



GUIDE FOR

USE OF LITHIUM BATTERIES IN THE MARINE AND OFFSHORE INDUSTRIES

15 JULY 2018 (Updated August 2018 – see next page)

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Updates

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Foreword

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

The purpose of this Guide is to establish safety guidelines for owners, operators, shipyards, designers, and manufacturers. The lithium battery types covered by this Guide include lithium-ion, lithium-alloy, lithium metal, and lithium polymer types. 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 Steel Vessels*. For requirements applicable to batteries used in underwater vehicles, please refer to the requirements in Subsection 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.

This Guide becomes effective on 15 July 2018.

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

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 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 Steel Vessels (Steel Vessel Rules)* and the *ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU 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 (15 July 2018)

This Guide is applicable to marine and offshore assets designed, constructed, or retrofitted with a lithium battery system used as an additional source of 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. When batteries are being used as the main source of power, the additional requirements set forth in Section 4 are to be met.

When Type Approval for a lithium 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 [Section 2, 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

Lithium battery types covered by this Guide include lithium-ion, lithium-alloy, lithium metal, and lithium polymer types.

For requirements related to conventional battery types, please refer to [4-8-3/5.9](#) of the *Steel Vessel Rules* or [4-3-3/3.7](#) of the *MODU Rules*.

For requirements related to the use of batteries in underwater vehicles, please refer to Subsection 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

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 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]

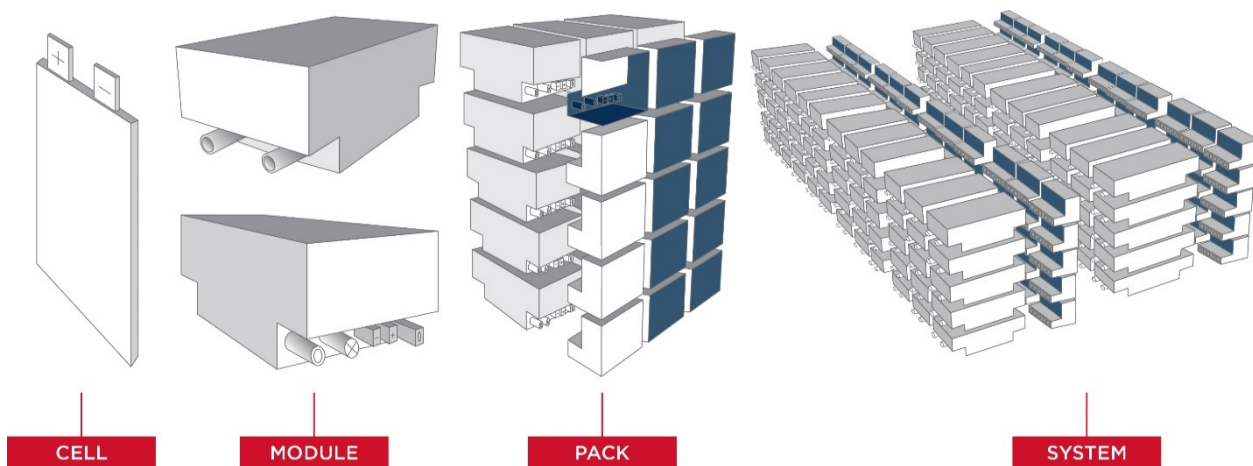
Battery Cell. The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, and terminals that is a source of electrical energy by insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode. 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.

**FIGURE 1
Battery Storage System**



Battery Space (Compartment). The space in which the battery system is physically located. A typical battery space (compartment) is illustrated in the *ABS Advisory on Hybrid Electric Power Systems*.

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.

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.

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.

9 Abbreviations and Acronyms (15 July 2018)

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

<i>ABS:</i>	American Bureau of Shipping
<i>BMS:</i>	Battery Management System
<i>CONOPS:</i>	Concept of Operations
<i>DPS:</i>	Dynamic Positioning System
<i>DVTP:</i>	Design Verification Test Procedures
<i>ESD:</i>	Emergency Shutdown
<i>IEC:</i>	International Electrotechnical Commission
<i>NAVSEA:</i>	Naval Sea Systems Command
<i>FFES:</i>	Fixed Fire Extinguishing System
<i>PMS:</i>	Power Management System
<i>PSTP:</i>	Periodic Safety Test Procedure
<i>SOC:</i>	State of Charge
<i>SOH:</i>	State of Health
<i>SOLAS:</i>	Safety of Life at Sea
<i>UL:</i>	Underwriters Laboratories
<i>UPS:</i>	Uninterruptible Power Systems

