Guide for

Use of Lithium-ion Batteries in the Marine and Offshore Industries

ABS

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GUIDE FOR

USE OF LITHIUM-ION BATTERIES IN THE MARINE AND OFFSHORE INDUSTRIES
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American Bureau of Shipping
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Foreword *(2022)*

ABS recognizes the increasing use and benefits of batteries in the marine and offshore industries. 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. The development of lithium-ion batteries for large energy applications is still relatively new, especially in the marine and offshore industries. ABS has produced this Guide to provide requirements and reference standards to facilitate effective installation and operation of lithium-ion battery systems.

The purpose of this Guide is to establish safety guidelines for owners, operators, shipyards, designers, and manufacturers. This Guide covers lithium-ion battery types currently used in the industry (for example, lithium-ion cobalt oxide, lithium-ion manganese oxide, lithium-ion nickel manganese cobalt oxide, lithium-ion nickel cobalt aluminum oxide, lithium-ion iron phosphate, and lithium-ion titanate). For requirements applicable to conventional battery types (such as lead-acid, alkaline, etc.), please refer to the requirements in Part 4 of the ABS *Rules for Building and Classing Marine Vessels*. For requirements applicable to batteries used in underwater vehicles, please refer to the requirements in 10/11 of the ABS *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities*.

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 this Guide and the ABS Rules.

The February 2020 edition clarifies and expands the requirements when the battery space is adjacent to a machinery space of category A.

The January 2022 edition includes changes to the title of the Guide to replace the "Lithium Battery" with "Lithium-ion Battery", and to update the requirements for emergency source of power, battery space, fire safety, hazardous areas, risk assessment approach and other editorial changes.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDE FOR

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SECTION 1
General

1 Introduction *(2022)*

ABS recognizes the increasing use of batteries in the marine and offshore industries and the benefits they can bring to operations. This Guide has been developed to facilitate the effective installation and operation of lithium-ion(Li-ion) batteries. This Guide is to be used in conjunction with and as a supplement to Part 4 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* and the ABS *Rules for Building and Classing Mobile Offshore Units (MOU Rules)*, as applicable. 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 ABS Rules are to be followed in general. These specific requirements are not repeated in this Guide.

3 Application *(2022)*

This Guide is applicable to marine and offshore assets designed, constructed, or retrofitted with a lithium-ion battery system used as a source of electrical power with a capacity greater than 25 kWh. An optional notation (**ESS-LiBATTERY**) may be granted to those assets once the battery installation has complied with the requirements of this Guide. Where batteries are being used as the main source of power, the additional requirements set forth in Section 4 are to be met. Where batteries are being used as the emergency source of power, the additional requirements set forth in 2/1.9 are to be met.

Certain criteria of this Guide may be applicable to marine and offshore assets designed, constructed, or retrofitted with a lithium-ion battery system used as a source of electrical power with a capacity less than 25 kWh on a case-by-case basis.

Where Type Approval of a lithium-ion battery system is requested, applicants should contact ABS for the approval process. For ABS Type Approval Program requirements, please refer to 1-1-4/7.7, Appendix 1-1-A3, and Appendix 1-1-A4 of the ABS *Rules for Conditions of Classification (Part 1)*. See 2/1.1 TABLE 1 for certification details. Alternative certification schemes are also available as documented in 1-1-A3/5.5 of the ABS *Rules for Conditions of Classification (Part 1)*.

5 Scope *(2022)*

Lithium-ion battery types covered by this Guide include lithium-ion cobalt oxide, lithium-ion manganese oxide, lithium-ion nickel manganese cobalt oxide, and lithium-ion nickel cobalt aluminum oxide, lithium-ion iron phosphate, and lithium-ion titanate.

For requirements related to conventional battery types, please refer to 4-8-3/5.9 of the *Marine Vessel Rules* or 4-3-3/3.7 of the *MOU Rules*.

For requirements related to the use of batteries in underwater vehicles, please refer to 10/11 of the ABS *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities*.

Battery technology is a field that is continuously evolving with respect to battery chemistries and designs. 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 this Guide and the ABS Rules.

7 Terminology *(2022)*

Battery Management System. 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 its 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 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*]

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. A typical battery space (compartment) is illustrated in Appendix 1/7 Figure 1 of this *Guide*.

