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Standard Guide for Shipboard Use of Lithium-Ion (Li-ion) Batteries¹

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1. Scope

1.1 The purpose of this guide is to provide standard methods for the safe use of Li-ion batteries onboard vessels. The guidelines in this document were developed primarily for larger Li-ion marine battery installations, such as for propulsion or ships service electrical power. The guidelines may not be appropriate for smaller battery packages such as those for computers, packaged uninterruptible power supply (UPS) units, and tools.

1.2 Advances in energy storage technology have enabled new possibilities in shipboard power systems. Currently, lead acid batteries comprise the vast majority of shipboard power storage installations due to their low cost and predictable performance. Li-ion batteries are very energy dense, are becoming less expensive and make all-electric or hybrid-electric power systems possible on some types of vessels. There are many unique safety concerns related to Li-ion battery installations which are addressed here. Battery technology is rapidly developing and users should be aware of additional safety practices unique to each particular battery chemistry.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.10 on Electrical.

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2. Referenced Documents

2.1 IEC Standards:²

IEC 62619 (2017) Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes — Safety Requirements for Secondary Lithium Cells and Batteries, for Use in Industrial Applications

2.2 UL Standards:³

UL 1642 Standard for Safety: Lithium Batteries

2.3 United States Code of Federal Regulations (CFR):⁴

CFR Title 46 Shipping

2.4 ABS Standards:⁵

ABS Guide for Use of Lithium Batteries in the Marine and Offshore Industries

3. Terminology

3.1 Definitions:

3.1.1 *anode, n*—the negative terminal of the battery.

3.1.2 *battery management system (BMS), n*—a system that provides comprehensive battery monitoring, control, and charging for the battery or battery bank. The BMS also detects and alarms to indicate potentially dangerous conditions.

3.1.3 *battery size categories, n*—installation sizes are based on the total energy storage capacity of all Li-ion batteries in the battery system. If multiple storage banks are installed, each installation may be sized separately if it can be shown that a failure in one battery bank will not propagate to the other.

<50 kWh—an installation with less than 50 kWh total energy storage capacity.

>50 kWh—an installation with greater than 50 kWh total energy storage capacity.

3.1.4 *capacity, n*—the number of ampere-hours which can be delivered by a battery on a single charge/discharge. The

² Available from International Electrotechnical Commission (IEC), 3, rue de Varembe, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, <https://www.iec.ch>.

³ Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

⁴ Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, <http://www.access.gpo.gov>.

⁵ Available from American Bureau of Shipping (ABS), ABS Plaza, 1701 City Plaza Dr., Spring, TX 77389, <http://www.eagle.org>.

battery capacity is determined by a number of factors, including the cutoff voltage, discharge rate, temperature, method of charge, and the age and life history of the battery.

3.1.4.1 *variations on capacity definitions, n*—for various reasons, a vendor may define a nameplate capacity, which is de-rated from the actual (electrochemical) capacity. Careful review of the cell ratings, battery design, etc., should be made to ensure that the assessed/controlled/accessible capacity is consistent with the installed capacity.

3.1.5 *cathode, n*—the positive terminal of the battery.

3.1.6 *cell, n*—an electrochemical device, composed of positive and negative electrodes and electrolyte, which is capable of storing electrical energy.

3.1.7 *electrolyte, n*—the solution in which the battery electrodes are immersed. This is typically composed of an organic solvent and dissolved lithium salt. The electrolyte may be flammable depending on the particular composition of the battery.

3.1.8 *lithium-ion (Li-ion), n*—a family of battery chemistries which contain metallic lithium, a lithium alloy, or a lithium ion, and may consist of a single electrochemical cell or two or more cells connected in series, parallel, or both, that convert chemical energy into electrical energy by an irreversible or reversible chemical reaction. This guide does not differentiate between the several unique chemistries that make up the family of Li-ion batteries. Special attention should be paid to the electrolyte fluid, as it is typically flammable.

3.1.9 *module, n*—a group of cells connected together in a series or parallel configuration, or both, with or without protective devices and monitoring circuitry.

3.1.10 *pack, n*—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.

3.1.10.1 *battery nomenclature, n*—a battery may share the nomenclature of the pack, if only a single pack is utilized within a system. If multiple packs are utilized in parallel, to meet a common requirement, it should be depicted as the integer number of packs. For example, a large system could be composed of ten each, 5P30S packs. It should be clearly defined in terms of number of packs, electrical configuration of the packs, and how the packs are isolated from each other in terms of electrical architecture.

3.1.10.2 *battery structure, n*—typically, batteries are defined in terms of their series and parallel cell configurations. Packs are increased in series to add end-to-end voltage; they are increased in parallel to add total energy content at a given potential. Batteries are built from modules and packs, and for the purpose of this guidance, a “battery” may consist of multiple packs in parallel; separated and segregated by electrical systems (for example, individual converters) or physical barriers, or both; but serving a common load, bus, or similar purpose.

3.1.10.3 *battery system, n*—system comprised of one or more cells, modules, or battery packs. It has a battery management system (BMS) to maintain the condition of the system.

3.1.10.4 *pack nomenclature, n*—in accordance with the basis defined in *battery structure* (3.1.10.2), the parallel/series configuration should be defined by the structure of the packs, as this is the structure where faults may influence cells and modules in a direct manner. The pack design may consist of a single series string of cells, multiple parallel strings consisting of single serial strings of cells, or serial strings of multiple cells connected in parallel. For example, a single serial string of 30 cells with no cells in parallel, would be defined as a “1P30S” pack. A pack consisting of groups of five cells in parallel and 30 of these parallel cell groups would be defined as a “5P30S” pack. A pack consisting of five individual series strings of 30 cells each, would be defined as a “30S5P” pack.

3.1.11 *state of charge (SOC), n*—the ratio of the amount of capacity remaining in a battery to the full charge capacity. This may be determined by voltage measurements, energy flow (for example, coulomb counting) or other methodologies. In theory, a battery at 25 % state of charge has 25 % capacity remaining (runtime or energy output) versus what it provides from fully charged. Consistent with *variations on capacity definitions* (3.1.4.1), the state of charge reported of a battery may be different from the ratio of installed electrochemically active material.

3.1.12 *state of health (SOH), n*—the ratio of the present health of the battery compared to a new battery. Capacity and power capability are parameters usually associated with battery health. For example, if actual battery capacity has degraded to 80 % of the nameplate capacity, the SOH would be considered 80 %. The state of health parameter is often proprietary in nature, and may align to a variety of characteristics, including impedance (power capability or voltage drop), accessible capacity in the correct electrochemically active voltage range, etc.

4. Summary of Guide

4.1 Li-ion batteries comprise a wide range of unique battery chemistries and physical characteristics. Vessel designers, system integrators, and onboard operators should take particular note of recommendations and operating requirements prescribed by the battery manufacturer. The use of Li-ion batteries in applications outside of the intended purpose can present significant hazards (for example, using a high-power battery for a high-energy application).

5. Testing Requirements

5.1 *Battery Testing*—Li-ion batteries should be tested to either UL 1642 or IEC 62619 (2017). The tests in [Table 1](#)

TABLE 1 Li-Ion Battery Tests

Battery Tests	IEC 62619 (2017)	UL 1642
External short-circuit	7.2.1	10
Impact	7.2.2	14
Thermal abuse	7.2.4	17 and 18
Overcharge	7.2.5	11
Forced discharge	7.2.6	12
Internal short-circuit	7.3.2	
Propagation	8.3.3	

