Guidelines on

Battery Powered Vessels

2019

IRCLASS
Indian Register of Shipping

Guidelines on Battery Powered Vessels

2019

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Section 1

Introduction

1.1 Scope and Applicability

1.1.1 These guidelines are applicable to battery installations on board vessels, where batteries are used for powering main propulsion systems. These guidelines are to be used in conjunction with applicable IRS rules. Depending on the type of vessel, the applicable IRS Rules would be as follows:

(a) Rules and Regulations for the Construction and Classification of Steel Ships
(b) Rules and Regulations for the Construction and Classification of High Speed Crafts and Light Crafts
(c) Rules and Regulations for the Construction and Classification of Inland Waterways Vessels
(d) Rules and Regulations for the Construction and Classification of Pleasure Crafts and Yachts

1.1.2 Battery systems can be used as a main or an additional source of power for propulsion.

1.1.3 Additional class notation **BATTERY PROP** would be assigned to vessels where the battery systems are used for ship propulsion and are in accordance with the requirements specified in these guidelines.

The requirements indicated in these guidelines are also applicable to configurations where batteries are used as additional source of power for propulsion as in a hybrid vessel.

1.1.4 When an emergency source of power is required on a vessel, the same is to remain independent from the battery source provided for propulsion and/ or main source of power. The arrangement and capacity of such battery is to be in accordance with applicable IRS rules.

1.1.5 It may be noted that as the battery technology is evolving continuously, additional safety requirements (other than those reflected in these guidelines, if any) will be assessed by IRS on case to case basis based on the technology used and risk assessment report.

1.1.6 Requirements of statutory authorities are also to be complied with, in addition to these guidelines.

1.2 Definitions

1.2.1 Following definitions and abbreviations are additional to those given in the applicable IRS Rules:

a) *Battery Management System (BMS)*: an electronic system that controls, manages, detects or calculates electric and thermal functions of the battery system and provides communication between the battery and upper level control systems. It monitors the state of the battery by protecting the battery from operating outside its safe operating area.

b) *Power Management System (PMS)*: a system providing monitoring and control of the ON BOARD Power sources

c) *Cell*: an individual electrochemical unit of a battery consisting of electrodes, separators, electrolyte, container and terminals.

d) *Battery*: assembly of cells ready for use as storage of electrical energy characterized by its voltage, size terminal arrangement, capacity and rate capability.

e) *Battery space*: compartments (rooms, lockers or boxes) used primarily for accommodation of battery system: the whole battery installation including battery banks, electrical interconnections, BMS and other safety features.

f) *State of Charge (SOC)*: state of charge is the available capacity in a battery expressed as a percentage of the rated capacity.

g) *State of Health (SOH)*: general condition of a battery, including its ability to deliver the specified performance compared with a new battery.

h) *Venting*: release of excessive internal pressure from a cell/battery in a manner intended by design to preclude rupture or explosion.

i) *Explosion*: failure that occurs when a cell container or battery case opens violently and major components are forcibly expelled.

j) *Fire*: the emission of flames from a cell or battery.

k) *Upper limit of the charging voltage*: the highest charging voltage in the cell operating region as specified by the cell Manufacturer.

l) *Thermal Runaway*: Uncontrolled intensive increase in the temperature of a cell driven by exothermic reaction. The cell enters a self-heating state where the heat generated is greater than the heat dissipated. Thermal runway can begin at temperatures as low as 120ºC depending on the cell size, design and chemistry. From initiation, a cell's temperature can rise to a maximum in under 2 minutes.

m) *Rated Capacity:* Capacity value of a cell or battery determined under specified conditions and declared by the manufacturer.