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.

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.

Gas Tight Door. A solid, close-fitting door designed to resist the passage of gas under normal atmospheric conditions.

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.

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 vessel is responsible for functions such as load sharing among different power sources, load shedding when generated power is insufficient, etc.

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.

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).

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.

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.

Transitional Source of Emergency Electrical Power: An accumulator battery suitably located for use in an emergency which shall 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 automatically for a specified period of time in the event of failure of either the main or emergency source of electrical power for the purpose of this Guide.

9 Abbreviations and Acronyms *(15 July 2018)*

The following abbreviations and acronyms are applied to the terms used in this Guide:

ABS: American Bureau of Shipping

BMS: Battery Management System

CONOPS: Concept of Operations

DPS: Dynamic Positioning System

DVTP: Design Verification Test Procedures

ESD: Emergency Shutdown

FFES: Fixed Fire Extinguishing System

IEC: International Electrotechnical Commission

NAVSEA: Naval Sea Systems Command

PMS: Power Management System

PSTP: Periodic Safety Test Procedure

SOC: State of Charge

SOH: State of Health

SOLAS: Safety of Life at Sea

UL: Underwriters Laboratories

UPS: Uninterruptible Power Systems

11 References

11.1 ABS *(15 July 2018)*

ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*

ABS *Rules for Building and Classing Mobile Offshore Units (MOU Rules)*

ABS *Rules for Building and Classing Facilities on Offshore Installation (Facilities Rules)*

ABS *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities*

ABS *Guide for Dynamic Positioning Systems*

ABS *Guidance Notes on Alternative Design and Arrangements for Fire Safety*

ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*

ABS *Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification*

ABS *Advisory on Hybrid Electric Power Systems*

11.3 IEC References *(2022)*

IEC 60079-10-1: *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

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

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

IEC 62660 Series: *Secondary lithium-ion cells for the propulsion of electric road vehicles*

IEC 62281: *Safety of primary and secondary lithium cells and batteries during transport*

IEC 60529: *Specification for classification of degrees of protection provided by enclosures*

IEC 61508: *Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements*

11.5 Other References *(2022)*

UL 1642: *Standard for Safety of Lithium Batteries*

UL 2054: *Standard for Household and Commercial Batteries*

NAVSEA TM-S9310-AW-SAF-010: *US Navy Technical Manual for Batteries, Navy Lithium Safety Program Responsibilities and Procedures*

NAVSEA SG270-BV-SAF-010: *High-Energy Storage System Safety Manual*

SOLAS: *International Convention for the Safety of Life at Sea*

IMO: *International Maritime Dangerous Goods (IMDG), Dangerous Goods List, Substance Details – UN 3481, Lithium Ion Batteries Contained in Equipment (including lithium ion polymer batteries), 1/2/2013*

USCG 46 CFR Subchapter J, Electrical Engineering

ASTM F3353-19: *Standard Guide for Shipboard Use of Lithium-ion (Li-ion) Batteries*

IMO MODU Code: *Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009*

MGN 550 (M+F) Electrical Installations: *Guidance for Safe Design, Installation and Operation of Lithium-ion Batteries*

11.7 Alternative Standards

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

13 Data and Plans to be Submitted

13.1 General *(2022)*

At a minimum, the following drawings and data are to be submitted to ABS for review:

i) Test reports, in accordance with 4-9-8/Tables 1 and 2 of the *Marine Vessel Rules* and 3/1 of this Guide

ii) Battery Management System (BMS) functional description and test reports, as per 2/5

iii) 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.

iv) Battery System capacity calculation for intended application

v) Battery System electrical schematic drawing (block diagram with system interface)

vi) Emergency Shutdown (ESD) arrangement

vii) Battery System location and arrangement plan

viii) Battery System Risk Analysis document (i.e., Failure Modes and Effects Analysis (FMEA)) and the associated sea-trial/commissioning safety procedures (i.e., Design Verification Test Procedures (DVTP) and Periodic Safety Test Procedures (PSTP))

ix) Battery System installation and sea-trial/commissioning procedures

x) Ventilation arrangement of battery space including fire dampers, emergency shutdown from outside space

xi) Environmental control arrangement, if applicable (temperature sensors, air conditioning unit)

xii) Fixed fire extinguishing system (FFES) arrangements, details, and validation of suitability for the battery chemistry involved.

