is to be hydrostatically tested to 1.5 times the design pressure for a period of 30 minutes after fabrication.

- After installation, the cooling system is to be subjected to a tightness test at the design pressure. No leakage will be allowed.
- The closed-loop cooling system is to be equipped with an appropriate tank featuring high and low liquid detection. Additionally, an alarm is to be provided to monitor the tank's liquid level.
- The liquid cooling system is to be protected by over pressure protection.
- The battery system is to be arranged with cooling fluid leakage detection. Any detection of cooling fluid leakage is to result in an alarm with closing of the cooling supply.
- Cooling pipes are to be arranged to minimize the number of joints.
- An appropriate detection system is to be provided to continuously monitor the operation of the liquid cooling system and alarm in case of a coolant leak.

2.2.5 Environmental control system

(a) The battery space is to be arranged to meet the environmental conditions as specified by the manufacturer of the battery system with respect to ambient temperature and humidity. Also, refer to 1.3 of Part VII of the Rules.

(b) A filter is to be provided to limit the ingress of dust, water, and salt mist into the battery space. The maintenance manual is to include clearly defined instructions for the frequency of filter changes or cleaning and the dimensional size and type of filter for replacements. These instructions are to provide directions for the removal and replacement of filters and pictorially illustrate and denote all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters. Refer to 1.5.17.

(c) The environmental control system is to be monitored and an alarm to the manned station is to be provided in case of failure of this system.

2.2.6 Heat exchangers and heaters

(a) Plans, calculations and data for all heat exchangers and heaters are to be submitted for review and approval applicable to pressure vessels per Part V of the Rules or recognized international standards. They are to be constructed, installed, inspected and tested to the satisfaction of the attending Surveyor in accordance with approved plans.

(b) The heater and cooling systems are to maintain the temperature of the battery system and other equipment installed within the battery space for which they were designed to operate.

2.2.7 Off-gas vent system

(a) Off-gas vent system of the battery space

The off-gas vent system serving the battery space is to comply with the following requirements:

(i) An effective vent system is to be provided for air circulation in the interior of the battery space. The mechanical exhaust vent system is to comprise at least two ventilation fans with 100% capacity each. Both fans are to be supplied from separate circuits and power sources.

(ii) The required capacity of the vent plant is normally based on the gross volume of the room. The ventilation system is to be capable of providing at least 6 air changes per hour. An increase in the required ventilation capacity may be necessary for rooms having a complex form such as L-shaped form supported by engineering calculations or analysis (for example: computational fluid dynamics CFD analysis).

(iii) The design of the mechanical exhaust vent is to be determined by analysis considering the number of cells/modules releasing off-gas during thermal runaway in a battery system. This analysis is to be submitted for review and approval. Where exhaust systems are equipped with thermal runaway insulation for individual cells, the reduction of the exhaust vent capacity and scantling may be accepted as determined by the risk assessment.

(iv) The design of vent fans serving the battery space during abnormal conditions is to be of the non-sparking type, and comply with 1.10.6(a) of Part VII of the Rules.

(v) If the fan motor is installed inside the duct, it is to be suitable for zone 2 with minimum temperature class T2 and gas group IIC.

(vi) Venting of the battery space is to be automatically activated upon:

(1) gas detection in the battery space. See 2.2.9.

(2) high cell temperature detection (maximum setpoint controlled by the BMS). See 2.3.

(vii) Vent ducts and openings are to be arranged so that water ingress does not reach the battery system. When conducting the risk assessment, it is important to consider the possibility of a leak or condensation in the vent duct and its impact on the battery system.

(viii) The outside vent openings are to be arranged to prevent rain/sea water from entering and at a height sufficient to comply with the International Load Line Convention without arranging any closing appliances.

(ix) The vent duct(s) are to be of fully welded construction and duct materials are to be compatible with the gases produced in abnormal and thermal runaway conditions. Ducts serving battery spaces should not pass through accommodation spaces, service spaces, or control spaces.

(x) The vent ducts are to be gas-tight and able to withstand the off-gas temperature and pressure build up associated with abnormal and thermal runaway conditions.

(xi) The ventilation is to function at all temperatures and environmental conditions the ship is expected to be operating in.

(xii) Vent inlets for the battery space are to be taken from areas which, in the absence of the considered inlet, would be deemed non-hazardous. Vent inlets are to be taken from non- hazardous areas at least 1.5 meters away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gas-tight and have over-pressure relative to this space.

(xiii) Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation openings on the open deck to prevent the entrance of foreign objects into the fan casing.

(xiv) Vent outlets are to be fitted with corrosion resistant flame-screens.

(xv) Vent outlets are to vent to the open deck or semi-enclosed spaces on deck at least 1.5 meters away from passenger spaces, egress routes, muster stations, air intakes, or ignition sources.

(xvi) Manual control of the vent system is to be arranged outside the battery space at a manned control station and locally at the entrance to the battery space.

(xvii) Venting is to be such that with the battery room door open, air flow is from the other space into the battery space. Loss of differential pressure is to be alarmed at a normally manned location.

(b) Off-gas vent system integrated to the battery space

For battery system with integrated off-gas vent ducts, the integrated vent system is to comply with the requirements of 2.2.7(a)(iii) to 2.2.7(a)(xv) and connected to an independent outlet vent duct directly to open air. This integrated outlet duct is to be arranged in addition to the battery space outlet duct.

### 2.2.8 Fire dampers

(a) Battery space vent inlet and outlet openings are to be provided with fail-safe automatic closing fire dampers which are to be operable from outside the battery space. All fire dampers are to be capable of manual operation.

(b) Before actuation of the gas-based fire-extinguishing system, if applicable, the fire dampers are to be closed.

(c) Installation of fire dampers is to be such that there is unobstructed access to the dampers for operation, maintenance, and inspection. Arrangements are to be provided to indicate whether the damper is open or closed. Where a fire damper is located within a ventilation coaming, such arrangements may include provision of an inspection port or opening at least 150 mm in diameter on the coaming to facilitate survey of the damper without disassembling the coaming or the ventilator. The closure provided for the inspection port or opening is to maintain the watertight integrity of the coaming and, if appropriate, the fire integrity of the coaming.

2.2.9 Gas detection system

(a) Gas detection required by this Chapter is to be continuous and without delay.

(b) The gas detection system is to have power supply from two separate supply circuits, one from the main source of power and one from the emergency source of power. An automatic changeover is to be arranged for the two supply circuits.