11 References

11.1 ABS (15 July 2018)

ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)

ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)

ABS Rules for Building and Classing Offshore Support Vessels (OSV 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

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*

11.5 Other References

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*

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

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 *Steel Vessel Rules* and Subsection 3/1 of this Guide
- ii) Battery Management System (BMS) functional description and test reports, as per Subsection 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

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

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

<i>Battery System Components</i>	<i>ABS Type Approval Tier</i>	<i>Guide Reference</i>
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

- i)* 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.
- 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.

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.

3 Battery Chargers

- 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 *Steel 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.

5 Battery Management System (BMS)

- 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
 - Failure of communication with asset's Power Management System (PMS)
 - Tripping of mechanism that provides electrical isolation
 - Failure/shutdown of the battery system or failure of any of the individual modules
- v) The BMS is to comply with the requirements in Section 4-9-3 of the *Steel Vessel Rules*. Appropriate computer-based system category for BMS is to be assigned in accordance with 4-9-3/7 of the *Steel 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.

Section 2 Battery System Design and Construction

- vi)* The safety system is to be activated automatically in the event of identified conditions that could lead to damage of the lithium 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.



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**

No.	Test	Type Test	Routine Test	Reference
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	Section 2/5
12	Type tests for control, monitoring and safety equipment	x		4-9-8/Table 1 of the <i>Steel Vessel Rules</i>
13	Unit Certification tests for control, monitoring and safety equipment.		x	4-9-8/Table 2 of the <i>Steel Vessel Rules</i>

Note: 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.

3 Battery Space (15 July 2018)

- i) Battery spaces are not to be located forward of the collision bulkhead of the vessel. Special cases may be considered for powering loads located forward of collision bulkhead.
- 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 *Steel Vessel Rules* or 4-1-1/3.5 of the *MODU 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/Table 8 of the *Steel Vessel Rules* or 4-1-1/Table 2 of the *MODU 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 *Steel Vessel Rules* or 4-3-1/17.3.1 of the *MODU 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. 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. Refer to 4-8-4/5.3.1(b) of the *Steel Vessel Rules* or 4-3-3/3.7.3(a) of the *MODU Rules* for ventilation system requirements for the battery space. 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 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.

3.1 Fire Safety

- 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 the structural fire protection requirements listed therein.
- 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 *Steel Vessel Rules* or Part 5 of the *MODU 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.
- iii) Portable fire extinguishers are to be provided as required in 4-7-2/1.7 of the *Steel Vessel Rules* or 5-2-4/1 of the *MODU Rules*.
- iv) The battery space is to be provided with fume-tight door to prevent escape of combustible gasses, deck drain, and not to be adjacent to spaces with combustible/flammable materials, berthing compartments, or machinery spaces of Category A except for emergency generator starting batteries located in an adjacent space to the emergency generator.

3.3 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:

- i) The Operations and Maintenance Manual [1/13.1xviii)] is to list hazardous gases released.
- ii) The equipment selection is to comply with applicable requirements in 4-8-4/27 of the *Steel Vessel Rules* or Section 4-3-6 of the *MODU 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 or no deck drain at all.

5 Battery System Risk Assessment (15 July 2018)

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.

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

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

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

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. Refer to 4-8-4/5.1.5 of the *Steel Vessel Rules* or 4-3-3/3.7.5 of the *MODU 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 Sections 2 and 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 Subsection 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 *Steel Vessel Rules* or 4-3-5/3.3.1 of the *MODU Rules*.

3.3 Capacity

In addition to the capacity submittal of 1/13.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 Subsection 2/5, a PMS is to be provided per 4-8-5/5.3.3 of the *Steel Vessel Rules* or 4-3-5/3.3.3 of the *MODU Rules*.

3.7 Protective Systems

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

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

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.

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 *Steel 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 *MODU 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 (15 July 2018)

This Section pertains to surveys carried out on lithium 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 Subsection 3/1 of this Guide** are to be carried out to the satisfaction of the attending Surveyor. The lithium 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

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

- Main source of power
- Additional/supplemental source of power
- Emergency source of power

Some examples of the benefits of batteries in different applications in marine and offshore industry 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.