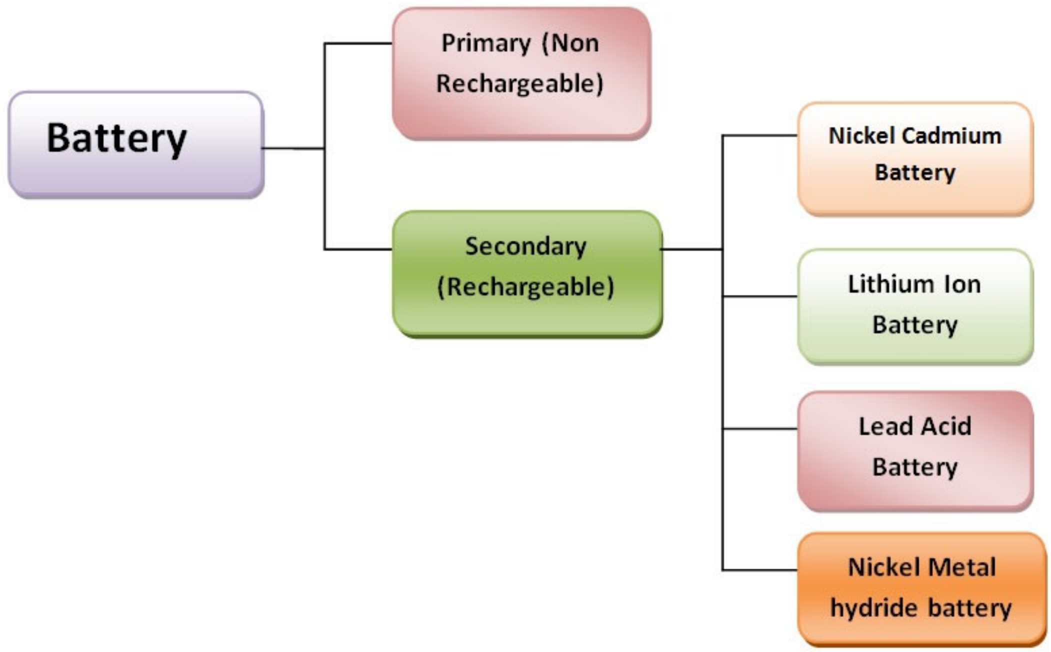
1.3 Reference Standards for Batteries

IEC 62619
IEC 62620
IACS UR E10

For other equipment / systems As per applicable IRS rules

1.4 Battery Types

1.4.1 Batteries can be broadly classified as primary and secondary batteries. Primary batteries are those that are non-rechargeable. The secondary batteries i.e. batteries which can be recharged have further variants based on the battery chemistry. The type of electrolyte used, aqueous (acid, alkaline) or non-aqueous play a major role in battery energy density and safety. These guidelines focus on secondary batteries i.e. the batteries which can be recharged.



1.4.2 Lead acid, Ni-Cd batteries are extensively used for various ship board applications. Over the years, Lithium ion batteries have started replacing other type of batteries in maritime installations due to their high energy density. Lithium-ion is named for its active materials; the words are either written in full or shortened by their chemical symbols. Battery chemistries are generally identified in abbreviated letters.

For example, lithium cobalt oxide, one of the most common Li-ions, has the chemical symbols $LiCoO_2$ and the abbreviation LCO. For reasons of simplicity, the short form Li-cobalt can also be used for this battery. Cobalt is the main active material that gives this battery character. Other Li-ion chemistries are

a) Lithium Cobalt Oxide($LiCoO_2$) - LCO
b) Lithium Manganese Oxide ($LiMn_2O_4$) -LMO
c) Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$ or NMC) NMC
d) Lithium Iron Phosphate($LiFePO_4$) LFP
e) Lithium Nickel Cobalt Aluminium Oxide ($LiNiCoAlO_2$) NCA
f) Lithium Titanite ($Li_4Ti_5O_{12}$) LTO

1.5 Documentation to be Submitted

1.5.1 In addition to the plans/ documents required by the applicable IRS Rules, the following documentation are to be submitted for review/ approval:

For Review

.1 Battery power philosophy document for the proposed battery system including voyage duration when used as only source of power, charging methodology, shore charging facilities, details of number of voyages planned in a day, time available at port including percentage of charging during the stay in port.

.2 Electrical load chart indicating various operational modes, capacity of each battery system. Power consumption at operational speed and minimum operational speed (in the event it is proposed to operate the vessel at reduced speed on failure of one battery system).

.3 Details of batteries such as battery chemistry, test certificates, cell voltage, system voltage, number of battery banks, manufacturer recommended charge and discharge rates and environmental requirements specified by battery manufacturer.

.4 Risk assessment document which cover all potential hazards represented by the type (chemistry) of batteries, the evaluation of the risk factors and measures to control and reduce the identified risks.

For Approval

.5 Block diagram and electrical wiring diagram of the battery system and system interfaces to the battery system, including control, monitoring and alarm system, emergency shutdown, etc.

.6 Functional description and control diagrams of battery management system (BMS) and power management system (PMS).