(c) At least two gas detectors are to be fitted in the battery space. The number of detectors in the battery space are to take into account the size, layout and ventilation of the space. The detection equipment is to be located where gas may accumulate and/or in the ventilation outlets based on the risk assessment. Gas dispersal analysis or a physical smoke test is to be used to identify the optimal arrangement.

(d) An audible and visible alarm is to be activated at a gas concentration of 30% of the LEL. The automated battery safety system is to be activated including the activation of battery space vent system and the emergency disconnect system at 30% of LEL of two detectors.

(e) The integrated vent duct is to be fitted with gas detector. The integrated exhaust vent is to be automatically activated upon gas detection in the integrated ventilation duct at 20% of LEL. An alarm is to be activated.

(f) Failure of the power supply for the gas detection system is to initiate an alarm at the manned control station.

(g) The gas detection system is to initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating gas, so that the alarms are heard and observed at the following locations as fitted:
- Navigating bridge
- Central control station
- Fire control station
- Battery space

(h) In case of gas detection in the battery space or the integrated exhaust vent system, the safety system is to carry out an automatic disconnect and isolation of the battery system or the affected section of the battery system if detectable.

2.2.10 Electrical system

(a) The electrical requirements in this Chapter supplement the requirements of Part VII of the Rules. Where electrical equipment is installed in hazardous areas it is to be selected, installed and maintained in accordance with a standard acceptable to CR (e.g., IEC 60079 series and IEC 60092-502, as applicable).

(b) Means are to be provided to protect the battery system against short circuits and flow of reverse current.

(c) Means are to be provided to protect against overload, earth-fault and overvoltage conditions and other hazards to prevent damage to equipment and maintain continuity of power supply to remaining circuits.

(d) Switchgear providing means for safe isolation of the battery system is to be arranged. The switchgear is to disconnect both poles in order to completely isolate the battery system. This isolation mechanism is to be independent of the emergency disconnect arrangement.

(e) Selective tripping of downstream circuit breakers and fuses is to be based on the short circuit current of the battery system according to the manufacturer’s specification.

2.2.11 Transformers and converters

(a) Transformers are to be designed, constructed, and tested in accordance with Chapter 7 of Part VII of the Rules as applicable.

(b) Power electronic converters are to be designed, constructed, and tested in accordance with Chapter 15 of Part VII of the Rules as applicable.

2.2.12 Emergency disconnect system

(a) The ship is to be fitted with an EDS operable from both the manned control station and outside of the battery space. Refer to 2.2.1(g). This is to allow a rapid and safe isolation of the battery system. When required, semiconductor converter assemblies shall be provided with an emergency stop function. The emergency stop circuit is to be hard-wired and independent of any control system signal. Refer to 2.1.1.

(b) A method to initiate an emergency disconnection is to be a separate control from the BMS (see 2.3), and have an independent means of actuation, (e.g. an emergency stop switch).

(c) The emergency stop is to have fail-to-safe functionality upon wire break or loss of power.

(d) Alarm in case of power loss is to be provided for normally de-energized emergency stop circuits.

2.2.13 Control, monitoring, alarm and safety systems

(a) Control, monitoring, and safety systems are to have self-check facilities. In the event of failure to the systems or power supply, an alarm is to be activated. See Table 2-2 for list of battery system monitoring requirements.

(b) In the event of failure to the safety system, any of its components or power supply, an alarm is to be activated. See Table 2-2 for list of battery system monitoring requirements.

(c) The safety system is to be designed so as to limit the consequence of failures. It is to be constructed on the fail-safe principle.

(d) Sensors for safety functions are to be independent from sensors used for other purposes (e.g., for alarm system).

(e) The sensors are to be designed to withstand the local environment. The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located. Any malfunctioning in the sensors is to be detectable. See Table 2-2 for list of battery system monitoring requirements.

(f) Loss of the required ventilation/exhaust ventilation (see requirements for vent system, 2.2.7) is to give an audible and visual alarm on the navigation bridge, in a manned central control station or fire control station, as well as locally.

(g) The following is to be monitored and give an alarm in case of abnormal conditions at a manned control station:

- ambient temperature in battery space
- indication of vent system running in the battery space
- indication of vent system running for the integrated off-gas vent duct as applicable

(h) A continuous insulation (earth fault) monitoring on both poles of the battery system is to be located inside the battery system on the battery side of any switchgear. The insulation monitoring is to remain in operation when the battery system is not connected. An alarm is to be provided in the event of detecting an earth fault at a manned control station.

(i) SOC and SOH are to be monitored and available for the operator and visible at the manned control station.

**Table 2-2**
**Monitoring of the Battery System**

| Parameter | Alarm and display | Automatic disconnect of the battery system | Comments |
|---|---|---|---|
| Failure of the cooling system | X | | See 2.2.4 |
| Liquid leak detection in cooling system | X | | See 2.2.4 |
| Low- and high-level cooling water tank | X | | See 2.2.4 |
| Failure of the environmental control system | X | | See 2.2.5 |
| High ambient temperature in the battery space | X | | See 2.2.13 and 3.2 |
| Failure of power supply | X | | See 2.2.12, 2.2.13, 2.3 |
| Failure of the safety system or its components | X | | See 2.2.13 |
| Failure of the battery charger | X | | See 2.4 |
| Abnormal conditions provided by the BMS | X | X | See 2.3 |
| Gas detection 30% of LEL in the battery space | X | X | See 2.2.9 |
| Gas detection in the integrated vent duct 20% LEL | X | X | See 2.2.9 |
| Electrical insulation | X | | See 2.2.10 and 2.2.13 |
| Loss of vent in the battery space | X | | See 2.2.13 |
| Loss of integrated vent system | X | | See 2.2.13 |
| Open gas-tight door of the battery space | X | | See 3.2 |
| Fire detection in the battery space | X | X | See 3.2.2 |
| Heat and smoke detection | X | X | See 3.2.2 |
| Low level of freshwater of the Fixed Fire Extinguishing System (FFES) | X | | See 3.2.2 |
| Liquid leak detection in the battery space | X | | See 3.2.3 |
| SOC and SOH of the battery system | X | | See 2.2.13 and 4.2.5 |
| Minimum capacity of the battery system | X | | See 4.2.2(d) |

2.2.14 Battery system used as main source of electrical power
See Chapter 4 for detailed requirements.

2.2.15 Battery system used as emergency source of electrical power
Batteries may be used as an emergency source of power provided that the following arrangements are met.

(a) Installations are to be designed for proper operations under the conditions as per 1.4 of Part VII.

(b) Automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power.