xiii) Fire detection and alarm system arrangement

xiv) Detailed stage by stage Fire Fighting Procedure/CONOPS

xv) Combustible gas detection and alarm system arrangement

xvi) Battery installation/mounting arrangement and associated drawings and information. This is to include battery weights, weight of the battery cabinets and connection details between battery cabinets and deck and/or bulkhead structure.

xvii) Hazardous Area Classification drawings, if applicable, and a list/booklet of intended electrical equipment in the indicated hazardous areas including a description of the equipment, applicable degree of protection, and ratings.

xviii) Operations and Maintenance manual for battery system and BMS

xix) Battery System Maintenance Schedule

xx) Structural Fire Protection details, joiner work details, and insulation arrangements, approved structural fire protection materials and equipment

15 Onboard Documentation

15.1 General

At a minimum, the following drawings and data are to be kept on board for easy reference by the crew during maintenance or repair:

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/CONOPS

SECTION 2

Battery System Design and Construction

1 Battery System Design and Construction *(15 July 2018)*

The provisions of this Section apply to vessel battery energy storage systems. The system is to compliment the electric propulsion, the main electrical generating source, and the emergency power sources.

1.1 Certification Details *(15 July 2018)*

TABLE 1
Certification Details – Battery System Components *(15 July 2018)*

Battery System Components	*ABS Type Approval Tier*	*Guide Reference*
1. Battery System Components	4/5	2/1.3, 3/1
2. Battery Chargers	4/5	2/3, 3/1
3. Battery Management Systems	4/5	2/5, 3/1

1.3 General *(2022)*

i) 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 and at the temperature to which it is likely to be exposed.

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

iii) 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).

iv) 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.

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

vi) 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.

vii) 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.

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

ix) As applicable, battery and/or module terminals are to be provided at an accessible position clearly marked and protected against mechanical damage and accidental contact for earthing, short-circuit or touching.

1.5 Control, Monitoring, Alarm and Safety Systems

i) 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.

ii) 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.

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

iv) 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.

1.7 Battery System Used as Main Source of Electrical Power *(2022)*

See Section 4 of this Guide for detailed requirements.

1.9 Battery System Used as Emergency Source of Electrical Power *(2022)*

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

i) Installations are to be designed for proper operations under the conditions as per 4-1-1/7.9 and 4-1-1/9 Table 7 of the *Marine Vessel Rules* and 4-1-1/7 Table 1 of the *MOU Rules* as applicable.

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

iii) Immediately supplying at least those services specified in 4-8-2/5.11 i) & ii) of the *Marine Vessel Rules* and 4-3-2/5.7.i) & ii) of the *MOU Rules* as applicable.

iv) Attention is directed to the requirements of the governmental authority of the country whose flag the vessel flies for the emergency services and the lithium-ion batteries required in various types of vessels.

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

vi) See additional requirements as per 4/3.3, 4/3.7, 4/3.9, 4/3.11, 4/3.13 of this Guide; and 4-8-2/5 of the *Marine Vessel Rules* and 4-3-2/5 of the *MOU Rules*.

vii) vii) Ventilation system for the battery space is to be operable upon loss of main source of electrical power

1.11 Battery System Used as Transitional Source of Electrical Power *(2022)*

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

i) Attention is directed to the requirements of the governmental authority of the country whose flag the vessel flies.

ii) See additional requirements as per 4/3.3, 4/3.7, 4/3.9, 4/3.11, 4/3.13 of this Guide; and 4-8-2/5.11 of the *Marine Vessel Rules* and 4-3-2/5.7 of the *MOU Rules*.

3 Battery Chargers *(2022)*

i) Battery chargers used for essential, emergency, and transitional sources of power are to meet the requirements specified in 4-8-3/5.9 of the *Marine Vessel Rules*, as applicable.

ii) 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.

iii) 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.

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

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

5 Battery Management System (BMS) *(2022)*

i) The battery system is to have a Battery Management System (BMS).