.7 Test programs which are to include functional tests (alarm system, safety system, control system,) and further tests, if any, resulting from the risk assessment for the specific battery chemistry.

.8 Plans for following systems designed to mitigate the effects of leakage of gas, fire / explosion as identified in detailed risk assessment are to be submitted. Where applicable, the plans are to clearly include engineering calculations, to confirm their suitability, in addressing the risks identified in the risk assessment document.

a) structural fire protection plan,
b) fire and gas detection system,
c) fire extinguishing system,
d) details of ventilation system including ducting arrangement plan,
e) hazardous area plan showing location of battery compartment, and
f) plan showing electrical equipment installed in hazardous area including list of equipment and their Ex. Protection details.

1.6 Equipment / System Certification

1.6.1 The following equipment/ systems are to be certified by IRS. Relevant manufacturer plans/ documents are to be submitted for approval. Software when used for control, safety, alarm and monitoring will be required to be assessed by IRS in accordance with IRS *Guidelines on Software Verification of Computer Based Systems.*

.1 Batteries – Batteries are to be type tested as per relevant IEC standard. Where the type tests are carried out in an accredited laboratory the tests results are to be submitted for review; else the tests are to be witnessed by IRS surveyor

.2 Battery Management System - Unit certification

.3 Power Management System - Type approval.

Section 2

System Design

2.1 Capacity

2.1.1 The capacity of the battery is to be sufficient for the intended operation of the vessel.

2.1.2 Where batteries are the main source of power required for ship propulsion, two battery systems are to be provided. With one battery system not operational, the capacity of remaining battery system is to be sufficient to ensure safe journey to the nearest port. The calculations are to include charging philosophy (whether on board/ shore).

Note: When charging is from a shore arrangement, the following details are to be included in the calculations:

(a)Number of stops in a day;
(b)duration of stay at port;
(c) maximum distance between stops;
(d) approximate charging rate.

2.1.3 Where the risk assessment of a particular battery installation based on battery chemistry requires the battery systems to be physically separated, the systems are to be located in different battery spaces/ rooms on the vessel.

2.1.4 IRS may consider novel designs based on risk assessment and vessel’s operational profile.

2.2 Installation Requirements

2.2.1 Battery units are to be installed in a separate room/space reserved for the purpose.

2.2.2 Access to the battery space is to be through normally closed doors with alarms or self-closing doors.

2.2.3 Battery spaces are to be positioned aft of the collision bulkhead. Battery space boundaries are to be part of the vessel’s structure or enclosures with equivalent structural integrity. The battery space is not to be adjacent to spaces with combustible/ flammable materials.

2.2.4 Batteries used for driving propulsion systems are to be installed such that a fire or collision will not result in total loss of propulsion power. The cables for redundant systems are to be separated as widely as practicable.

2.2.5 The battery compartment is to be regarded as a machinery space of category A, as defined in SOLAS Regulation II-2. The structural fire protection requirements may be provided in accordance with the applicable Rules.

2.2.6 The battery space is not to contain other systems supporting essential services, and also heat sources of high fire risk equipment. Different types of batteries i.e. cells of different characteristics are not to be installed in same space/ compartment.

2.2.7 The battery terminals are to be clearly marked with polarity indication and are to be rated for the maximum current. Manufacturer's specific recommendations on cable termination are to be followed. The battery terminals are to be suitably protected to prevent risk of short circuit.

2.2.8 The minimum degree of ingress protection of battery units is to suit the area of installation. Minimum IP44 degree of ingress protection is recommended.

2.3 Control, Monitoring and Alarms

2.3.1 Each battery system is to be protected against overload and short-circuit.

2.3.2 An emergency shutdown system is to be provided to disconnect battery system in an emergency situation. An alarm is to be provided at manned station upon activation of emergency shut down system. The activation of emergency shut down system is to be possible from outside battery space and also from manned control location. IRS may consider activation of emergency shut down system from only one location outside battery space in case of small vessels.

2.3.3 The vessel is to be provided with a Battery Management System (BMS). The BMS is required to maintain the condition of the cells and battery and protect them from unsafe situations such as internal battery defects, excessive external demands (e.g. a high current demand) and overcharging. The key features would include state of charge monitoring, voltage and current protection, thermal management etc. It is to be ensured that the BMS is compatible with the requirements of the battery system, other battery components and the vessel's electrical equipment.