(c) Immediately supplying at least those services specified in 11.3.7 (for passenger ships) or 11.4.7 (for cargo ships) of Part VII of the Rules as applicable. The required capacity and SOC of this system are to be based on the required power and time for these services. The minimum remaining emergency time is to be documented in the electrical load analysis.

(d) Attention is directed to the requirements of the governmental authority of the country whose flag the ship flies for the emergency services and the lithium-ion batteries required in various types of ships.

(e) Are to be installed directly adjacent to, but not in the same space as the emergency switchboard

(f) See additional requirements as per 4.2.2, 4.2.4, 4.2.5, 4.2.6, 4.2.7; and 11.3 (for passenger ships) and 11.4 (for cargo ships) of Part VII of the Rules.

(g) Vent system for the battery space is to be operable upon loss of main source of electrical power

2.2.16 Battery system used as transitional source of electrical power
Batteries may be used as a transitional source of power provided that the following arrangements are met.

(a) Attention is directed to the requirements of the governmental authority of the country whose flag the ship flies.

(b) See additional requirements as per 4.2.2, 4.2.4, 4.2.5, 4.2.6, 4.2.7; and 11.3.7 (for passenger ships) or 11.4.7 (for cargo ships) of Part VII of the Rules.

## 2.3 Battery Management System

2.3.1 The battery system is to have a BMS.

2.3.2 The BMS is to be appropriately designed for the associated cells and modules. The BMS is to be designed by the same manufacturer as the batteries or to be certified by both the BMS manufacturer and the battery manufacturer for compatibility.

2.3.3 The BMS is to monitor the battery cell voltage, cell temperature, and battery string current.

2.3.4 The BMS is to be continuously powered and an alarm is to be given in the event of failure of the normal power supply.

2.3.5 The following conditions are to be tested as specified in 3.1 and to result in an individual or group audible and visual alarm to be displayed in a continuously manned location:

(a) Cell overvoltage

(b) Cell undervoltage

(c) Cell voltage unbalance

(d) Cell over-temperature

(e) Battery module/pack ground fault

(f) Failure of communication with asset’s Power Management System (PMS) (if applicable)

(g) Tripping of mechanism that provides electrical isolation

(h) Recommendations as specified in the result of the risk assessment

2.3.6 The BMS is to comply with the requirements in Chapter 3 of Part VIII of the Rules. Appropriate computer-based system category for BMS is to be assigned in accordance with 3.3.1 of Part VIII of the Rules. The BMS is to be considered as a computer-based system with system Category II or III. The exact category is dependent on the risk assessment for all operational scenarios (e.g., intended use for battery system, etc.). The relevant software design requirements and CR Surveyor witness requirements for Category II or III systems are to be complied with.

2.3.7 The safety system is to be activated automatically in the event of identified conditions that could lead to damage of the lithium-ion battery system. Activation of any automatic safety actions is to activate an alarm in a continuously manned location.

2.3.8 A software-based feature/mechanism is to be installed to prevent the crew from over-riding or ignoring critical BMS system alarms and disconnect. Manual override of safety functions is not permitted.

2.3.9 The BMS is to be capable of the following conditions:

(a) Measuring and communicating battery voltage, battery current, battery internal temperatures, battery balance, ground fault.

(b) Incoming and outgoing communications with batteries.

(c) Calculating and communicating SOC, SOH, and time remaining*.

(d) Balancing the batteries as necessary.

(e) Isolating batteries using control gear (e.g midpack contactor) in case of damage or incorrect operation.

Note:
* Time remaining can also be calculated and communicated via the energy management system or PMS. Refer to 4.2.

## 2.4 Battery Chargers

2.4.1 Battery chargers used for main, emergency, and transitional sources of power are to meet the requirements specified in Chapter 6 of Part VII of the Rules, or constructed and tested according to recognized standard as applicable.

2.4.2 The battery charger is to operate within the limits (i.e., charging and discharging) set in the BMS as specified by the battery cell manufacturer.

2.4.3 The battery charger is to be designed to maintain charging within the voltage, current, and temperature limit for the battery as specified by the battery cell manufacturer.

2.4.4 The battery charger is to be interfaced with and controlled by the BMS.

2.4.5 An alarm is to be provided to indicate a failure of the battery charger.

2.4.6 Battery charger is to be kept away from any heat source or flammable materials and the battery is to be continuously monitored during charging. Refer to 2.3.

## 2.5 Marking and Designation

Marking and designation is to be in accordance with clause 5 of IEC 62620.

# Chapter 3 Battery System Installation

## 3.1 Battery System Testing Requirements

The battery system is to undergo type test and routine tests carried out to the satisfaction of attending CR Surveyors as per Table 3-1. Type tests are to be carried out on one prototype while the routine tests are to be carried out on all battery systems, as per the test procedure in the respective standard/section given.

**Table 3-1**
**Summary of Type and Routine Tests**

| No. | Test | Type test | Routine test | Reference[1] |
|---|---|---|---|---|
| | Cell tests | | | |
| 1 | External short-circuit test | X[2] | | IEC 62619 7.2.1 |
| 2 | Impact test | X[2] | | IEC 62619 7.2.2 |
| 3 | Drop test | X[2] | | IEC 62619 7.2.3 |
| 4 | Thermal abuse test | X[2] | | IEC 62619 7.2.4 |
| 5 | Overcharge test | X[2] | | IEC 62619 7.2.5 |
| 6 | Forced discharge test | X[2] | | IEC 62619 7.2.6 |
| 7 | Discharge performance | X[2] | | IEC 62620 6.3 |
| 8 | Charge (capacity) retention and recovery | X[2] | | IEC 62620 6.4 |
| 9 | Cell internal resistance | X[2] | | IEC 62620 6.5 |
| 10 | Endurance in cycle | X[2] | | IEC 62620 6.6 |
| 11 | Internal short-circuit test | X[2] | | IEC 62619 7.3.2 |
| | Battery system test[4] | | | |
| 12 | Ingress test | X[2] | | IEC 60529 |
| 13 | Flammability test | X[2] | | IEC 60092-101 |
| 14 | Propagation test | X | | IEC 62619 7.3.3[3] |
| 15 | Overcharge control of voltage | X | | IEC 62619 8.2.2 |
| 16 | Overcharge control of current | X | | IEC 62619 8.2.3 |
| 17 | Overheating control | X | | IEC 62619 8.2.4 |
| 18 | Over discharge protection | X[2] | | UL 1973 19 |
| 19 | Imbalance charging | X[2] | | UL 1973 21 |
| 20 | Static force (enclosure) | X[2] | | UL 1973 31 |
| 21 | Impact (enclosure) | X[2] | | UL 1973 32 and 33 |
| 22 | Resistance to moisture | X[2] | | UL 1973 39 |
| 23 | Salt fog exposure | X[2] | | UL 1973 40 |
| 24 | Insulation resistance | | X | 5.8.3 of Part VII of the Rules |
| 25 | Dielectric strength | | X | 5.8.2 of Part VII of the Rules |

| No. | Test | Type test | Routine test | Reference[(1)] |
|---|---|---|---|---|
| 26 | Battery system/BMS safety function tests | | X | 2.3 |
| 27 | Type tests for control, monitoring and safety equipment | X | | Table VIII 2-2 of the Part VIII of the Rules |
| 28 | Unit certification tests for control, monitoring and safety equipment. | | X | Table VIII 4-1 of Part VIII of the Rules |
| 29 | Pressure test of cooling system[(5)] | X | X | 2.2.4 |