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

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

iv) The following conditions are to result in an individual or group audible and visual alarm to be displayed in a continuously manned location:

- Cell overvoltage
- Cell undervoltage
- Cell voltage unbalance
- Cell over-temperature
- Battery module/pack ground fault
- Tripping of mechanism that provides electrical isolation
- Failure of communication with asset's
- Recommendations as specified in the result of the risk assessment

v) The BMS is to comply with the requirements in Section 4-9-3 of the *Marine Vessel Rules*. Appropriate computer-based system category for BMS is to be assigned in accordance with 4-9-3/7 of the *Marine Vessel 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 ABS Surveyor witness requirements for Category II or III systems are to be complied with.

vi) 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.

vii) 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.

viii) The BMS is to be capable of the following conditions:

- Measuring and communicating battery voltage, battery current, battery internal temperatures, battery balance, ground fault.
- Incoming and Outgoing communications with batteries.

- Calculating and communicating state of charge (SOC), state of health (SOH), and time remaining [1].
- Balancing the batteries as necessary.
- Isolating batteries in case of damage or incorrect operation.

Note:

1 Time remaining can also be calculated and communicated via the Energy Management System (EMS) or Power Management System (PMS).

7 Marking and Designation *(2022)*

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

SECTION 3

Battery System Installation

1 Battery System Testing Requirements *(15 July 2018)*

The Battery System is to undergo Type Test and Routine Tests carried out to the satisfaction of attending ABS Surveyors as per Table 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 1
Summary of Type and Routine Tests *(2022)*

No.	*Test*	*Type Test* (2)	*Routine Test*	*Reference* (1)
1	External short-circuit test	x		IEC 62619 7.2.1
2	Impact test	x		IEC 62619 7.2.2
3	Drop test	x		IEC 62619 7.2.3
4	Thermal abuse test	x		IEC 62619 7.2.4
5	Overcharge test	x		IEC 62619 7.2.5
6	Forced discharge test	x		IEC 62619 7.2.6
7	Internal short-circuit test/Propagation test	x		IEC 62619 7.3.2/7.3.3
8	Overcharge control of voltage	x		IEC 62619 8.2.2
9	Overcharge control of current	x		IEC 62619 8.2.3
10	Overheating control	x		IEC 62619 8.2.4
11	Battery system/BMS safety function tests		x	2/5
12	Type tests for control, monitoring and safety equipment	x		4-9-9/15.7 TABLE 1 of the *Marine Vessel Rules*
13	Unit Certification tests for control, monitoring and safety equipment.		x	4-9-9/15.7 TABLE 2 of the *Marine Vessel Rules*

Notes:

1 Battery systems may comply with requirements in an alternative standard provided it has been determined by ABS as being not less effective. Where applicable, requirements may be imposed by ABS 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 1 above, are not to be repeated on units already tested, approved and certified by a National Recognized Testing Laboratory (NRTL), and test reports verified by ABS; therefore, Surveyor attendance is not required for those "type tests".

3 Battery Space *(2022)*

The battery space is to meet the following requirements:

i) Battery spaces are not to be located forward of the collision bulkhead of the vessel.

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

iii) Battery spaces are not to contain any equipment (including cables and pipes) supporting essential services as defined in 4-8-1/7.3.3 of the *Marine Vessel Rules* or 4-1-1/3.5 of the *MOU 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.

iv) The rated capacity of the battery system is to be determined for the ambient temperature conditions in 4-1-1/9 TABLE 8 of the *Marine Vessel Rules* or 4-1-1/7.7 TABLE 2 of the *MOU Rules*. Where the expected ambient temperatures are different from those in the applicable table, the rating of the battery system is to be based on the actual ambient temperature.

v) If the battery system is installed in an environmentally controlled space, the applicable requirements in 4-8-3/1.17.2 of the *Marine Vessel Rules* or 4-3-1/17.3.1 of the *MOU Rules* are to be complied with.

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

vii) 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.

viii) 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.

ix) 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. Inlet and exhaust ventilation duct(s) for the battery space are to be from and to a safe location on open deck. 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 fan is to be of the non-sparking type and shall provide six (6) air changes per hour. The ventilation ducting for the battery space is to be separate from the HVAC systems used to ventilate other spaces on the vessel.

x) The battery space is to be fitted with flammable and toxic 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% LEL.

xi) In the case where batteries are used as main source of electrical power (i.e., ship service loads) and/or propulsion power, see 3/3.1.5 and 4/3.11 of this Guide for structural fire protection requirements.

xii) 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. Ducts serving hazardous areas should not pass through accommodation spaces, service spaces, or control spaces.