2.3.4 The battery management system may actively manage battery operations with respect to the temperature of the battery to improve efficiencies and to further reduce the risk of high temperature incidents. Due to the importance of temperature on lithium-ion batteries, continuous temperature monitoring may also be linked to responses external to the battery (e.g. isolation of the battery, early warning alarms and fixed fire suppression systems). Further, Lithium-ion cells, unlike other conventional battery technologies, should not be charged in excess of 100% state of charge as this may cause rapid failure of the electrodes and possible thermal runaway. Discharging below the minimum safe voltage can also cause cell damage.

2.3.5 The battery management system should limit currents to ensure the battery remains in a safe condition. Permitted currents may be controlled relative to the state of charge and should take account of the battery's state of health through-life.

2.3.6 The battery management system should be capable of monitoring cell voltages and currents to a high resolution in order to ensure that the voltage of each cell remains within the range specified by the manufacturer.

2.3.7 The system is to be provided with power supply failure alarm. The following parameters are to be monitored by Battery Management System:

a) Battery charging/discharging;
b) Battery temperature (at cell level);
c) Cell balance;
d) Cell voltage
e) Available power;
f) Battery system shut down; and
g) Battery system breaker trip

2.3.8 The following parameters are to be continuously monitored at manned control station:

a) Cell temperature and voltage;
b) Battery current;
c) Battery space temperature
d) Battery charge and discharge
e) Available charge
f) Available energy
g) Failure of ventilation

2.3.9 Audible and visual alarms are to be provided for the following at manned location (preferably bridge):

a) Operation of the battery protective device,
b) Cell temperature High
c) Battery space high temperature
d) Ventilation fan running status (on/off)
e) Cell voltage - over voltage
f) Opening of cell safety venting device or high pressure in the battery
g) State of charge – minimum alarm at manned local station and at bridge
h) Gas detection

2.3.10 Sensors used for battery space temperature alarm and indication are to be independent of sensors used for temperature monitoring of batteries.

2.4 Safety System

2.4.1 Battery manufacturer recommended practices for safety are to be documented and implemented.

2.4.2 The safety system is to be activated automatically on detection of manufacturer recommended conditions (such as but not limited to overcharge, undercharge, high temperature, gas leakage, etc.) which can lead to battery damage and also has the potential to create a hazardous situation. The activation of such a system is to result in activation of audio visual alarm at manned control station and bridge.

2.4.3 The battery charging voltage and current are to be in accordance with manufacturer recommended values and audio visual alarm is to be initiated when the values are out of recommended range.

2.4.4 Voltage of each single cell and gas release are to be monitored. Interfaces to systems to maintain safety e.g. emergency ventilation systems, fire extinguishing systems, shutdown etc. are to be provided and their effectiveness is to be demonstrated during trials.

2.5 Risk Assessment

2.5.1 Risk assessment is to be carried out during the design phase addressing all potential hazards associated with the type of battery chemistry, battery system design and its incorporation on the vessel. The aim of the risk assessment is to demonstrate the vessel safety and the continuity of power supply in case of failure of the battery.

A Failure Modes and Effects Analysis (FMEA) may be used. Alternatively, other risk assessment techniques may also be used. All foreseeable hazards, their causes, consequences (local and global effects), and associated risk control measure are to be documented. The hazards considered as a minimum, are to include the following:

- Development of corrosive gas and toxic gas;
- Fire and water ingress;
- Effect of thermal event on cells within a module or between modules (thermal runway, based on accurate information provided by the battery manufacturer);
- Loss of propulsion or auxiliary power for essential services;
- Excessive heating due to loss of ventilation or heating from adjacent compartments;

- Explosion
- Short Circuit
- Electrolyte leakage/ spillage

2.5.2 The risk factors are to be evaluated from view point of operating conditions of the subject vessel to identify specific controls to mitigate the risk.

2.5.3 Risk assessment need not be carried out for installations with lead acid and Ni-Cd batteries. Installations with lead acid and Ni-Cd batteries are to comply with requirements for battery installations in the applicable IRS Rules.

2.6 Measures to Address Risks

In battery installations where development of toxic gas, explosive gas or fire is possible, following safety measures may be considered:

2.6.1 Ventilation

2.6.1.1 Battery compartments are to be adequately ventilated by an independent ventilating system to avoid accumulation of inflammable gases. The ventilation system is to be of mechanical type. Particular attention should be given to the fact that these gases are lighter than air and tend to accumulate at the top of the spaces.