Notes:

(1) Battery systems may comply with requirements in an alternative standard provided it has been determined by CR as being not less effective. Where applicable, requirements may be imposed by CR in addition to those in the alternative standard so that the intent of the Rules is met.

(2) For type approved products and design approval (e.g., battery cells), the type tests as required in Table 3-1 above, are not to be repeated on units already tested, approved and certified by a national recognized testing laboratory, and test reports verified by CR; therefore, Surveyor attendance is not required for those "type tests".

(3) The test should be conducted in worst-case location and in worst-case orientation with regard to propagation. The triggering method for thermal runaway is to be by overcharge or heating. Acceptance criteria is defined as only the cell or module which is directly caused to fail by testing show fire or off-gassing and that all other cells in module or other modules show no external signs of thermal runaway and still produce a measurable voltage within normal operating range. For liquid cooled modules the integrity of the liquid cooling system is to be intact.

(4) The static and dynamic inclination tests listed in Item 19 of Table VIII 2-2 of Part VIII of the Rules are not required for battery system.

(5) Applicable for battery systems arranged with liquid cooling systems.

(6) The required tests per IEC 62619 should be conducted for battery cells that are stored for not more than six months under conditions specified by the battery manufacturer.

## 3.2 Battery Space

3.2.1 The battery space is to meet the following requirements:

(a) Battery spaces are not to be located forward of the collision bulkhead of the ship.

(b) Boundaries of the battery space are not to be contiguous to the ship’s side shell and the bottom shell.

(c) When the battery space is located below the ship’s damaged waterline, or when it is located below the main deck on ships that are not subject to damage stability requirements, the boundaries of the battery space are to be watertight. A battery space that is not completely watertight may be accepted provided the battery systems have an IPX7 rating.

(d) Battery spaces are not to contain any equipment not related to the battery system and its associated safety components including heat sources or high fire risk objects external to that of the battery system.

(e) Battery spaces are not to contain any equipment (including cables and pipes) supporting essential services as defined in 1.3 of Part IV of the Rules, so as to prevent loss of such essential services in the event of an incident such as thermal runaway.

Note:
This requirement does not apply to cables supplying power to and from the battery system itself.

(f) The rated capacity of the battery system is to be determined for the ambient temperature conditions in 1.3 of Part VII of the Rules. Where the expected ambient temperatures are different from those in the applicable requirements, the rating of the battery system is to be based on the actual ambient temperature.

(g) The battery system is installed in an environmentally controlled space, the applicable requirements in 2.2.5. The failure of the environmentally controlled system is to be alarmed at a manned location.

(h) High ambient temperature in the battery space is to be monitored and alarmed at a continuously manned location.

(i) The battery space is to be installed with appropriate means to vent gases, which may be generated during an abnormal situation, from the battery space to open deck.

(j) The battery system location and arrangement plan should clearly show the battery pack with respect to the space it is being installed in as well as the clearance of distances between any other equipment in the room and the battery pack.

(k) Battery spaces are to be mechanically ventilated and the vent system is to comply with the requirement given in 2.2.7. The vent ducting for the battery space is to be separate from the HVAC systems used to ventilate other spaces on the ship.

(l) The battery space is to be fitted with flammable and toxic gas detection, appropriate to the battery chemistry being used. Refer to 2.2.9. The gas detection is to give an alarm at a continuously manned location and automatically disconnect the battery system if the concentration of gas in the battery space reaches 30% LEL. Gas detection system is to be interlocked with the battery chargers to prevent battery charging.

(m) In the case where batteries are used as main source of electrical power (i.e., ship service loads) and/or propulsion power, see 3.2.2(e) and 4.2.6 for structural fire protection requirements.

(n) The ventilation duct is to be arranged with means to close the fire damper when the battery space is fitted with a combined fire extinguishing system according to 2.2.8.

(o) Access to the space is to be through normally closed gas-tight doors or hatches with alarm at a normally manned location or self-closing gas-tight doors or hatches with no holdback arrangement.

(p) Means to disconnect the battery system in the event of a fire in the lithium-ion battery space are to be provided and located outside of the protected space.

(q) Means of escape from the battery space are to be in accordance with SOLAS Regulations for machinery spaces.

(r) Warning signs are to be appropriately placed to identify access to the battery space, electrical hazards, and contents from drain valves. Symbols should be standardized and comply with ISO 3864-2.

### 3.2.2 Fire Safety

(a) General

In general, the battery space is to meet the following requirements:

(i) The battery space is to be considered a machinery space other than category A as defined in SOLAS Regulation II-2 and is subject to additional structural fire protection requirements listed therein. Battery spaces are considered as not normally manned. The fire rated insulation arrangements for the boundaries of the battery space should be designed to contain the fire within the space of origin. The fire loads associated with the lithium-ion batteries should not exceed the endurance of the fire rated divisions.

(ii) The battery space is to be fitted with a FFES that provides continuous cooling and appropriate to the battery chemistry used. A fixed system is to have provisions (i.e., selection of proper metallic material for nozzles, grounding methods) to prevent a buildup of static electricity at nozzle during release of extinguishing agent. The FFES is to comply with the provisions of 8.3 of Part IX of the Rules, to the extent applicable, and is to adequately consider the potential fire loads involved (e.g., size of the batteries, battery chemistry used, specific materials involved, etc.). Technical validation of the system is to be carried out in accordance with the procedures outlined in the Chapter 12 of Part IX of the Rules for alternative design and arrangements and sufficient documentation to verify the same is to be submitted along with arrangements and details of the system for review. Where the FFES requires closing of vent, fire damper, etc., provisions are to be made in the design to ensure that it does not lead to over pressurization or toxic gas buildup in the room as lithium-ion battery fire is self-perpetuating.