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

xiv) 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.

xv) 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.

xvi) 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.

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

3.1 Fire Safety

3.1.1 General *(2022)*

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

i) 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 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 Li-ion batteries should not exceed the endurance of the fire rated divisions.

ii) 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 4, Chapter 7 of the *Marine Vessel Rules* or Part 5 of the *MOU 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 ABS *Guidance Notes on Alternative Design and Arrangements for Fire Safety* 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 Li-ion battery fire is self-perpetuating.

iii) Portable fire extinguishers are to be provided as required in 4-7-2/1.7 of the *Marine Vessel Rules* or 5-2-4/1 of the *MOU Rules*. Additionally, if the chemical composition of the Li-ion battery can lead to Class-D fires, a suitable portable fire extinguisher for Class-D fires should be provided. 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.

iv) 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.

3.1.2 Battery Space Adjacent to accommodation Space, Control Station or Service Spaces *(2022)*

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 Subsection 3/5.

3.1.3 Battery Space Adjacent or within Machinery Space of Category A *(2022)*

In addition to the requirements in 3/3.1.1, 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 category A machinery space 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.

3.1.4 Battery Space for Battery Systems Used as Emergency Source of Power *(2022)*

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

i) At a minimum, "A-60" class insulation is to be provided for battery space. However, 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 Subsection 3/5 of this Guide.

3.1.5 Battery Space Adjacent to Fuel Tanks or Spaces *(2022)*

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 forming boundaries between Battery spaces and F.O tank/spaces are to be insulated to "A-60" class standard and the insulation is to extend at least 450 mm (18 in.) outside the area of the joint bulkheads and decks.
- The top/bottom of the battery space is not to be in direct contact with the Fuel Tank's Bottom/top.
- Alternatively, the top/bottom 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 Li-ion battery space should be separated from space containing fuel containment system by a cofferdam of at least 900mm with structural fire insulation with A-60 Class. For type C tanks, the fuel storage hold space may be considered as a cofferdam in accordance with 5C-13-11/3.3 of the *Marine Vessels Rules*.

3.3 Hazardous Area Requirements *(2022)*

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:

i) The Operations and Maintenance Manual [1/13.1.xviii] is to list hazardous gases released.

ii) The equipment selection is to comply with applicable requirements in 4-8-4/27 of the *Marine Vessel Rules* or Section 4-3-6 of the *MOU Rules*.

iii) 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.

iv) The battery space is to have an independent deck drain. The independent deck drain is to be drained to a safe location or to a closed drain tank. 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.

v) Areas on the open deck within 3 meters (10 ft) of the battery space intake(s) and exhaust ventilation outlet(s) are to be considered as hazardous areas.

3.5 Cable Installations *(2022)*

i) General

In general cable installations are to comply with 4-8-4/21 of the *Marine Vessel Rules* and 4-3-3/5 of the *MOU Rules* as appropriate.

ii) 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 4-8-4/1.9 of the *Marine Vessel Rules* and 4-3-3/3.29 of the *MOU Rules*, their cable installation should be in accordance with 4-8-4/21.17.2 of the *Marine Vessel Rules* and 4-3-3/5.17.2 of the *MOU Rules*.

5 Battery System Risk Assessment *(2022)*

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 vessel. The risk assessment is to demonstrate the vessel safety and the continuity of power supply in case of failure of the battery. 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 ABS (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 Li-ion batteries on marine vessels and offshore units.

A Failure Mode and Effects Analysis (FMEA) is typically used but alternatively other risk assessment techniques may also be used. The use of other risk assessment techniques should be discussed with ABS prior to performing the risk assessment. The risk assessment is to be carried out in accordance with ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries*, ABS

Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification or other ABS-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:

i) 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.

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

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

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

v) Temperature and voltage measurement sensor failure.

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

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

viii) A fire and explosion analysis of the battery due to rapid chemical fire and explosion. Prior to performing the fire and explosion analysis, please consult ABS, and if applicable, the regulations, guidance notes, and circulars from the Flag Administration to establish the basis for conducting the fire and explosion analysis related to the installation of Li-ion batteries on marine vessels and offshore units.

ix) Risk of chemicals used and chemical fire are to be considered.

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 *i)*, *ii)* and *iii)*.

