Top 11 Lithium Ion Battery Regulations

Lithium ion batteries have received increased scrutiny due to a number of high-profile events that have brought undesired attention to the industry. In the past few years, many new regulations have been created to ensure the safety of lithium ion batteries and products incorporating lithium ion batteries.

Li-ion Tamer® develops products to improve battery safety and to ensure adherence to safety regulations. This article is meant to share some of the knowledge we have gained in hopes to ensure that lithium ion batteries are created safely and solidify this technology's place in our future.

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1&2 TIE - UN DOT 38.3 & IEC 6228: Safety of primary and secondary lithium cells and batteries

UN DOT 38.3 and IEC 62281 are the most important regulations to adhere to because, regardless of the application, batteries will need to be shipped and, therefore, need to adhere to these regulations!

In order to ship lithium ion battery cells or packs in the USA, lithium ion batteries must pass the eight tests in the UN DOT 38.3 regulation. In order to ship internationally, batteries must pass nine tests in IEC 62281, which are similar to the eight tests in UN DOT 38.3 with an extra drop test. UN DOT 38.3 and IEC 62281 consist of the most fundamental tests a safe battery should pass and many other regulatory bodies refer to these tests as a part of their pass criteria.

These regulations try to cover reasonable misuse scenarios such as impact, shock and vibe, as well as demonstrating the battery's ability to survive typical shipping conditions (thermal cycling, altitude simulation). In order for cells to be shipped anywhere, they must adhere to these regulations.

- The United Nations issues recommendations for the transport of dangerous goods worldwide, including lithium ion batteries
- The US DOT defines shipping regulations for the US under 49 CFR 173.185
- Together, both organizations have combined to defined UN DOT 38.3 which consists of tests and requirements for the safe packaging and shipment of lithium ion batteries
- UN DOT 38.3 can be self-declared, but liability lies with the organization who claims compliance; third party organizations exist that perform certification services
- UN DOT 38.3 pass criteria involve no battery disassembly or fire

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- IEC 62281 is similar to UN DOT 38.3 in that it is IEC's recommended criteria for transport and shipping of lithium ion batteries
- IEC 62281 is a more internationally accepted version of UN DOT 38.3, whereas UN DOT 38.3 is largely accepted in the USA
- The two requirements are detailed and compared in the Table to the right

Table 1. Comparing UN DOT 38.3 and IEC 62281

	UN DOT 38.3	IEC 62281
External short circuit	x	x
Abnormal charging	x	x
Forced discharge	x	x
Impact	x	x
Shock	x	x
Vibration	x	x
Thermal cycling	x	x
Altitude simulation	x	x
Drop		x

3 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

With large format lithium ion batteries starting to become more common in industrial applications, IEC 62619 comes in at third on our list because of how broadly it can be applied and how it dictates the system-level design parameters of large format lithium ion batteries.

This regulation deals with batteries on a system level and defers to other regulations, such as IEC 62133, for cell level standards. IEC 62619 ensures batteries are designed for their application and has several failure scenario tests. For example, the BMS is pushed to operational regions where it should not function and mitigating actions are observed (e.g. shutdown of module or system).

Propagation tests are also utilized to demonstrate the ability of module designs to contain full-fledged battery events. This regulation is already very important and as more industrial batteries become installed, this regulation will continue to develop to adjust to lithium ion battery industry innovations.

- IEC 62619 is a standard for lithium ion batteries used in industrial applications
- This standard has guidelines for large format lithium ion batteries
- There are tests specific to the battery management system (BMS) which cover general requirements, overcharge control of current, overcharge control of voltage, and overheating control
- There are also electrical and mechanical tests such as external short-circuit tests, impact tests, drop tests, thermal abuse tests, overcharge tests, and forced discharge tests
- The electrical and mechanical tests take place on the cell or cell block, therefore the nature of the overcharge tests will be different from the battery management system overcharge tests
- The drop tests consist of both battery cell level drop testing and battery system level drop testing

- There are also general safety considerations for assembly of the cells, modules and packs into battery systems, insulation and wiring, venting, and temperature/voltage/current measurements
- The venting requirement in the general safety considerations consists of cell, module, pack and system level venting
- An approval of the battery system design is necessary and the operating region of the battery systems for safe use needs to be defined
- IEC 62619 also requires a propagation test where one cell in a fully chargevvd battery system is heated until the cell enters thermal runaway
  - After thermal runaway is initiated the heater is turned off and the battery system is observed for one hour
  - Pass criteria requires no external fire from the battery system or battery module rupture

4 DNV GL Rules for classification of ships – Part 6, Chapter 2, Section 1 Battery Power

DNV GL, a maritime classification society, has developed a very comprehensive set of prescriptive rules for implementing lithium ion batteries on ships. These rules have a degree of scrutiny not seen in other applications and, therefore, we have put this ruleset as fourth on our list. Regardless of application, when a dedicated space is being created for batteries, these rules can be used to help guide the installation and design process to have a safe lithium ion battery.