(iii) The FFES is to be designed to limit the heat dissipated into the load bearing structure during a specific period identified in the risk assessment to control the fire during a thermal runaway event.

(iv) The following FFESs may be accepted subject to CR approval:

- Fresh water-based system complying with the provisions of 8.3.1(a)(iii) of Part IX of the Rules. The freshwater quality and quantity are to be provided based on the manufacturer’s recommendation and addressed during the risk assessment. Additionally, an alarm is to be provided when the freshwater tank level is low and next stage of the firefighting procedure is to be initiated. See 3.2.2(a)(v). The stability of the ship, when the battery space is completely flooded with water, is subject to intact stability requirements outlined in Chapter 30 of Part II of the Rules.
- A combined system: The battery space is to be protected with both a freshwater based water spray system and a gas-based system complying with the provisions of the requirements of 8.3.1(a)(i) & (iii) of Part IX of the Rules. The two systems are to be separated, each with its own independent components.

(v) Gas-based systems are not to be used as the main and only FFES due to their limited cooling capabilities and the risk of toxic gas generation.

(vi) A non-automatic seawater-based firefighting system is to be installed for the battery space. It is to be used as a last resort system and after deploying all the recommended systems defined in 3.2.2(a)(iv), and if the fire mitigation and temperature increase are not successful. The immediate evacuation of ship is to be initiated.

(vii) A fire hydrant is to be provided close to and outside the battery space.

Note:

It is not recommended to use seawater for extinguishing fires during thermal runaway because of its electrical conductivity. This poses several risks, including electrocution, asset damage, electrolysis, and the release of chlorine gas.

(viii) In addition to the requirements of 3.2.2(a)(iv), the following active fire extinguishing systems or agents to preventing fire spread and thermal runaway propagation may be accepted subject to CR approval:

- Condensed aerosol complying with the provisions of 8.3.1(a) of Part IX of the Rules. Refer to the Revised guidelines for the approval of equivalent fixed gas fire-extinguishing systems, as referred to in SOLAS 74, for machinery spaces and cargo pump-rooms (MSC/ Circ.848 as amended by MSC.1/Circ.1267) and the Guidelines for the approval of fixed aerosol fireextinguishing systems equivalent to fixed gas fire-extinguishing systems, as referred to in SOLAS 74, for machinery spaces (MSC/Circ.1270).
- Foam based extinguishing systems in accordance with 8.3.1(a)(ii) of Part IX of the Rules.

(ix) Portable fire extinguishers are to be provided as required in 8.2 of Part IX of the Rules. Portable fire extinguishers for the Class fires of the battery system are to be provided based on the battery manufacturer recommendation. The number and sizes of the portable fire extinguishers should be governed by the calculated fire load(s) in the battery space. Specific Personal Protective Equipment (PPE) and Safety equipment is to be included in the operation and maintenance manual.

(x) Openings and penetrations in the boundaries of the battery space are to maintain the fire, gas-tight and watertight integrity of the space.

(xi) Combined smoke and heat detectors or a combination of smoke and heat detectors are to be installed in the battery space and in the integrated vent duct as applicable. The arrangement is to comply with the International Code for Fire Safety Systems (FSS Code).

(xii) Means are to be provided in the battery space to remove the flammable and toxic gases after incident without causing the risk of ignition. These procedures should be explicitly outlined in the post-incident protocol.

(xiii) The battery room or space is to be provided with gas-tight door to prevent escape of combustible gasses. The battery room or space is to be provided with a deck drain. Refer 3.2.3(d).

(b) Battery space adjacent to accommodation space, control station or service spaces

Where battery space is located adjacent to accommodation space, control station, or service spaces, the following additional requirement is to be met:

(i) At a minimum, "A-60" class insulation is to be provided for battery space, subject to the results of the Risk study in 3.3.

(c) Battery space adjacent to or within machinery space of category A

In addition to the requirements in 3.2.2(a), where battery space is located adjacent to or within machinery space of category A, the following additional requirements are to be met:

(i) A-60 Fire integrity between the battery space and machinery space of category A. The fire rated insulation arrangements for the boundaries of the battery space and the adjacent machinery space(s) should contain the fire(s) within the space of origin. The protection provided by A-60 fire rated insulation should be appropriate for the cumulative fire loads within the battery space and the adjacent machinery space of category A. The fire load(s) associated with the battery room or adjacent the machinery space of category A should not exceed the endurance of the A-60 fire rated divisions.

(ii) Ventilation duct(s) from the battery space are to be A-60 insulation.

(iii) At least two separate escape routes are to be provided, situated as far apart as practicable, to allow ready means of escape to the open decks and/or embarkation stations. Exceptionally, one means of escape may be considered, taking into account the nature and location of the space.

(d) Battery space for battery systems used as emergency source of power

Where battery system is used as emergency source of power, the following additional requirement is to be met:

(i) With regard to structural fire protection, the battery space is considered machinery space category A (as defined in SOLAS Regulation II-2) and is subject to the structural fire protection requirements listed therein.

(ii) At a minimum, "A-60" class insulation is to be provided for the battery space. However, the level of fire protection and blast resistance of the bulkheads and decks are to be properly considered through fire and explosion analysis.
Note:
Fire and explosion analysis may be required if it is determined by the required risk assessment in 3.3.

(e) Battery space adjacent to fuel tanks or spaces

(i) Where battery space is located adjacent to fuel oil tank/space having a flash point of 60°C or above, the following additional requirements are to be met:

- Bulkheads and decks forming boundaries between Battery spaces and fuel oil tank/ spaces are to be insulated to "A-60" class standard and the insulation is to extend at least 450 mm outside the area of the joint bulkheads and decks.
- The top of the battery space is not to be in direct contact with the fuel tank's bottom. Alternatively, the top of the battery space is to be fitted with a cofferdam. The cofferdam is to be fitted with suitable drainage arrangements to prevent accumulation of oil in the event of oil leakage from the tank.

(ii) Where battery space is located adjacent to low-flash point fuel tanks, the lithium-ion battery space should be separated from space containing fuel containment system by a cofferdam of at least 900 mm with structural fire insulation with A-60 class. For type C tanks, the fuel storage hold space may be considered as a cofferdam.

