

INDIAN REGISTER OF SHIPPING

CLASSIFICATION NOTES

Approval of Lithium-ion Battery Systems

July 2020



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Section 1

Introduction

1.1 Scope

This Classification Note is applicable to approval of Lithium-ion battery systems to be used in ships and offshore installations classed or intended to be classed with IRS.

This Classification Note provides requirements for approval of Lithium-ion battery systems to be used in battery powered vessels or hybrid vessels classed or intended to be classed with IRS. The installation requirements for Li-ion battery systems including the relevant IEC standards and environmental standards are indicated in IRS *Guidelines on Battery Powered Vessels*.

1.2 Definitions

Definitions relating to approval of battery systems are given in Section 2.

1.3 Overview

1.3.1 Approval Process

1.3.1.1 Type Approval

Type approval would be required for each type of Li-ion battery (i.e. for each battery chemistry). The type approval process consists of the following:

- drawing and specification approval,
- works assessment
- approval of type testing programme,
- type testing & functional testing, (review type test records if the tests are carried out in Govt. lab or were witnessed by any other IACS society.
- issue of a type approval certificate upon satisfactory testing

1.3.1.2 Unit Certification

The Li-Ion battery systems fitted on each vessel would be subjected to unit certification. The designer/ manufacturer is to forward vessel specific plans along with valid type approval certificate of the battery system. The battery system would be tested as per vessel specific plans and approved test protocol.

1.4 Documentation Requirements

The documents / plans as given below (giving an overview of the design and performance of the battery system) are to be submitted to IRS for review:

- a. Functional description and detailed specification of battery systems for which type approval is requested. The document to include limiting conditions and specific requirements for installation, operation and safety.
- b. Functional description of Battery management systems along with circuit diagram of BMS clearly indicating safety and protective devices.
- c. System block diagram clearly indicating arrangement of modules, strings and battery pack. The plans are also to include communication system between battery modules, BMS and overall controller including details of external interfaces.
- d. Details and arrangement of forced cooling systems (where required) for safe operation of battery.
- e. List of controlled and monitored points
- f. List of alarm and monitoring parameters
- g. Battery system manufacturer's quality plan
- h. Battery management system software quality plan
- i. Documentation on battery state of charge and state of health calculation
- j. System Operation manual
- k. Type test and performance test protocol along with acceptance criterion for testing at manufacturer's works. Tests required to assess the LAN performance are to be included
- l. Quality Assurance Plan.
- m. Maintenance manual
- n. Overall dimensional details

1.5 Design Assessment and Documentation Review

The design assessment would comprise of review of documents/drawings as above. The design assessment is to ensure that the product conforms to the requirements specified in the reference standards/guidelines/IRS Classification Notes.

1.5.1 Design Assessment

The design assessment will broadly include, but not be limited to the following:

- a) The battery management system circuit diagram would be verified towards compliance to requirements for control systems indicated in Part 4 Chapter 7 of the *Rules and Regulations for the Construction and Classification of Steel Ships* and *IRS Guidelines on battery powered vessels*, relevant IEC standards and manufacturer specific requirements.

- b) The control system plans will be reviewed to verify the provision to control, monitor and interface with other ship systems/ network.
- c) Review of Communication system between battery modules and battery management systems and external networking requirements.
- d) Review of battery safety, alarms, trips and battery calculations.
- e) Review of forced cooling arrangements, rack arrangements when used for housing multiple battery modules.
- f) Review of measures to address Risks

1.5.2 All batteries are to have valid type approval certificates from IRS.

1.5.3 The Battery Management System (BMS) is subject to unit testing and certification. The review of environmental test reports would be in accordance with the requirements of the IRS Classification Note *“Type Approval of Electrical Equipment used for Control, Monitoring, Alarm and Protection Systems for use in Ships”*. The assessment of the BMS software is also to be carried out.

1.5.4 Test Protocol

Test protocol for testing the complete system is reviewed to check for compliance of following inspections/tests with the relevant test specification(s) and specified standards/IRS Classification Notes. The test protocol is to be submitted by the manufacturer and mutually agreed to form the basis for testing and acceptance:

1.5.5 Quality Plan

The battery system manufacturer is to prepare and implement a quality plan that defines procedures for the inspection of materials, components, cells, modules, battery packs, and battery systems and which covers the whole process of producing each type of cell, module, battery pack, and battery system. Manufacturers are to define document required process controls as they relate to product safety.