3 The battery vendor/manufacturer's risk assessment covers items *iv)*, *v)*, *vi)* and *vii)*.

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 Subsection 3/5 of this guide.

7 Battery System Operation and Maintenance

7.1 Installation and Commissioning

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

i) Correct interface between the battery system and the DC-bus or battery charger, as applicable.

ii) 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.

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

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

7.3 Operation and Maintenance *(2022)*

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 maintenance procedure is to include calibration of the BMS as required by the manufacturer. 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. Refer to 4-8-4/5.1.5 of the *Marine Vessel Rules* or 4-3-3/3.7.5 of the *MOU Rules* for requirements related to the maintenance schedule.

SECTION 4

Battery System Used as Main Source of Electrical Power

1 General

This Section 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 Section 2 and Section 3 covering design, construction, and installation.

3 System Requirements *(15 July 2018)*

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 1/13, as applicable, the following requirements are to be met.

3.1 Redundancy

i) At a minimum, 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.

ii) The propulsion design is to incorporate at least two independent systems as defined in 4-8-5/5.3.1 of the *Marine Vessel Rules* or 4-3-5/3.3.1 of the *MOU Rules*.

3.3 Capacity

In addition to the capacity submittal of 1/13.1.iv, design capacity based on the asset's intended operations is to be submitted.

3.5 Power Management System (PMS)

In addition to the requirements of 2/5, a PMS is to be provided per 4-8-5/5.3.3 of the *Marine Vessel Rules* or 4-3-5/3.3.3 of the *MOU Rules*.

3.7 Protective Systems

i) *Circuit Protection*. System protection requirements of 4-8-2/9 of the *Marine Vessel Rules* or 4-3-2/9 of the *MOU Rules* are applicable.

ii) Load Shedding Arrangements are to be in accordance with 4-8-2/9.9 of the *Marine Vessel Rules* or 4-3-2/9.3.3 of the *MOU Rules*.

3.9 Monitoring

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.

- Available batteries' energy
- Available batteries' power
- Remaining range/time that batteries can supply energy for the planned operation/voyage

3.11 Fire Protection *(2022)*

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.

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 3/3.1 of this Guide for battery space requirements for fire safety.

3.13 Trials

In addition to the requirements of 3/7.1, complete tests of the system are to be carried out during sea-trials in accordance with 4-8-5/5.19 of the *Marine Vessel Rules*.

SECTION 5

Battery System Surveys

1 General *(15 July 2018)*

The provisions in this Section are requirements for obtaining and maintenance of classification of **ESS-LiBATTERY** notation. These requirements are in addition to the provisions noted in other ABS Rules and/or Guides, as applicable, to the asset. See the ABS *Rules for Survey After Construction (Part 7)* or Part 7 of the *MOU Rules* for further detailed requirements.

For the purposes of this Section, the commissioning date will be the date on which a Surveyor issues an Interim Class Certificate to the asset with the **ESS-LiBATTERY** notation.

3 Surveys During Construction *(2022)*

This Section pertains to surveys carried out on lithium-ion battery system(s) with **ESS-LiBATTERY** 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 Sections 1, 3, and 4 of this Guide.

All surveys and testing listed in 3/1 of this Guide 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 Guide.

The following items are to be verified by the attending Surveyor:

i) *Location and Arrangements*. Battery system(s) are to be installed in accordance with the location and arrangement plan.

ii) *Testing*. Battery system(s) testing are to follow the approved sea trial/commissioning procedures and are to include at least the following items:

- Visual inspection
- Operational tests
- Tests of all the alarms and safety functions
- Emergency shutdown operation
- Fire protection systems
- Fire and Gas detection systems
- Simulation of communication failure with power management system
- Correct operation of ventilation, cooling, gas detection system, fire detection system, fire extinguishing system, etc., where provided.

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

iv) *Maintenance and Replacement*. A maintenance schedule and procedures of batteries replacement are to be provided and maintained onboard.

v) *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 Surveys After Construction *(1 March 2018)*

For requirements for surveys after construction, see Section 7-9-25 of the ABS *Rules for Survey After Construction (Part 7)*.

APPENDIX 1

Commentary on Batteries

1 General

A battery is an electrochemical device designed to store and release energy by direct conversion of chemical energy to electricity. A battery may be either a single cell or multiple cells connected in series or parallel configurations. It can be used in any marine and offshore application.