3.2.3 Hazardous area requirements

Flammable gases and toxic gases are released during abnormal conditions and thermal runaway. For batteries of this type, the vent systems of the battery space and the integrated vent system (Refer to 2.2.7(a) and 2.2.7(b)) are to be classified as a hazardous area Zone 2 and the following additional requirements are to be met:

(a) The operations and maintenance manual (Refer to 1.5.17) is to list hazardous gases released.

(b) The equipment selection is to comply with applicable provisions in IEC 60079.

(c) The related electrical equipment list for the battery space (e.g. electrical equipment located in the vent ducts, installed either within 0.4m of the ceiling or suspended from the ceiling, exposed to the off-gas release) is to be part of the overall hazardous area plan for the asset.

(d) The battery space is to have an independent deck drain. The independent deck drain is to be drained to a closed dedicated drain tank or from a bilge well to a safe location. Refer to 2.2.4. The drain tank is to be provided with:

- A vent pipe to a safe location on the open deck
- Adequate capacity
- A high level alarm
- The material of the drainage piping systems, tanks, and other components which may come into contact with corrosive materials in the presence of liquid electrolyte solution is to be of a suitable grade of alloyed steel coated with appropriate anti-corrosion coating, non-combustible plastic, or other compatible material established to be suitable for the application. Non-alloyed steels, copper, copper containing alloys, and zinc-coated steels are not to be used for the drain tank or piping systems

(e) Areas on the open deck within 1.5 meters of the battery space intake(s) and exhaust ventilation outlet(s) are to be considered as hazardous areas.

(f) The areas on the open deck are to have the same area classification as the vent ducts.

3.2.4 Cable Installations

(a) General

In general cable installations are to comply with Chapter 8 of Part VII of the Rules.

(b) Services necessary under a fire condition

Where battery systems are used in any of the services that are required to be operable under a fire condition as defined by 8.5.4 of Part VII of the Rules, their cable installation should be in accordance with 8.5.3 of Part VII of the Rules.

## 3.3 Battery System Risk Assessment

The primary objective of the risk assessment (e.g. HAZID) is to identify technical risks and uncertainties associated with the proposed battery system design and its incorporation on a ship. The risk assessment is to demonstrate the ship safety (e.g. HAZID) and the continuity of power supply in case of failure of the battery (e.g. FMEA). Considering the risk of fire and explosion, a fire and explosion analysis may be necessary. However, prior to performing the fire and explosion analysis, please consult CR (see Note (5) below), and if applicable, the regulations, guidance notes, and circulars from the Flag Administration to establish the basis for conducting the fire load and explosion assessment related to the installation of lithium-ion batteries on marine ships and offshore units.

A Failure Mode and Effects Analysis (FMEA) is typically used but alternatively other risk assessment techniques may also be considered acceptable. The use of other risk assessment techniques should be agreed upon with CR prior to performing the risk assessment. The risk assessment is to be carried out in accordance with CR-recognized industry standards (e.g., IEC 60812).

All foreseeable hazards, their causes, consequences (local and global effects), and associated risk control measures are to be documented. The Battery System Risk Analysis document submitted for review is to, at a minimum, address the following issues:

3.3.1 Power system redundancy and overall safety considerations

3.3.2 Appropriate measures taken into account for internal hazards (i.e. internal short-circuit, cell swelling, and fire propagation inside a module)

3.3.3 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

3.3.4 Appropriate measures taken into account for external hazards (i.e., external short-circuit, fire, gas development, water ingress and flood, etc.)

3.3.5 Loss of communication with the asset's PMS, as applicable: Appropriate measure taken to isolate the battery pack in the event of a loss of communication with the PMS

3.3.6 Inherently safer design[(4)] implemented (usually by the BMS) for the safe operation of the battery system, redundancies in place and communication protocols used

3.3.7 Temperature and voltage measurement sensor failure

3.3.8 Appropriate quality plan implemented by the vendor to identify manufacturing defects in individual cells

3.3.9 Failure due to abuse conditions (such as overvoltage, over temperature, and mechanical stress)

3.3.10 A fire and explosion analysis of the battery due to rapid chemical fire and explosion. Prior to performing the fire and explosion analysis, CR is to be consulted, and if applicable, the relevant regulations, guidance notes, and circulars from the Flag Administration are to be used to establish the basis for conducting the fire and explosion analysis related to the installation of Lithium-ion batteries on marine ships and offshore units

3.3.11 Risk of chemicals used and chemical fire are to be considered

3.3.12 Arrangement of the vent ducts and gas detectors within the battery space

3.3.13 FFES including the quality, duration, and quantity of the extinguishing agent

3.3.14 Post incident clean up procedure

Notes:

(1) There may be two risk assessments carried out in some cases. One performed by the battery vendor/ manufacturer and the other by the shipyard/system integrator.
(2) The shipyard/system integrator's risk assessment covers items 3.3.1, 3.3.2 and 3.3.3.
(3) The battery vendor/manufacturer's risk assessment covers items 3.3.4, 3.3.5, 3.3.6 and 3.3.7.
(4) Inherently safer design exists in some specific equipment as a permanent and inseparable element. The safety mechanisms in place are built in by virtue of the design and not added on. Traditionally, the approach to safer design considers preventive controls and/or mitigation measures as options to minimize hazardous events.
(5) Fire and explosion analysis may be required if it is determined by the required risk assessment in 3.3.

## 3.4 Installation and Commissioning

The battery system installation and sea-trial/commissioning procedures submitted for review are to address the following:

3.4.1 The necessary information for the preliminary work of setting up the battery system, including the mechanical protection system such as the shock absorber, if applicable, and the fixation system such as anchorage or bolting.

3.4.2 Corrected interface between the battery system and the DC-bus or battery charger, as applicable.

3.4.3 Testing of the following safety functions and associated alarms (Refer to Table 2-2): cell balancing detection/protection, overvoltage detection/protection, undervoltage detection/protection, emergency disconent arrangement, ground fault detection, loss of communication detection/protection.

3.4.4 Testing of the expected performance functions of the battery system on the particular asset. Refer to Table 2-2.

3.4.5 Testing of protective functions in the battery space, as applicable to asset specific installation. Refer to Table 2-2.

# Chapter 4 Battery System Used as Main Source of Electrical Power

## 4.1 General

This Chapter covers battery systems used as the main source of electrical (i.e., ship service loads) and propulsion power. These requirements are to be in addition to those specified in Chapter 2 and 3 covering design, construction, and installation.

## 4.2 System Requirements

Battery systems used as the main source of electrical power must meet flag state and SOLAS requirements, as applicable.

In addition to the plans and data to be submitted in accordance with 1.5, as applicable, the following requirements are to be met.