1.6 Manufacturer Works Assessment

IRS would assess the manufacturers' facilities for design, manufacture and testing of batteries. The assessment would include verification of implemented quality control procedures.

1.7 Type Tests

1.7.1 Type tests as per IEC Standards as referenced in this Classification Note are to be carried out as applicable, and are to be witnessed by IRS surveyors (See Appendix 1).

1.7.2 Presence of IRS surveyor during type tests may be exempted if the tests are carried out in an accredited laboratory recognised by IRS.

1.8 Type Approval Certificate

On completion of satisfactory works assessment and witnessing type and functional tests IRS would issue a type approval certificate. The duration of validity of the type approval certificate will be five (05) years.

1.9 Withdrawal of Certificate

The type approval certificate will be invalid if there are substantial modifications in the design, in the manufacturing or control processes or in the characteristics of the materials unless approved in advance by IRS.

1.10 Intermediate Audit

IRS will carry out an intermediate audit of the manufacturing works during the five year period. The intervals between initial, intermediate audits is not to be more than 30 months.

1.11 Type Approval Certificate Renewals

A renewal of type approval certificates will be granted upon:

- a) Submission of request for renewal
- b) Submission of modified documents or new documents with substantial modifications replacing former documents compared to the previous submission(s) for TA.
- c) A declaration that no substantial modifications have been applied/undertaken since the last TA was issued.

Section 2

Definitions

- a) *Cell*: an individual electrochemical unit of a battery consisting of electrodes, separators, electrolyte, container and terminals.
- b) *Battery*: assembly of cells ready for use as storage of electrical energy characterized by its voltage, size terminal arrangement, capacity and rate capability.
- c) *Battery System*: system which comprises one or more cells, modules. It has a battery management system to cut off in case of overcharge, overcurrent, over discharge and overheating.
- d) *Battery Management System (BMS)*: an electronic system that controls, manages, detects or calculates electric and thermal functions of the battery system and provides communication between the battery and upper level control systems. It monitors the state of the battery by protecting the battery from operating outside its safe operating area.
- e) *State of Health (SOH)*: general condition of a battery, including its ability to deliver the specified performance compared with a new battery.
- f) *State of Charge (SOC)*: state of charge is the available capacity in a battery expressed as a percentage of the rated capacity.
- g) *Module* : a group of Li-ion cells which are grouped in series and/ or parallel combinations.