Note: The battery space ventilation system is to be a ducting system independent from any other HVAC system serving other spaces, unless the risk assessment concludes that the battery space is a non-hazardous area, in which case the supply may be taken from other spaces and with exhaust directly to air.

2.6.1.2 The battery compartment is to be provided with an effective air inlet near the floor level.

2.6.1.3 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimize risk of sparking in the event of the impeller touching the casing. Non-metallic impellers are to be of an anti-static material. Depending upon the location of the battery compartments, intrinsically safe exhaust fans may be required.

2.6.1.4 During normal operation the battery compartment is provided with 2 air changes per hour and in an emergency situation resulting due to release of flammable gases minimum 6 air changes per hour are to be provided.

Note: If the battery system is designed based on the risk analysis, then the ventilation system capacity would be based on the estimation of the gases evolved due to an event (for ex: fire, thermal runway). The same is to be verified during testing.

2.6.1.5 The emergency exhaust fan is to operate automatically upon detection of gases from the batteries. The fan is to be provided with remote means of activation from manned control station. Local activation of the ventilation system is to be feasible in case of failure of remote or automatic operation.

2.6.2 Electrical Equipment

2.6.2.1 Electrical equipment installed in battery spaces are to be of certified safe type. They are to be certified for gas and temperature group as per type of gas composition for battery type used. They are to be at least of Type IIC T1.

2.6.2.2 Hazard area categorization and equipment proposed to be installed in battery compartment are to meet the requirements of IEC 60079. Where flammable gases may be evolved, zone 2 classification is to be assigned to the battery space.

2.6.2.3 The tools used for maintenance should have rubberized coating to prevent any chance of short circuiting by mistake. The coating would also prevent any spark generation, when the tool falls on the floor.

2.6.3 Fire and Gas Detection Systems

2.6.3.1 Battery spaces are to be monitored by smoke detectors. The smoke detectors are to comply with the IMO FSS Code.

2.6.3.2 A fire detection system is to be installed in the battery compartment. The fire alarm is to be located at the manned control station and the location of remote operation of emergency exhaust fans.

2.6.3.3 Where gas can be released in charging or explosion, a gas detection system is to be installed. Arrangements are to be provided for automatic exhaust of the developed gases when detected. Battery chemistry including manufacturer recommendations are to be considered, whilst selecting the system.

2.6.3.4 The gas detector is to give an alarm at 30% LEL. It should also be interlocked to ensure automatic disconnection of batteries, at 30% LEL. Any electrical circuit in the battery space is to be de-energized at 60% LEL. Based on the alarm sounded at bridge, the emergency ventilation system is to be activated in the battery space.

2.6.3.5 The gas detectors are to be of approved make and type.

2.6.4 Temperature Monitoring

2.6.4.1 Automatic monitoring of temperature in battery room/ space is to be provided.

2.6.4.2 In installations using lithium ion batteries, fitment of thermographic cameras or use of portable thermographic cameras is recommended.

2.6.5 Fire Extinguishing System

2.6.5.1 Battery spaces are to be protected by a fixed water based extinguishing system approved for use in machinery spaces of category A. The system is to be designed taking into account the ventilation arrangement in the battery space

> **Note**: 1) Water based extinguishing systems have been found to be effective in extinguishing lithium ion battery fires, even though lithium, when it comes in contact with water produces H_2S gas. Water type fire extinguishing system has the advantage of providing immediate cooling for the heated surface. Other types of fire extinguishing systems can be considered based on the battery chemistry, type of battery room cooling and heat dissipation systems arranged.
>
> 2) When lithium ion batteries are used, it may not be possible to enter the battery room/space once thermal runaway commences. Control and activation of firefighting systems therefore are to be designed for outside battery space operation. In automatically activated systems, an interlock is to be provided to prevent automatic release when the access doors are open.
>
> 3) The hazards due to heat and release of toxic gases depends on the battery chemistry and installed battery capacity. The hazards can be mitigated by effective ventilation/ cooling of battery space, detection of any developing dangerous situation due to release of gas / heat and firefighting methods.

2.6.5.2 The firefighting requirements are to be identified as part of risk mitigation measures in risk assessment document. The type and arrangement of the fire extinguishing system for the battery room should take into account the recommendations of the battery manufacturer.

