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CR CLASSIFICATION SOCIETY

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

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

CONTENTS

Chapter 1 General Requirements

1.1 Introduction

1.1.1 CR recognizes that the increasing use of batteries in the marine and offshore industries and their benefits. Lithium-ion batteries, as the dominant rechargeable battery, exhibit favorable characteristics such as high energy density, lightweight, faster charging, low self-discharging rate, and low memory effect. Lithium cells and batteries offer many advantages compared to other power sources.

1.1.2 The development of lithium-ion batteries for large energy applications is still relatively new, especially in the marine and offshore industry. However, they are high-energy devices and shall be considered hazardous at all times.

1.1.3 The Guidelines for Use of Lithium-ion Batteries in the Marine and Offshore Industries (hereinafter referred to as the Guidelines) has been developed to provide requirements and reference standards to facilitate efficient installation and operation of lithium-ion battery systems, as well as to minimize hazards associated with their use.

1.1.4 The purpose of the Guidelines is to establish safety guidelines for owners, operators, shipyards, designers, and manufacturers.

1.1.5 Battery technology is continuously evolving with respect to battery chemistries and designs. Alternative arrangements or battery technologies 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 for the Construction and Classification of Steel Ships (hereinafter referred to the Rules for Steel Ships).

1.2 Application

1.2.1 The Guidelines applies to the product inspection of marine lithium-ion batteries and their battery management systems (BMS), as well as the system design, construction, and inspection.

1.2.2 Lithium-ion battery system can be used for marine power storage batteries, starting batteries and general purpose batteries.

1.2.3 Marine and offshore assets equipped with a lithium-ion battery system having an aggregated capacity greater than 20 kWh have to comply with this guideline. The notation **CLB** (CERTIFICATION LITHIUM-ION BATTERY) may be granted if the requirements of the Guidelines are complied.

1.2.4 Marine and offshore assets equipped with a lithium-ion battery system having an aggregated capacity of 20 kWh or less shall only comply with Chapter 7 of the Guidelines.

1.2.5 Notwithstanding the requirement of 1.2.3 and 1.2.4 of the Guidelines, when the lithium-ion batteries, regardless of their aggregated capacity, are being used as the main source of power, the notation **CLB** will be mandatory. In this case, the additional requirements set forth in Chapter 4 of the Guidelines are to be met.

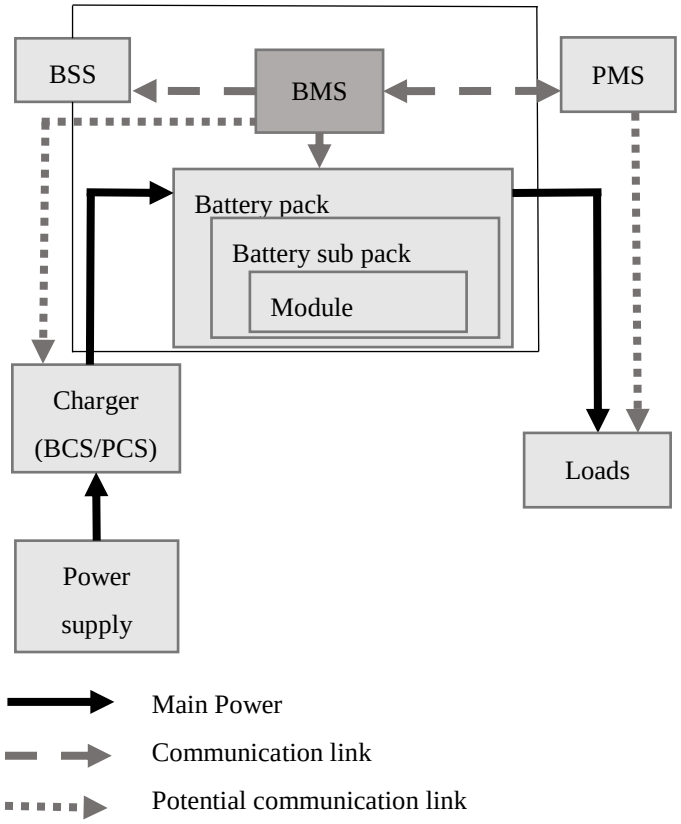
1.2.6 The basic safety principles such as having sufficient power generation (storage) capacity, having adequate standby and emergency power sources, arrangements to have continuity of supply in the event of a fault, general