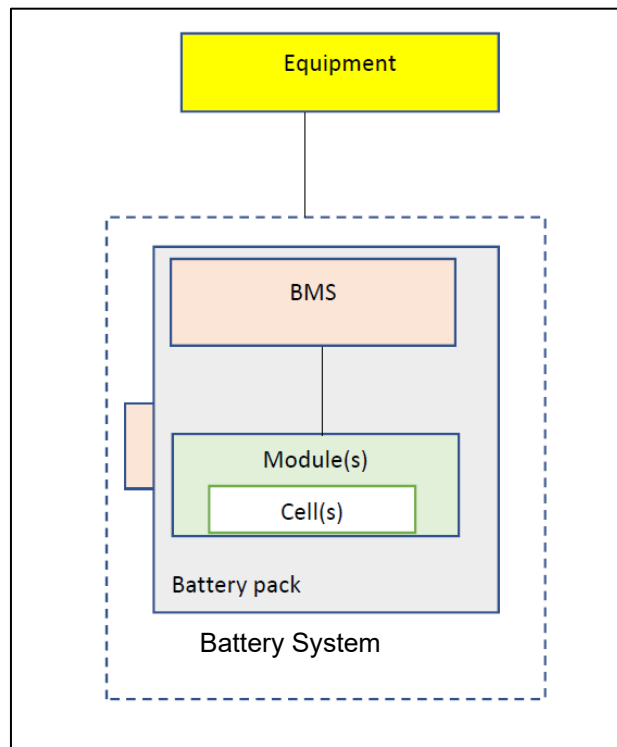


Fig. 2(a) : All functions of BMS are in the battery pack

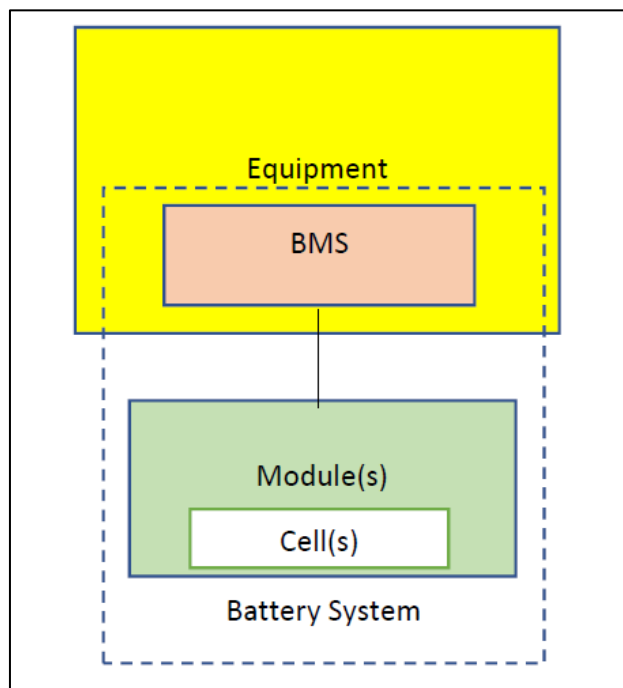


Fig. 2(b): Combination of equipment with BMS and Modules

Fig 2 : Typical examples of BMS locations and Battery System Configurations

Section 3

Battery Types

3.1 Classification of Batteries

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

3.2 Over the years, Lithium ion batteries have been developed to replace other type of batteries in marine use due to their high energy density. The nomenclature of Lithium-ion is based on its active materials; and safety chemistry the words are either written in full or shortened by their chemical symbols. Battery chemistries are generally identified in abbreviated letters.

3.3 For example, lithium cobalt oxide, one of the most common Li-ions, has the chemical symbols LiCoO_2 and the abbreviation LCO. Cobalt is the main active material that gives this battery its character and are designated in three parts viz; name/symbol/Chemistry of the battery.

3.4 Li-ion chemistries are:

- a) Lithium Cobalt Oxide (LiCoO_2) - LCO
- b) Lithium Manganese Oxide (LiMn_2O_4) -LMO
- c) Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO_2 or NMC) NMC
- d) Lithium Iron Phosphate (LiFePO_4) LFP
- e) Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAlO_2) NCA
- f) Lithium Titanite ($\text{Li}_4\text{Ti}_5\text{O}_{12}$) LTO

Section 4

Battery Management System (BMS)

4.1 The battery management systems (BMS) is part of battery system. The BMS may be housed along with battery module or may be installed separately. BMS is required to maintain the condition of the cells/ battery and protect them from unsafe situations such as internal battery defects, excessive external demands (e.g. a high current demand) and overcharging.

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

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

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

- a) High and low values of cell voltage and temperature
- b) Battery current
- c) Battery space temperature
- d) Battery charge and discharge current
- e) Available power
- f) Available energy
- g) Ventilation fan running status(on/off).

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

- a) Operation of the protective device
- b) Cell temperature high
- c) Battery space high temperature
- d) Failure of ventilation
- e) Cell voltage- over voltage
- f) Cell voltage – under voltage
- g) Opening of cell safety venting device or high pressure in the Battery
- h) State of charge-minimum alarm at manned local station and at bridge
- i) Gas detection.

Section 5

Works Assessment and Testing

6.1 Works Assessment

Manufacture's quality plan is to be reviewed for documented procedures for inspection of materials components, cells and various components of battery systems which are required in the complete manufacturing and assembly process of battery cells, modules and battery management system. The scope also includes review of software quality plan for battery management system

An inspection of manufacturer's works will be carried out to assess the manufacturing, inspection and testing facilities including quality control measures. Type test is to be witnessed as per agreed test protocol.

6.2 Inspection and testing

- a. Visual inspection for conformance with design drawings
- b. Performance test.
- c. Lithium Cell tests and acceptance criterion:
 - i) External short Circuit - Short-Circuit between the positive and negative terminals shall not cause a fire or explosion
 - ii) Impact - An impact to the cell shall not cause fire or explosion
 - iii) Drop Test - A drop of a cell or cell block, and battery system shall not cause fire or explosion
 - iv) Thermal abuse - An elevated temperature of a cell or cell block shall not cause fire or explosion
 - v) Overcharge - Charging for longer periods than specified by the manufacturer shall not cause a fire or explosion
 - vi) Forced Discharge - A cell in a multi-cell application shall withstand a forced discharge without causing a fire or explosion

d) Lithium Battery System tests and acceptance criterion:

