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Small craft — Lithium-ion batteries

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 188, *Small craft*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Small craft — Lithium-ion batteries

1 Scope

This document provides requirements and recommendations for the selection and installation of lithium-ion batteries for boats. It applies to lithium-ion batteries and to battery systems with a capacity greater than 600 Wh, installed on small craft for providing power for general electrical loads and/or to electric propulsion systems. It is primarily intended for manufacturers and battery installers.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
ampere interrupt capacity
AIC
maximum current a circuit breaker or fuse is rated to safely interrupt at a specific voltage

3.2
battery
collection of *cells* (3.7) wired in series (or series/parallel) and constituting a single physical unit

3.3
battery bank
set of *batteries* (3.2) electrically connected (parallel/series) to increase capacity and or voltage

3.4
battery capacity
C
capacity of the *battery* (3.2), expressed in ampere-hours (Ah) at a nominal voltage or in watt hours (Wh), from the manufacturer's specified fully charged to discharged voltage levels

Note 1 to entry: Ah capacity rating at a given discharge rate or time.

3.5
battery management system
BMS
system designed to protect a lithium-ion *battery* (3.2) from potentially damaging events, such as overcharging or overdischarging and high and low temperatures

3.6
battery system
battery (3.2) or batteries and all ancillary components

3.7
cell
fundamental building block that is inside a lithium-ion *battery* (3.2) where electrical energy is derived from the insertion/extraction reactions of lithium ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode

3.8
C rating
measure of *battery* (3.2) charge and discharge rating expressed as a function of the rated Ah capacity of the battery

Note 1 to entry: A 100 Ah battery charged or discharged at 100 A is a 1C rate.

3.9
contactor
protection relay/switch controlled by the *battery management system* (3.5) for *battery* (3.2) protection

3.10
high voltage cutout
HVC
battery management system's (3.5) response to a *high voltage event* (3.11) that protects the *battery* (3.2) from overcharging

3.11
high voltage event
HVE
condition where a *cell* (3.7) has been charged to a voltage above the manufacturer's cell maximum voltage limit

3.12
low voltage cutout
LVC
battery management system's (3.5) response to a *low voltage event* (3.13) that protects the *battery* (3.2) from overdischarging

3.13
low voltage event
LVE
condition where a *cell* (3.7) has been discharged beyond the cell manufacturer's cell low voltage limit

3.14
main contactor
in the case of a multiple *contactor* (3.9) system [*high voltage event* (3.11), *low voltage event* (3.13), plus the main], device intended to be the last one to open, or closest to the *battery* (3.2), and, in case of a single contactor system, device intended to serve as *high voltage cutout* (3.10)/*low voltage cutout* (3.12)/main protection

3.15
overcharging
charging a *cell* (3.7) above the cell manufacturer's upper cell voltage limit, which may result in damage to the cell

3.16
safe operating limits
SOL
set of voltage, temperature and other parameters, within which the *battery* (3.2) is intended to be operated and which, if exceeded, initiates a *battery management system* (3.5) response to correct the problem or to shut the battery down

3.17
state of charge
SOC
indication of the amount of usable capacity available in the *battery* (3.2), expressed as a percentage
EXAMPLE: 0 % = empty; 100 % = full.

3.18
thermal runaway
potentially dangerous and self-propagating *battery* (3.2) heating condition that can occur within a *cell* (3.7) or cells

4 System design requirements

4.1 All battery system design should be done in a way that ensures all installed lithium-ion batteries are kept within the battery manufacturers specified safe operating limits.

4.2 There should be a BMS installed to control all installed lithium-ion batteries and maintain the battery manufacturers specified safe operating limits.

NOTE A BMS can be internal or external to the battery.

4.3 It is recommended to only use cells that are constructed according to recognized international standards, such as IEC 62619 and IEC 62620.

4.4 The battery system should be sized in accordance with the application and the battery manufacturer's defined operating limits, and with the appropriate C rating listed in the system specifications.