Lithium batteries include lithium-ion, lithium-alloy, lithium metal, and lithium polymer types. This section provides an overview of the technology and focuses on the characteristics of Li-ion batteries common to the majority of available batteries. Additional information on Li-ion batteries is available in the ABS *Advisory on Hybrid Electric Power Systems*.

3 Battery Type

3.1 Battery Categories

International standards divide batteries into two broad categories:

i) *Primary (Non-rechargeable) Batteries*. Primary batteries have a lower discharge rate and once fully drained these batteries cannot be recharged. These are the best alternative solutions for low cost, low drain applications such as watches, calculators, hearing aids, toys, etc.

ii) *Secondary (Rechargeable) Batteries*. Secondary batteries can be charged/discharged many times over their life. These batteries are more cost efficient over the long term and are the best solution for high drain applications such as laptops, cars, motor drives, power tools, etc.

Note:

Terms "Primary" and "Secondary" are used in recognized international standards such as IEC to categorize batteries.

Secondary batteries have more popular applications in the marine and offshore industries. The most common rechargeable batteries are Lead-acid, Nickel-cadmium (NiCd), Nickel Metal Hydride (NiMH) and Lithium-ion (Li-ion).

Of the above battery types, Lead-acid is the oldest rechargeable battery, Nickel-cadmium is mature and well understood, Nickel-metal-hydride serves as a replacement for NiCd and Li-ion is a technology that came to use in the 2010s. Recent advances in the development of Li-ion chemistry are facilitating their use for energy storage in applications that were previously the domain of more traditional battery chemistries and have opened the door to new applications.

3.3 Lithium-ion Battery Basis

The fundamental element of a lithium-ion battery system is the lithium-ion cell. It is within the cell that the electrochemical reaction takes place to absorb energy when charging and releases stored energy when discharging.

The four primary functional components of a practical lithium-ion cell are as follows,

- Anode (Negative Electrode)
- Cathode (Positive Electrode)
- Electrolyte
- Separator

There are more components such as current collectors, cell enclosures (cases and pouches), charge interrupt devices, positive temperature coefficient switches, battery pack protection electronics, and battery pack enclosures.

5 Battery Use *(2022)*

Li-ion batteries can be generally used for the following applications in marine and offshore industries:

- Main source of electrical power
- Emergency source of electrical power
- Transitional source of electrical power

Some examples of the benefits of batteries in different applications in marine and offshore industries are:

i) Batteries may be used as the main source of power for the propulsion of the asset.

ii) An asset can run an electrical motor at low speed (using batteries) in port or during transit or in zero emission areas and transition to a diesel engine or a gas turbine for medium or high speed for its voyage.

iii) When used for load levelling/peak-shaving, batteries act as a buffer to supply/absorb energy allowing generator sets to be operated at a near constant load. Use of these batteries can reduce maintenance on engines due to optimal loading and reduced engine running hours. With optimal loading, a higher average load can be maintained resulting in a smoother and more stable operation of engines.

iv) Batteries may be used in some instances as an additional power source in case of generator shutdown.

v) Using batteries as a standby power source may mean fewer generators need to be in operation.

vi) Batteries may be used for blackout prevention, fault ride thru and blackout recovery in some instances.

vii) Batteries may be used as an emergency source of power for essential and emergency services in some instances.

viii) *Dynamic Positioning Vessels*. Batteries may be used to supply thrusters and act as a buffer in DP mode and/or standby power for fault ride through on DP-2/DP-3 vessels operating in closed bus. For DPS-2/DPS-3 redundancy criteria applies.

ix) *Bollard Pull*. Also vendors have proposed allowing a battery to be used in order to meet maximum bollard pull required power on AHTS vessels.

x) *Heave Compensation*. On MODUs as a buffer for heave compensation equipment and to capture regenerative power from cranes.

xi) *Military/Naval Vessels*. As a buffer for pulse power weapons systems (electromagnetic rail guns, catapults, lasers, high power radar systems).

xii) *Renewable Energy/DC Grid*. As a storage device on vessels with cyclic renewable energy sources such as wind, solar, wave power.

7 Battery System (Compartment) Figure *(2022)*

FIGURE 1