- i) Propagation/Internal thermal event - A forced internal short-circuit within a cell will not result in fire of the entire battery system or fire propagating outside the battery system.
- ii) Overcharge with voltage - The Battery Management System shall control the charging voltage below the upper limit charging voltage of the cells.
- iii) Overcharge with current - In case the input current to the cells and batteries exceeds the maximum charging current of the cells, the Battery Management System shall interrupt the charging to protect the battery system from hazards related to charging currents above the cells specified maximum charging current
- iv) Overheating control - The Battery Management System shall terminate charging when the temperature of the cells and/or battery exceeds the upper limit that is specified by the cell manufacturer.
- v) Capacity Validation - This test determines firstly the capacity which a cell retains after storage for an extended period, and secondly the capacity that can be recovered by a subsequent recharge.
- vi) Di-Electrical Strength (high voltage test) - To verify the high voltage withstanding capacity
- vii) Insulation Resistance - To verify the strength of Insulation
- viii) Pressure test of cooling system - Pressure withstanding capacity of liquid cooling system

e) Lithium battery Electrical tests: The Following Electrical tests are to be carried out as per IEC 62620 (Individual clause reference of Table 2 is as mentioned)

- i) Discharge performance at +25 Deg C to verify that the delivered capacity is not to be less than as specified (Cl.6.3.1 of IEC 62620)
- ii) Discharge performance at low temperature: The test is conducted to identify the temperature at which the cell can deliver 70% of rated capacity. (Cl. 6.3.2 of IEC 62620)
- iii) High rate permissible current: The test is conducted to verify the ability of battery of a specific type to withstand high currents. (Cl.6.3.3 of IEC 62620)

- iv) Internal AC Resistance test: The test is conducted to verify that the measured resistance is not more than manufacturer declared value. (Cl 6.5.2 of IEC 62620)
 - v) Internal dc resistance: Test is conducted to verify that the measured resistance is not more than manufacturer declared value. (Cl.6.5.3 of IEC 62620)
 - vi) Endurance in Cycle: The test is conducted to verify the capacity of a battery after cyclic charge and discharge. (Cl.6.6.1 of IEC 62620)
 - vii) Endurance in storage: The test is conducted to verify the capacity of battery when used for standby application. (Cl.6.6.2 of IEC 62620)
- f) Lithium Battery System Environmental tests: to confirm satisfactory working of the battery system under stipulated environmental conditions
- i) Vibration - To verify vibration withstanding capacity
 - ii) Dry Heat - To verify the dry heat withstanding capacity
 - iii) Damp Heat - To verify the damp heat withstanding capacity in humid condition
 - iv) Cold** - To verify the low temperature withstanding capacity
 - v) Corrosion** - To verify the capability of operation in salty atmosphere
 - vi) Flame retardant - To verify the flame exposure withstanding capacity
 - vii) EMC - To verify the Electromagnetic compatibility

**Only applicable when the batteries are to be located on weather deck.

g) Acceptance parameter tolerance levels .

- a) $\pm 0,5$ % for voltage;
- b) ± 1 % for current;
- c) ± 2 °C for temperature;
- d) $\pm 0,1$ % for time;
- e) ± 1 % for dimensions.

6.3 Marking

6.3.1 The marking and cell designation (i.e. type of cell chemistry, discharge rate etc.) is to be in accordance with IEC 62620. Each cell or battery is to be clearly marked giving the following information:

- secondary (rechargeable) Li or Li-ion;
- polarity;
- date of manufacture;
- name or identification of manufacturer or supplier;
- rated capacity;
- nominal voltage;
- appropriate caution statement.

6.3.2 The model name and manufacturing traceability is to be marked on the cell and battery surface. The other items listed above can be marked on the smallest package or supplied with the cell or the battery.

6.3.3 The following information is to be marked on or supplied with the cell or the battery:

- disposal instructions;
- recommended charge instructions.

6.3.4 The following information is to be marked on the cell or when there is no marking place on the cell, it is to be marked in the manual.