4.5 Consideration should be given to providing power for critical systems (e.g., engine starting, navigation lights, etc.) if a BMS shuts down the battery.

4.6 Consideration should be given to battery locations to keep the system operating temperature within the manufacturer's specified range.

NOTE A BMS can disconnect the battery at manufacturer-specific temperature limits.

4.7 Output control from charging sources should be within the battery manufacturer's specified ranges.

4.8 If a shut-down condition is approaching, a BMS or system should notify the operator with a visual and/or audible alarm, clearly perceptible from the main helm position, prior to disconnecting the battery from the DC system.

4.9 In normal operation, different battery chemistries should not be connected in parallel or in series. Combining/automated charging relays should not be used between systems using different chemistries.

4.10 The main battery switch or other means of manual disconnection should be used as an isolation switch, but not as a primary protection device in the output from a lithium-ion battery bank.

4.11 The system should communicate on the delivered systems communication network with all installed charging components as an integrated system.

NOTE Small self-contained systems might not have internal communication capabilities.

4.12 Multiple contactors are permitted (HVC, LVC, plus main), each providing specific protection from high voltage, low voltage and load isolation. A single main contactor is permitted, if the control system provides for protection from all conditions.

5 Safe operating limits

5.1 The safe operating limits of a lithium-ion battery are defined by the manufacturer and are comprised of high and low voltage limits, charging and discharge current limits, and charging and discharging temperature limits, etc. The SOL shall be adhered to during the design, installation, storage, and operation of a lithium-ion battery.

All lithium-ion batteries lose capacity through cycling and over time. Capacity is also adversely affected by operating at higher temperatures and maintaining a lithium-ion battery in a high SOC and/or extended periods at a low SOC. This needs to be taken into account in terms of the SOL.

5.2 Overcharging can cause damage to the cells, and shall be prevented by using a BMS appropriate for the installation.

5.3 Lithium-ion batteries have very strict temperature operating limits established by the battery/cell manufacturers. To prevent damage and potentially hazardous conditions, the system shall be operated within specified operating temperatures under all operating conditions.

For craft in long term storage, the battery installation should follow the manufacturer-recommended battery storage procedures, based on ambient temperature, connected charging sources, and parasitic loads.

6 General lithium-ion battery installations

6.1 Lithium-ion batteries should not be installed in locations where temperatures outside (high or low) acceptable parameters can be expected to occur. Battery manufacturer installation specifications shall be met. This consideration should extend to areas that can be heated from the sun or other external heat sources.

Consideration should be given to avoiding potential hot spots.

6.2 System connections and BMS electronics should be protected from corrosion.

6.3 Lithium-ion batteries should be installed in locations that prevent damage from shock and vibration, unless batteries are approved specifically for that application by the manufacturer.

6.4 Lithium-ion battery systems should be constructed or installed so that they do not have their safe operation jeopardized, during normal craft operation, by the damaging effects of exposure to water.

Components exposed to water should be in a IP67 rated container.

6.5 Devices located in compartments that require ignition protection should be protected against ignition in accordance with ISO 8846.

6.6 Installation tie down requirements — Lithium-ion battery banks should be restrained such that, as installed, the bank cannot move more than 10 mm in any direction when a pulling force of twice the battery weight is applied through the centre of gravity of the battery as follows:

— vertically, for a duration of 1 min;

— horizontally and parallel to the boat's centreline, for a duration of 1 min, each in the fore and aft directions; and

— horizontally and perpendicular to the boat's centreline, for a duration of 1 min, each in the starboard and port directions.

6.7 Lithium-ion battery connections — No electrical connections should be made directly to a lithium-ion battery that would bypass the BMS or the protection relays, unless specified by the battery system manufacturer's instructions.

6.8 Overcurrent protection — All lithium-ion battery output circuits should have overcurrent protection in accordance with ISO 13297.

6.9 Ampere interrupting capacity (AIC) — If necessary, the lithium-ion battery bank should be subdivided into units such that the AIC rating of fusing is not exceeded.