### 4.2.1 Redundancy

(a) For all-electric ships, two independent battery systems are to be provided and located in separate spaces.

Note:

Heightened fire risk associated with thermal runaway is the main reason for separate compartments.
The redundant source of energy is to provide the power needed for the period denoted in 4.2.2 for normal operation and after a single failure event. However, having regard to overall safety considerations, a partial reduction in propulsion capability from normal operation may be accepted.

(b) Each battery system is to be connected to an independent switchboard.

(c) The switchboards are to be placed as near as practicable to the battery systems.

(d) The propulsion design is to incorporate at least two independent systems as defined in 13.2 of Part VII of the Rules.

### 4.2.2 Capacity

In addition to the capacity submittal of 1.5.5, design capacity based on the asset's intended operations is to be submitted.

(a) Remaining times are the duration available for normal operations and single failure event, which depend on the available capacity of the battery storage and the average power consumption. They are to be calculated and submitted to CR for approval based on the electrical load profiles for the intended application and the design capacity of the system.

(b) The remaining time that the ship can operate from the battery storage during normal operation is to be calculated and displayed at the navigation bridge and at a manned control station.

(c) The remaining time that the ship can operate from battery storage under the single failure condition is to be calculated and displayed at the navigation bridge and at a manned control station.

(d) An audible and visual alarm is to be announced at the navigation bridge and at a manned control station when the battery system capacity reaches minimum capacity as required for the intended operation or voyage. For instance, the alarm can be based on:

- The remaining time for normal operation after the single failure
- The energy required for supplying essential services
- Remaining time for normal operation (Top)

$$Top = \frac{Ca}{Pavr}$$

Where

| | | |
|---|---|---|
| Top | = | remaining time for normal operation, in h. |
| Ca | = | available capacity of the main battery system (main and redundant systems) , in kWh . |
| Pavr | = | average power consumption of all electrical loads defined for relevant period , in kW. |

- Remaining time after single failure (Tsf)

$$Tsf = \frac{Car}{Pavr + Paux - Pem}$$

Where

| | | |
|---|---|---|
| Tsf | = | remaining time for operation after a single failure, in h. |
| Car | = | remaining capacity of the redundant battery system if available, in kWh. |
| Pem | = | available power generated from additional available power sources, in kW. |
| Pavr | = | average propulsion power consumption for relevant period, in kW. |
| Paux | = | average auxiliary power consumption for relevant period, in kW. |

(e) For SOLAS compliant all-electric ships, when the main battery system is out of service, the remaining available capacity (Car) is to be sufficient to carry all the loads for ship services during Tsf. Tsf time is to be adequate to return to port or start up additional power sources as indicated in the load profiles. The ship services include essential services, normal services and for minimum comfortable conditions of habitability and the propulsion loads to provide for a speed of not less than 7 knots or one half of the design speed, whichever is the lesser.

### 4.2.3 Power management system

In addition to the requirements of 2.3 for a BMS, a PMS is to be provided per 13.3 of Part VII of the Rules.

### 4.2.4 Protective systems

(a) Circuit protection. System protection requirements of 2.2 of Part VII of the Rules.

(b) Load shedding arrangements are to be in accordance with 11.2.2 of Part VII of the Rules.

### 4.2.5 Monitoring

(a) Battery Systems. SOC and SOH are to be monitored and available for the operator and visible at the manned control station. The results of the SOH of the battery system are to be monitored and documented continuously by the operator and checked during the annual Survey. A verification procedure provided by the manufacturer for the SOH is to be included in the maintenance manual for the battery system.

Note:

The calculation of available capacity is to take into account the possible inaccuracy of the SOC and SOH given by the battery system. If there is a larger deviation than +/- 5% during the verification of SOH, a correction factor Kc is to be determined for the calculation of the available capacity Ca = Cd/Kc.

Where

Ca = available capacity of the battery system, in kWh.

Kc = Correction factor. The determination of Kc can be performed by coulomb counting during a complete charge or discharge, or other method as documented in the maintenance manual.

Cd = Design capacity provided by the manufacturer, in kWh.

(b) PMS. The parameters below are to be monitored remotely at the navigation bridge.

- Available batteries' energy.
- Available batteries' power.
- Remaining range/time that batteries can supply energy for the planned operation/voyage and during a single failure event, see 4.2.2.

(c) In case of over-temperature in the battery system, an audible and visible alarm is to be provided for manual load reduction at the navigation bridge. Alternatively, an automatic load reduction is to be arranged.

### 4.2.6 Fire protection

For battery spaces housing batteries in accordance with this Chapter, the Battery Space is considered machinery space Category A (as defined in SOLAS Regulation II-2) and is subject to the structural fire protection requirements listed therein.

The fire rated insulation arrangements for the boundaries of the battery space and the adjacent machinery space(s) should contain the fire(s) within the space of origin. The protection provided by A-60 fire rated insulation should be appropriate for the cumulative fire loads within the battery space and the adjacent spaces or tank. The fire loads associated with the battery room (Cat. A machinery space) or the adjacent space(s) should not exceed the endurance of the A-60 fire rated divisions.

See 3.2.2 for battery space requirements for fire safety.

### 4.2.7 Trials

In addition to the requirements of 3.4, complete tests of the system are to be carried out during sea-trials in accordance with 13.11 of Part VII of the Rules.

# Chapter 5 Battery System Surveys

## 5.1 General

The provisions in this Chapter are requirements for obtaining and maintenance of classification of **CLB** notation. These requirements are in addition to the provisions noted in other CR Rules and/or Guidelines, as applicable, to the asset.

For the purposes of this Chapter, the commissioning date will be the date on which a Surveyor issues an interim class certificate to the asset with the **CLB** notation.

## 5.2 Surveys During Construction

5.2.1 This Chapter pertains to surveys carried out on lithium-ion battery system(s) with **CLB** notation during construction, installation, and testing of the asset at the builder's yard/facility, including required onboard testing and trials. The documentation requirements for design review are given in Chapter 1, 2, 3, and 4.

5.2.2 All surveys and testing listed in Table 3-1 are to be carried out to the satisfaction of the attending Surveyor. The lithium-ion battery system(s) are to be installed and tested in accordance with the Guidelines.
The following items are to be verified by the attending Surveyor:

(a) Location and arrangements. Battery system(s) are to be installed in accordance with the location and arrangement plan.