- cell designation

References

IRS Classification Notes Type Approval of Electrical Equipment used for Control, Monitoring, Alarm and Protection Systems for use in Ships

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

IRS Guidelines on Battery Powered Vessels

Appendix 1**Battery Tests****a) Type Tests of Battery Cells****(Lithium Cell Tests)**

Item	Test	Ref. Standard/Clause	Remarks
1.	External Short Circuit Short-Circuit between the positive and negative terminals shall not cause a fire or explosion	IEC 62619 Cl. 7.2.1	
2.	Impact An impact to the cell shall not cause fire or explosion	IEC 62619 Cl. 7.2.2	
3.	Drop Test A drop of a cell or cell block, and battery system shall not cause fire or explosion	IEC 62619 Cl. 7.2.3	
4.	Thermal abuse An elevated temperature of a cell or cell block shall not cause fire or explosion	IEC 62619 Cl. 7.2.4	
5.	Overcharge Charging for longer periods than specified by the manufacturer shall not cause a fire or explosion	IEC 62619 Cl. 7.2.5	
6.	Forced Discharge A cell in a multi-cell application shall withstand a forced discharge without causing a fire or explosion	IEC 62619 Cl. 7.2.6	

b) Tests on Battery Systems.**(Lithium Battery System Tests)**

Item	Test	Ref Standard/Clause	Remarks
1	Propagation/internal thermal event A forced internal short-circuit with in a cell will not result in fire of the entire battery system or fire propagating outside the battery system.	IEC 62619 Cl. 7.3.3	
2	Overcharge with voltage The BMS shall control the charging voltage below the upper limit charging voltage of the cells.	IEC 62619 Cl. 8.2.2	
3	Overcharge with current In case the input current to the cells and batteries exceeds the maximum charging current of the cells, the BMS shall interrupt the charging to protect the battery system from hazards related to charging currents above the cells specified maximum charging current	IEC 62619 Cl. 8.2.3	
4	Overheating control The BMS shall terminate charging when the temperature of the cells and/or battery exceeds the upper limit that is specified by the cell manufacturer.	IEC 62619 Cl. 8.2.4	
5	Capacity validation This test determines firstly the capacity which a cell retains after storage for an extended period of time, and secondly the capacity that can be recovered by a subsequent recharge	According to Battery specification, IEC 62620 Cl. 6.4 may be used.	
6	Di-electrical strength (high voltage test) To verify the high voltage withstanding capacity	Test No. 10, Section 3, ANNEXURE – I ,Type Tests and Related Criteria Type Approval of Electrical Equipment used for Control, Monitoring, Alarm and Protection, Systems for Use in Ships – <i>July 2019</i>	
7	Insulation resistance To verify the strength of Insulation	Test No. 9, Section 3, ANNEXURE – I ,Type Tests and Related Criteria Type Approval of Electrical Equipment used for Control, Monitoring, Alarm and Protection, Systems for Use in Ships – <i>July 2019</i>	
8	Pressure test of cooling system Pressure withstanding capacity of liquid cooling system	In case of liquid cooled system	

c) Electrical Type Tests: Ref IEC 62620

Sl. No.	Tests	Clause of IEC 62620	Remarks
1	Discharge performance at +25 °C	6.3.1	
2	Discharge performance at low temperature	6.3.2	
3	High rate permissible current	6.3.3	
4	Internal a.c. resistance (cell)	6.5.2	
5	Internal d.c. resistance	6.5.3	
6	Endurance in cycle for battery/cell are designed for cyclic application	6.6.1	
7	Endurance in storage at constant voltage to be conducted when battery /cells are designed for stand by applications.	6.6.2	

d) Environmental Tests of Batteries.**(Lithium Battery System Environmental Tests)**

Item	Test	(Ref. Annexure – I of IRS Classification Notes on Approval of Electrical Equipment used for Control, Monitoring, Alarm and Protection, Systems for Use in Ships)	Remarks
1	Vibration To verify vibration withstanding capacity	Test No. 7, Section 3,	
2	Dry Heat To verify the dry heat withstanding capacity	Test No. 5, Section 3,	
3	Damp Heat To verify the damp heat withstanding capacity in humid condition	Test No. 6, Section 3	
4	Cold** To verify the low temperature withstanding capacity	Test No. 11, Section 3	
5	Corrosion** To verify the capability of operation in salty atmosphere	Test No. 12, Section 3	
6	Flame retardant To verify the flame exposure withstanding capacity	Test No. 21, Section 3, (if use of flammable materials)	
7	EMC To verify the Electromagnetic compatibility	Test No. 13 to 20, Section 3,	

** Applicable only when Batteries are located outside.

Note:

- a. If similar tests as mentioned above have been performed according to other standards, may be examined for equivalence for acceptance.
- b. The tests are to be carried out as per mutually agreed test protocol submitted by the manufacturer for every individual battery system.
- c. The tests are to be witnessed by a surveyor or be performed at a recognized laboratory.