electrical safety (such as proper cable sizing, appropriate insulation, appropriate equipment enclosure ratings, etc.) contained in the Rules for Steel Ships are to be followed in general.

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.

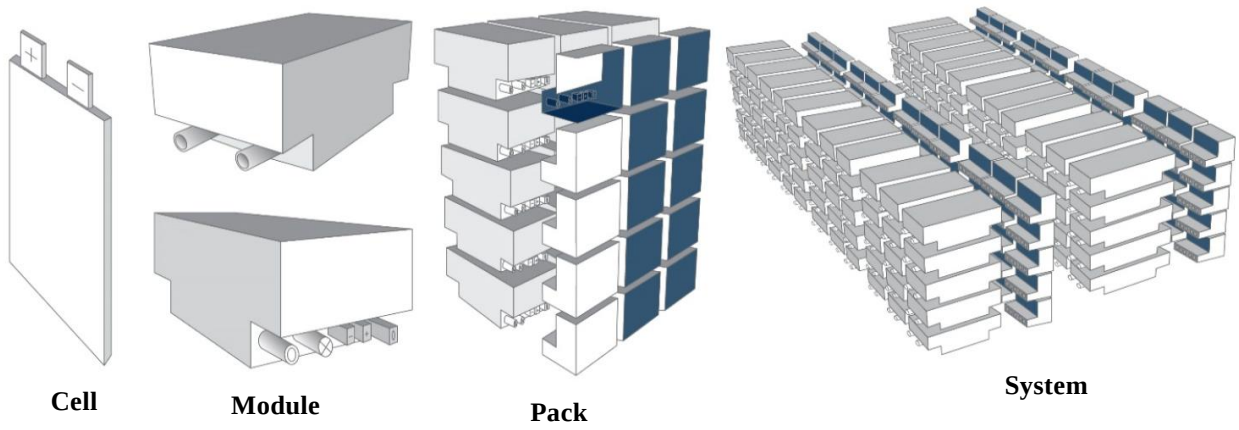


Fig. 1-2
Battery Storage System

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 is a source of 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 not ready for use in an application since it is not yet 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 mechanism of forcing all battery cells within a battery module to have identical voltages. Cell balancing is achieved by means of a "balancing circuit" (usually implemented as part of the battery management system). In the absence of a balancing circuit, one or more cells (as a result of ageing differently over its lifetime) may become under-charged or overcharged, either of which can lead to a failure of the battery module. Cell balancing is not an instantaneous process and requires some time for its completion.

Battery management system (BMS)
An electronic device controls or manages the electrical or thermal performance, such as overcharge, overcurrent, over-discharge, and overheating of a battery system, and provides communication between the battery system and upper level control systems, such as a power management system (PMS).

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 1: Such systems are, for example, electrolyte circulation pumps, cooling and heating devices or fire extinguishers.

Power Management System (PMS)
Power Management System is a complete switchboard and generator control system which 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 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, high ambient operating temperatures, etc., and can lead to a catastrophic or destructive failure of the battery cell.

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, battery management system (BMS) principal block diagram

1.5.3 Battery Management System (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 battery management system (BMS)

1.5.18 Battery System Maintenance Schedule

Chapter 2 Battery System Design

2.1 The Design of Battery System

2.1.1 General

(a) The exposed battery casing (for cells and modules) is to be constructed of durable, flame-retardant, moisture resistant materials, which are not subject to deterioration in the marine environment and at the temperature to which it is likely to be exposed.