In Europe, many vessels, in an effort to be more environmentally friendly, are shifting away from combustion engines to lithium ion batteries. The maritime lithium ion battery industry is aware of how a catastrophic battery event will destroy this young industry's reputation. Therefore, DNV GL has developed strict guidelines for implementing lithium ion batteries on ships.

The rules are largely prescriptive and have the most comprehensive guidelines, even reaching beyond the lithium ion battery system itself and advising how battery spaces should be designed. The level of detail of the guidelines will help other industries and rulemaking organizations when trying to create rules for deploying large format lithium ion batteries.

These rules dictate the design principles for battery spaces and battery systems

- Battery spaces require
  - Risk analyses
  - Fire integrity management
  - Fire control plans
  - Fire extinguishing system documentation
  - Fire detection arrangement
  - Fire detection system
  - Ducting diagrams and ventilation systems
  - Gas detection systems
- Battery systems require
  - Safety descriptions
  - Function descriptions
  - Power supply arrangements
  - Circuit diagrams
  - Calculation reports (SOH and SOC)
  - Operational manual
  - Maintenance manual

Extensive testing is also necessary including

- IEC 62281/UN DOT 38.3 tests on cells
- IEC 62619 system level testing
- Sensor failure mode testing
- Functional safety testing
  - Emergency stop functions
  - Alarms and shutdowns
  - BMS temperature protection
  - BMS overvoltage protection
  - BMS undervoltage protection

UL 1642: Standards for Lithium Ion Batteries

Lithium ion battery cells are the building blocks of a pack or module and need to be held to certain standards which is the purpose of UL 1642. This regulation has its place on this list because regulating and ensuring lithium ion batteries at the most fundamental level, the cell level, are designed safely is critical to the any and every application where they are used.

UL 1642 is a cell focused test that where the cells are passed through a multitude of tests demonstrating their ability to handle relatively extreme conditions. Many of these tests are similar to shipping regulations such as UN DOT 38.3 or UL 1642, but are directed specifically at lithium ion battery cells being used in technician- or user-replaceable applications. UL 1642 is referenced in many pack-level UL certifications, such as UL 2054, UL 2271, and UL 2580. Therefore, the cells must adhere to UL 1642 in order for packs to be constructed as UL certified.

- The UL 1642 certification is a cell level requirement that ensures any electrochemical device with 1.0 g of lithium and less than 5.0 g of lithium used for energy storage is safely manufactured
- UL 1642 applies to cells used in the USA
- Commonly used battery cells are likely already tested to the UL 1642 standard by a third-party laboratory
- UL 1642 tests consist of
  - Short-circuit
  - Abnormal charging
  - Forced-discharging
  - Crush
  - Impact
  - Shock
  - Vibration
  - Heating
  - Temperature cycling
  - Fire exposure

6 UL 62133/IEC 62133: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications

Similarly to UL 1642, IEC 62133 is a cell level certification but is internationally accepted, whereas UL 1642 is generally accepted only in the USA.

Similarly to UL 1642, IEC developed a cell-level standard for lithium ion batteries as IEC 62133. This standard is more internationally accepted than UL 1642 and has a few more tests beyond the UL 1642 tests, including drop, continuous low-rate charging, and an internal short circuit test. UL has also adopted UL 62133 which is the same standard as IEC 62133 for harmonization purposes. The Table below summarizes a comparison between UL 1642 and UL/IEC 62133.

Table 2. Comparison between UL 1642 and IEC 62133

	UL 1642	UL/IEC 62133
Short-circuit	x	x
Abnormal charging	x	x
Forced discharge	x	x
Crush	x	x
Impact	x	
Shock	x	x
Vibration	x	x
Heating	x	x
Temperature cycling	x	x
Altitude simulation	x	x
Fire Exposure	x	
Drop		x
Continuous low-rate charging		x
Internal Short Circuit		x

7, 8 & 9 Tie: UL 2054, UL 2271, and UL 2580

Lithium ion batteries are being used in many commercial applications, such as electric shavers, E-bikes, or electric vehicles. Every application has a unique version of environmental, electrical, and mechanical tests a pack must survive in order to be approved. Among these pack level certifications, UL 2054, UL 2271, and UL 2580 are the most common which is why they are an important regulation to be aware of.

UL has many pack-level certifications and the capacity of the lithium ion battery pack and intended application largely dictate which pack-level certification is necessary. For example, batteries intended for smaller, rechargeable devices such as electric shavers with capacities less than 10 Ah are tested according to the UL 2054 (Standard for household and commercial batteries) certification. Mobile products such as E-bikes or robotics products which have larger loads and require longer duty cycles are tested according to UL 2271 (Batteries for use in Light Electric Vehicle Applications) and electric vehicle and heavy-duty robotics products lithium ion battery packs are tested to UL 2580 (Batteries for use in Electric Vehicles).