(b) Testing. Battery system(s) testing are to follow the approved sea trial/commissioning procedures and are to include at least the following items:
   (i) Visual inspection
   (ii) Operational tests
   (iii) Tests of all the alarms and safety functions
   (iv) Emergency disconnect operation
   (v) Fire protection systems
   (vi) Fire and gas detection systems
   (vii) Simulation of communication failure with power management system
   (viii) Correct operation of ventilation, cooling, gas detection system, fire detection system, fire extinguishing system, etc., where provided

(c) Ventilation and environmental control. Battery system(s) spaces are to follow the approved ventilation arrangement and environmental control arrangement plan, as applicable.

(d) Maintenance and replacement. A maintenance schedule and procedures of batteries replacement are to be provided and maintained onboard.

(e) Installation of the battery system. The installation of the battery system and associated cabinets are effectively secured to the surrounding structure to the satisfaction of the attending Surveyor.

## 5.3 Testing Onboard and Commissioning

The commissioning, testing and trials are to be carried out as per approved plans as described in 1.5.19 listed below:

- Commissioning test plan

- Inspection/ survey plan

5.3.1 General

Onboard testing is to verify that the specified functionality is achieved with all systems in operation.

(a) Onboard testing is to verify that correct functionality has been achieved with all systems in operation. These systems include and not limited to:
  - Piping system and cooling system if applicable
  - Vent system
  - Gas detection system
  - Electrical installation
  - BMS
  - Control system

(b) All systems in the Guidelines are to be examined and tested to the satisfaction of the attending Surveyor in accordance with the approved plans.

5.3.2 Onboard Testing

Each battery system is to be tested under normal operating conditions after installation onboard to demonstrate satisfactory operation. All battery system components are to be tested and include :

(a) the verification of the battery capacity is consistent with the SOH value calculated for all the battery systems. If there is a deviation larger than +/- 5%, the values in the battery system are to be adjusted. In case of large deviation and/or adjustment, test results are to be submitted for review and approval by CR.

(b) charging and discharging capacity test to verify maximum C-rates as specified for the intended operation of the ship.

5.3.3 Trials

In addition to the requirements of 3.4, complete tests of the system are to be carried out during sea-trials in accordance with 13.11 of Part VII of the Rules.

## 5.4 Surveys after Construction

5.4.1 Annual survey

In order to retain the **CLB** notation, at each Annual Survey the lithium-ion battery system(s) are to be generally examined so far as can be seen and placed in satisfactory condition.

The survey is also to include:

(a) Schedule of batteries. Details of the schedule and records for storage, maintenance, and replacement of batteries are to be verified.

(b) Verification onboard documentation:

(i) Operations and maintenance manual for battery system and BMS

(ii) Battery system maintenance manual and schedule

(iii) Detailed stage by stage fire fighting procedure

# Chapter 6 Lithium-ion Battery Systems Having an Aggregated Capacity Less than 20 kWh

## 6.1 Battery System

6.1.1 Where the lithium-ion battery system having an aggregated capacity less than 20 kWh, it is to be housed in a gas-tight steel enclosure with a gas-tight ventilation duct leading to a safe space on open deck and is to be suitable for withstanding the temperatures and pressures generated in the worst case thermal runaway condition. The battery system is to satisfy the requirements specified in 3.1 of the Guidelines, or an equivalent and acceptable National or International Standard, amended where necessary for a battery space ambient temperature of 45°C. Alternative arrangements will be subject to special consideration.

## 6.2 Safety Assessment

The arrangement of the battery spaces shall be such that the safety of passengers, crew and ship is ensured. This shall be documented by a safety assessment with the following steps:

6.2.1 Identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes)

6.2.2 Assessment of risks (evaluation of risk factors)

6.2.3 Risk control options (devising measures to control and reduce the identified risks)

6.2.4 Actions to be implemented

Note:
The safety assessment should cover all potential hazards represented by the type of battery system and cover at least:
- gas development risk (toxic, flammable, corrosive)
- fire risk
- explosion risk
- necessary detection and alarm systems (gas detection, fire detection etc.) and ventilation
- external risks (fire, water ingress, etc.)
- loss of propulsion or auxiliary power for essential or important services

# Appendix 1 Battery Systems for Non-SOLAS Ships

## A1.1 General

This Appendix covers battery systems used on board non-SOLAS ships operating in controlled and domestic waters. This Appendix modifies the requirements contained elsewhere in the Guidelines.

## A1.2 System Requirements

Battery systems used as the main source of electrical power on board non-SOLAS ships are to meet flag state and/or coastal state requirements , as applicable.

The plans and data to be submitted are to be in accordance with 1.5, as applicable. However, certain relaxation from those requirements can be considered as described below for these ships.

### A1.2.1 Redundancy

Redundancy requirements in 4.2 need not to be met for the battery systems used as main power source if the risk assessment indicates sufficient mitigations are in place.

The redundancy and overall safety considerations are to be addressed during the risk assessment process depending upon the ship's size and service. Refer to 3.3.

Note:
Mitigations may include ships in the operational area assigned to provide assistance and/or available shoreside firefighting resources.

### A1.2.2 Fire protection

In general, freshwater is to be used for cooling purposes in case of thermal runaway event. The quantity of freshwater available on board may be limited and less than required as determined per 3.2.2(a). where additional marine or shoreside firefighting resources are available for support. The ship response procedure is to include emergency plans and procedures for transferring responsibility of firefighting to first responders.

Where the storage of freshwater is not practical due to limited space onboard, an alternative system combining a gas-based or condensate aerosol with an integrated foam-based extinguishing system may be accepted subject to design review, survey during construction, test and approval by CR as applicable. In addition, a non-automatic seawater-based firefighting system is to be provided and to be used as last resort.

### A1.2.3 Battery system used as emergency source of electrical power

(a) Alternate arrangement for non-SOLAS ships and mobile offshore units

Where the main source of electrical power is located in two or more spaces which have their own systems, including power distribution and control systems, completely independent of the systems in other spaces and such that a fire, flooding or other casualty in any other of the spaces will not affect the power distribution from the others, or to the essential services, the requirements for self-contained emergency source of power may be considered satisfied without an additional emergency source of electrical power, subject to acceptance of the same by the ship flag state, provided that:

(i) There are at least two battery systems meeting the environmental requirements of 2.1.1

(ii) Each battery system is of sufficient capacity to meet the requirements of 2.2.16

(iii) The battery systems are located in at least two separate spaces; and

(iv) The arrangements required by 2.2.16 in each such space are equivalent with 3.2, 11.3 (for passenger ships) or 11.4 (for cargo ships) of Part VII of the Rules, so that a source of electrical power is available at all times for the services required by 2.2.16.