(b) 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 spilling of electrolyte.

(c) The battery module enclosures are to have a degree of protection not lower than IP44.

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

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

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

(g) The battery system is to have means by which it can be electrically isolated for maintenance purposes. This isolation mechanism is to be independent of the emergency shutdown arrangement.

(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) The battery system is designed for no propagation between cells within a module, or as a minimum, the battery system is designed for no propagation between modules - with or without an extinguishing agent.

2.1.2 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.

(b) 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.

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

(d) 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.

(e) Any abnormal condition in the battery system shall initiate an alarm in the ship's main alarm system with individual or group-wise indication. For ships without a centralized main alarm system, battery alarms shall be presented at the bridge.

(f) Abnormal conditions that can develop into safety hazards shall be alarmed before reaching the hazardous level.

2.2 Battery Management System (BMS)

2.2.1 The BMS is to, at a minimum, monitor the battery cell voltage, cell temperature, and battery string current.

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

2.2.3 The following conditions are 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) Failure/shutdown of the battery system or failure of any of the individual modules

2.2.4 Appropriate computer-based system for BMS shall be complied with 2.7 of Part VIII of the Rules for Steel Ships.

2.2.5 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.

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

2.3 Battery Chargers

2.3.1 Battery chargers used for essential, emergency, and transitional sources of power are to meet the requirements specified in Chapter 6 of Part VII of the Rules for Steel Ships and IEC 62040 Series, as applicable.

2.3.2 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.

2.3.3 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.

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

Chapter 3 Battery System Installation

3.1 Battery Space

3.1.1 General

(a) Battery spaces are not to be located forward of the collision bulkhead of the ship. Special cases may be considered for powering loads located forward of collision bulkhead.

(b) Batteries are not to be placed in sleeping quarters

(c) Battery spaces are not to contain any heat sources or high fire risk objects external to that of the battery system.

(d) Battery compartments are to be ventilated by an independent ventilating system.

(e) Battery spaces are to be mechanically ventilated and discharges from the exhaust fans are to be led to a place on the open deck where such discharges will not cause a fire or explosion hazard or toxic hazard to nearby personnel.

(f) The ventilation of the battery space is to have sufficient capacity to minimize the possibility of accumulation of flammable vapors, especially during an abnormal condition. The ventilation ducting for the battery space is to be separate from the Heating, Ventilation and Air Conditioning (HVAC) systems used to ventilate other spaces on the ship.

(g) The battery space shall not contain other systems supporting essential ship services, including pipes and cables serving such systems, to prevent loss of propulsion or steering upon possible incidents (e.g. thermal runaway) in the battery system.

(h) Every battery is to be so arranged that each cell is readily accessible for replacing, inspection, testing, replenishing and cleaning.

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

(j) The battery space is to be fitted with flammable gas detection, appropriate to the battery chemistry being used. 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% Lower Explosion Limit (LEL).

3.1.2 Fire Safety

(a) The battery space is to be considered an Auxiliary Machinery Space or a Machinery Space other than category A as defined in SOLAS Regulation II-2 and is subject to the structural fire protection requirements listed therein.

(b) The battery space is to be fitted with a suitable Fixed Fire Extinguishing System (FFES) recommended by the vendor 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 Part IX, Chapter 8 of the Rules for Steel Ships, 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.).

(c) Portable fire extinguishers are to be provided as required in 8.2 of Part IX of the Rules for Steel Ships.

(d) The battery room or space is to be provided with gas-tight door to prevent escape of combustible gasses, a deck drain, and not to be located adjacent to spaces with combustible/flammable materials and berthing compartments.

(e) Where battery space is located adjacent to and 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.

(ii) The ventilation duct(s) are to be of fully welded construction and duct materials are to be compatible with the gases produced in a thermal runaway condition. Where ventilation duct(s) from the battery space is passing through high fire risk areas, A-60 insulation is to be provided for the duct(s).