2.6.5.3 In addition, two portable dry powder fire extinguishers or two CO_2 fire extinguishers of at least 5 kg capacity are to be provided near the battery room.

2.6.6 Risks during/ after fire-fighting in battery spaces

2.6.6.1 An operation and maintenance manual, as indicated in Section 4 is to be provided. The manual is also to include aspects, related to risks during/ after fire-fighting in battery spaces. Few such aspects are indicated in the guidance notes below:

Guidance Note:

- An assessment should be made that all thermal, electrical or mechanical stimuli that may act on the system have been mitigated.
- In the short term, cells may appear to 're-ignite' after a few minutes due to incomplete removal of heat from the system or an electrical short due to liquid or water.
- Cells that have not been burnt may remain intact. Shock may be caused. during water suppression
- If batteries are disturbed, arcing can be caused.
- Stored energy in partially burnt batteries may be an issue in the system. These cells may pose a shock/ arcing risk and can reignite if physically damaged, reheated or allowed to short.
- In general, battery fires resemble plastic fires in terms of emission of toxic gases including CO, HCL, HF, HCN, benzene and toluene. The average toxicity of the fire is equivalent to many plastics on a per mass basis. Li-ion generally will have short peaks of toxicity as individual cells randomly fail. However, battery fires, even once extinguished, continue to emit CO as long as the batteries remain hot.
- Continuous monitoring of CO from battery fires in enclosed spaces and the continued use of personal protective equipment (PPE) is recommended until the CO levels are shown to be at normal levels. Monitoring of HCl may also be included, as applicable or feasible.

Section 3

Surveys

3.1 General

3.1.1 The requirements in this Section are provided in addition to the provisions for surveys in the applicable IRS rules.

3.2 Installation Surveys

3.2.1 Arrangement of following equipment/ systems is to be verified:

(a) Battery installation
(b) BMS
(c) PMS
(d) Cable routing
(e) Fire detection and extinguishing systems
(f) Ventilation

3.3 Testing

3.3.1 Battery systems are to be subjected to functional and safety tests according to IEC 62620 or in accordance with other equivalent national or international standards.

3.3.2 Performance tests are to be carried out on the battery system according to an approved test program.

3.3.3 After installation, and after any major repair or alteration which may affect the safety of the arrangement, following a check of compliance with the plans, the battery system is to be subjected following tests and shown to the satisfaction of the attending Surveyor

- Visual Inspection
- System installation operational test for BMS, PMS;
- Tests of all the alarms and safety functions;
- Charging and discharging;
- Emergency shutdown operation;
- Fire and gas detection system
- Fire extinguishing system
- Ventilation system, cooling system; and
- Additional tests, as identified in risk assessment.

3.4 Periodical Surveys of Battery Systems

3.4.1 Annual Surveys

3.4.1.1 At each annual survey, the battery spaces and equipment are to be generally examined, as far as practicable and placed in satisfactory condition.

3.4.1.2 The onboard documentation regarding the operation and maintenance manual for BMS and PMS is to be verified:

3.4.1.3 The survey is also to include the following:

.1 verification of details of the schedule and records for storage, maintenance and replacement of batteries;

.2 operation of UPS and confirmation of satisfactory performance;

.3 test of all installed emergency shutdown arrangements

.4 test of all smoke, gas and fire detectors

.5 test of ventilation systems

.6 general examination of firefighting systems in battery spaces

.7 test of alarms and safety functions

Section 4

Operation and Maintenance

4.1.1 The manufacturer is to provide instruction manual clearly specifying practices and procedures for safe installation, commissioning, testing and maintenance of battery systems. The manual is to be kept on board.

4.1.2 A battery maintenance log specifying the details of maintenance carried out on batteries and their systems is to be kept on board and submitted to attending surveyor for review

4.1.3 The operation and maintenance manual is to include procedures/instructions for the following, as a minimum:

- Tests on all the equipment affecting the battery system (e.g. instrumentation, sensors, etc.),
- Routine battery maintenance and checks
- Periodical tests
- Functional tests of control, monitoring, safety and alarm system,
- State of Health (SOH) and state of charge, records verification
- Instructions for Software Maintenance.

4.1.4 Attention is also drawn to inclusion of aspects, related to risks during/ after fire-fighting in battery spaces, as indicated in 2.6.6.1.