6.10 Lithium-ion battery disconnect — The operator should be able to safely operate a lithium-ion battery system disconnect switch or switches when the batteries are in an overheating situation. The lithium-ion battery system disconnect switch should be readily accessible without reaching over the lithium-ion battery. Consider locating the lithium-ion battery disconnect outside dedicated battery enclosure.

Multiple disconnect switches are recommended to prevent a dead ship in the event of a LVC/HVC occurrence.

6.11 Series and paralleling installations should comply with the lithium-ion battery manufacturer specifications.

Special attention should be paid to draw even power from all batteries in a battery bank, to avoid disbalancing.

Appropriate measures should be taken to allow for balancing and overcurrent protection between batteries.

6.12 Charging sources should be operated/controlled to meet the charging profile recommendations provided by the lithium-ion battery or cell manufacturer.

7 Fire protection and cell venting

7.1 Fire protection from thermal runaway — Lithium-ion batteries technologies have unique fire characteristics. See Annex A for more information.

7.2 Fire protection from external fires — Consideration should be given to installation of a fire detection system, according to ISO 9094, when batteries are installed in enclosed compartments. When the batteries are installed in spaces susceptible to fire, considerations should be given to installing batteries in containers that provide protection from an external fire.

7.3 Cell venting — Battery installations should be provided with guidance for battery compartment ventilation directly to open air to avoid concentration of gasses if cell venting occurs. Consult with the battery cell manufacturer for ventilation requirements for the battery/battery compartment.

When the battery banks are installed in an enclosed habitable space, the battery bank should be installed in a (separate) container allowing for independent ventilation.

8 Battery management system and testing

8.1 Cells, batteries and BMS's should be of a fail-safe design and constructed and tested to recognized standards that reflect marine applications and duty cycles, with the testing conducted by a recognized laboratory.

NOTE Examples of laboratory performance requirements can be found in ISO 9001 or ISO/IEC 17025.

The BMS should be designed and tested to manage:

a) Safety related:

— Overcharge, to protect the lithium-ion battery from excessive charging;

— Overdischarge, to protect the lithium-ion battery from excessive discharging;

— Over temperature, to protect the lithium-ion battery from excessive temperature.

b) Performance related:

— Balancing, to provide for automatic balancing of cells or strings of cells.

8.2 The BMS should be equipped with HVC and LVC actions to prevent an HVE or LVE in the event the programmed functions in the charging sources, inverters, or inverter/chargers fail to do so. Actions taken by the BMS should be in addition to the programmed functions in the charging sources, inverters, or inverter/chargers.

8.3 The BMS should monitor cell voltage to determine if an HVE or LVE is imminent.

8.4 HVE/HVC — The BMS protects a lithium-ion battery from an HVE by initiating a multistage HVC consisting of the following steps:

— it should provide a stop charging signal to each charging source;

— if stopping the charging sources does not stop the HVE, an alarm (visual and/or audible) should be provided for the operator, clearly perceptible from the main helm position;

— if the operator fails to stop the HVE, the BMS should initiate an isolation of the sources that are creating the HVE.

8.5 LVE/LVC — The BMS protects the lithium-ion battery from an LVE by initiating a multistage LVC consisting of the following steps:

— it should provide an audible and/or visual alarm to the operator, clearly perceptible from the main helm position, that indicates that the SOC of the lithium-ion battery bank is approaching the low SOC threshold specified by the manufacturer;

— if the operator fails to prevent the LVE, the BMS should initiate the disconnection of non-essential electrical consumers;

— if this does not prevent the LVE, the BMS should disconnect all electrical loads.

8.6 Temperature — The BMS should respond to low or high temperature situations in a manner that ensures the battery cannot be driven into an unsafe condition. Temperature sensing should be sufficient to monitor all potential areas of overheating.

8.7 An output disconnect device should be provided and designed to disconnect under full load without failure.