(iii) Ventilation is to be such that with the battery room door open, air flow is from the machinery space into the battery room with overpressure. Loss of ventilation overpressure is to be alarmed at a normally manned location.

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

(v) Means to disconnect the battery system in the event of a fire in the machinery space of category A or within the lithium-ion battery space are required to be provided and located outside of the protected space.

(vi) The risk assessment document discussed in section 3.2 shall address the following:

- Chemical composition of the lithium-ion batteries.
- Indicate if flammable gas is or is not released during normal operations, including charging mode. If flammable gas release is possible in normal operations, then the ventilation system is to be interlocked with the battery chargers to prevent battery charging when the ventilation is not operating.
- Means of escape from the battery space.

3.1.3 Hazardous Area Requirements

Depending on the battery design and chemistry, flammable gases may be released during operation. For batteries of this type, the battery space is to be classified as a hazardous area per IEC 60079-10-1 and the following additional requirements are to be met.

(a) The Operations and Maintenance Manual is to list hazardous gases released.

(b) The equipment selection is to comply with applicable requirements of 1.10 of Part VII of the Rules for Steel Ships.

(c) The hazardous area plan and related electrical equipment list for the battery space is to be part of the overall hazardous area plan for the asset.

(d) The battery space is to have an independent deck drain or no deck drain at all.

(e) Areas on the open deck within 3 meters of the battery space intake(s) and exhaust ventilation outlet(s) are to be considered as hazardous areas.

3.2 Battery System Risk Assessment

The primary objective of the risk assessment 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 and the continuity of power supply in case of failure of the battery.

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:

3.2.1 Appropriate measures taken in the design of the battery space to prevent the possibility of thermal runaway of the battery modules.

3.2.2 Appropriate measures taken into account for external hazards (i.e., possible fire, gas development, and flood, etc.).

3.2.3 Loss of communication with the Power Management System (PMS) of equipment, as applicable: Appropriate measure taken to isolate the battery pack in the event of a loss of communication with the PMS.

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

3.2.5 Temperature and voltage measurement sensor failure.

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

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

3.3 Battery System Operation and Maintenance

3.3.1 Installation and Commissioning

The Battery System installation and sea-trial/commissioning procedures submitted for review is to address the following:

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

(b) Testing of the following safety functions and associated alarms: cell balancing detection/protection, overvoltage detection/protection, undervoltage detection/protection, emergency shutdown arrangement, ground fault detection, loss of communication detection/protection.

(c) Testing of the expected performance functions of the battery system on the particular asset.

(d) Testing of protective functions in the battery space, as applicable to asset specific installation.

3.3.2 Operation and Maintenance

The Battery System Operations and Maintenance manual submitted for review is to address normal and emergency operating procedures and maintenance procedures for the use of the battery system. The emergency procedures are to include those that should be taken in events such as fires, overheated batteries, etc.

A Battery System maintenance schedule is to be provided for review and maintained on board. The schedule is to include at least the following information regarding the batteries, which is to be submitted for review, during their plan approval or the new building survey.

- Type and manufacturer's type designation.
- Voltage and ampere-hour rating.
- Location.
- Equipment and/or system(s) served.
- Maintenance/replacement cycle dates.
- Date(s) of last maintenance and/or replacement.
- For replacement batteries in storage, the date of manufacture and shelf life

Maintenance procedures are to be put in place to show that, where batteries are replaced, they are to be of an equivalent performance type. Details of the schedule, procedures, and the maintenance records are to be included in the ship's safety management system and integrated into the ship's operational maintenance routine, as appropriate, which are to be verified by the Surveyor.

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 of the Guidelines covering design, construction, and installation.

4.2 System Requirements

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

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

(a) At a minimum, two independent battery systems are to be provided and located in separate spaces.

(b) The propulsion system is to be designed as that all electrical equipment of propulsion drive train part to be of redundancy and fulfill the requirement in chapter 13 of Part VII of the Rules for Steel Ships, as appropriate.

(c) In addition to the capacity submittal specified in 1.1.5 of the Guidelines, design capacity based on the asset's intended operations is to be submitted.

(d) In addition to the requirements of 2.2 of the Guidelines, a Power Management System (PMS) is to be provided.

(e) Circuit Protection: System protection requirements of 2.2 of Part VII of the Rules for Steel Ships.

(f) Load Shedding Arrangements are to be in accordance with 11.2.2 of Part VII of the Rules for Steel Ships.

(g) Monitoring function should be provided as follows:
  (i) Battery Systems: SOC and SOH are to be monitored and available for the operator.
  (ii) PMS: The parameters below are to be monitored remotely at the navigation bridge.
    (1) Available batteries' energy
    (2) Available batteries' power
    (3) Remaining range/time that batteries can supply energy for the planned operation/voyage

(h) Fire Protection: For battery spaces housing batteries in accordance with this Section, 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.

(i) Sea-Trials: In addition to the requirements of 3.3.1 of the Guidelines, complete tests of the entire electric propulsion system are to be carried out during sea-trials including the following:
  — Duration runs with the ship at full propulsion load.

- Maneuvering tests which should include a reversal of the ship from full speed ahead to full speed astern during which important measurements such as system currents, voltages, speed, etc. shall be recorded.
- Tests to check for operation of all protective devices, safety functions, alarms, indicators, control modes and stability tests for control.

4.2.3 All tests necessary to demonstrate that major components of the electric propulsion plant and the system as a whole are satisfactory for duty are to be performed. Immediately prior to trials, the insulation resistance is to be measured and recorded.

Chapter 5 Battery System Testing Requirement

5.1 General

The Battery System is to undergo Type Test and Routine Tests carried out to the satisfaction of attending Surveyors as per the following items. 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 given. Alternatively, 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 Guidelines is met.

5.2 Type Test

5.2.1 External short-circuit test, refer to IEC 62619 7.2.1

5.2.2 Impact test, refer to IEC 62619 7.2.2

5.2.3 Drop test, refer to IEC 62619 7.2.3

5.2.4 Thermal abuse test, refer to IEC 62619 7.2.4

5.2.5 Overcharge test, refer to IEC 62619 7.2.5

5.2.6 Forced discharge test, refer to IEC 62619 7.2.6

5.2.7 Internal short-circuit test/Propagation test, refer to IEC 62619 7.3.2/7.3.3.

5.2.8 Overcharge control of voltage, refer to IEC 62619 8.2.2

5.2.9 Overcharge control of current, refer to IEC 62619 8.2.3

5.2.10 Overheating control, refer to IEC 62619 8.2.4

5.2.11 Capacity validation, refer to IEC 62620 6.3.1

5.2.12 Type tests for control, monitoring and safety equipment, refer to Table VIII 2-1 of Part VIII of the Rules for Steel Ships.

5.3 Routine Test

5.3.1 Battery system/BMS safety function tests, refer to 2.2 of the Guidelines.

5.3.2 Performance tests, refer to Table VIII 4-1of Part VIII of the Rules for Steel Ships.

Chapter 6 Battery System Surveys

6.1 Surveys During Construction

6.1.1 This secion 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, 3, and (or) 4 of the Guidelines.

6.1.2 All surveys and testing listed in Chapter 5 of the Guidelines 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 shutdown 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.

6.2 Surveys after Construction

6.2.1 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 Maintenances Manual and Schedule
  (iii) Detailed stage by stage Fire Fighting Procedure

Chapter 7 Lithium-ion Battery Systems Having an Aggregated Capacity of 20 kWh or Less

7.1 Battery System

7.1.1 Where the lithium-ion battery system having an aggregated capacity of 20 kWh or less then it is to be housed in a gastight steel enclosure with a gastight 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 5.2 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.

7.2 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:

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

7.2.2 Assessment of risks (evaluation of risk factors)

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

7.2.4 Actions to be implemented.

Notes:
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.