- UL 2054: Standard for Household and Commercial Batteries
- UL 2271: Batteries for Use in Light Electric Vehicle (LEV) Applications
- UL 2580: Batteries for Use in Electric Vehicles
- These UL certifications are the most common pack level requirements for larger lithium ion batteries that consist of multiple lithium ion batteries in series or parallel within an enclosure and with a battery management system

Table 3. Typical battery capacities for UL battery pack level certifications

	UL 2054	UL 2271	UL 2580
Typical capacity (Ah)	< 10	10 - 20	20 +

- The certification tests defer cell level requirements to UL 1642
- The following tables summarize the electrical tests, mechanical tests, and environmental tests for each certification

Table 4. Environmental tests required for the UL certifications

	UL 2054	UL 2271	UL 2580
Heating	x		
Temperature cycling	x	x	x
Altitude simulation			
Immersion		x	x
Water exposure (IP Code Rating)		x	
Label Permanence		x	
Salt Spray			x
External Fire Exposure	x		x
Internal Fire Exposure			x

Table 5. Electrical tests required for the UL certifications

	UL 2054	UL 2271	UL 2580
Short-circuit	x	x	x
Abnormal charging	x		
Forced-discharging	x		
Abusive overcharging	x	x	x
Limited power source	x		
Battery component temperature	x		
Battery pack surface temperature	x		
Overdischarge		x	x
Imbalance charging		x	x
Dielectric voltage withstand		x	x
Isolation resistance		x	x
General temperature			x
Continuity			x
Internal Short Circuit			x
Failure of cooling/thermal stability system			x

Table 6. Mechanical tests required for the UL certifications

	UL 2054	UL 2271	UL 2580
Crush	x	x	x
Impact	x		
Shock	x		
Vibration	x	x	x
General enclosure	x		
250 N steady force enclosure	x		
Mold stress relief	x		
Drop impact		x	x
Roll over		x	x
Strain relief (cords)		x	x
Handle loading		x	x
Rotation			x

10 NMA Circular Series V

Norway has employed rules which require all boats entering its ports to be zero emission. This necessitates fuel cells and/or lithium ion battery technology to be utilized when entering Norwegian ports. This ruleset has its place on this list because it has largely influenced the battery module and battery system designs of many system integrators so they can enter Norwegian ports.

The NMA has released a Circular Series which is directed at battery integrators providing an explosion and gas analysis of their battery systems during failure. Propagation tests are a large part of these explosion analyses and dealing with failing batteries within modules has largely dictated the direction of module-level innovations for battery integrators.

- Norway is at the forefront of deploying batteries for marine systems and is targeting that ships with installed battery systems maintain the same level of safety as conventional ships. In order to achieve this, the Norwegian Maritime Authority has very strict rules for implementing battery systems on marine vessels.
- The NWA Circular Series V is a set of rules that focus on large format lithium ion batteries
- The intent of the circular is to provide an explosion analysis (Section 5) informed by propagation testing of failed cells (Section 3) and an analysis of the potential for gas release (Section 6).
- The rules emphasize that failures should not propagate outside of the module where the failure has occurred
    - Battery modules consist of several cells within an enclosure and a battery management system (typically 5 - 10 kWh in capacity)
    - Large format lithium ion batteries on marine vessels consist of many modules if they are to be used for auxiliary power
- There are two tests in the NMA Circular Series V, Propagation Test 1 and Propagation Test 2
- Both Propagation Tests consist of the following elements
    - A cell failure should be initiated within a battery module by either overheating or overcharging
    - The module should be surrounded by other modules and arranged similar to the rack system design as intended to be used on ships
    - The cell being failed should be in the least favorable position
    - The module with the least favorable position should be where the cell failure is initiated and the cell within the module should be in the least favorable position
    - All cells within each module should be at 100% SOC
    - The battery management system should be non-functioning
- In Propagation Test 1, the module where the cell was failed should completely contain the battery event and no propagation to neighboring modules can occur
    - This must be done without the usage of external safety systems, such as fire extinguishing
- In Propagation Test 2, non-propagation must occur, but the usage of external safety systems can be used
- The crucial difference between Test 1 and Test 2 is that Test 1 identifies modules that are designed to be inherently safe and can contain battery events without external means

11 IEC 61508: Functional safety of electrical/electronic/programmable electronic

The battery management system is a critical aspect of lithium ion batteries and, therefore, the standard which they are held to is very important as well, which is why this regulation sneaks its way into this top regulations list.

Instrumented safety systems are crucial to many industrial processes and even more crucial to lithium ion batteries because of how little room for error there is in their operation. Batteries which enter outside of their voltage range quickly become unstable and can cause catastrophic events when not dealt with properly. The job of a battery management system is to ensure that cells are properly balanced and that batteries are not operated outside of their ideal temperature, experience higher current draw than they are designed for, and stay within the ideal operational voltage window. IEC 61508 is the standard which battery management systems are held to.

- IEC 61508 is the standard that battery management systems are held to
- For large format batteries, pack controllers are also held to this standard
- In this standard, the EUC or equipment under control are the lithium ion batteries and the EUC control system is the battery management system
- The EUC risks are the risks associated with lithium ion batteries (such as overcharge, overdischarge, overtemperature, overcurrent, etc.)

This standard consists of seven parts

1. General requirements: defines the activities to be carried out at each stage of the overall safety lifecycle, documentation, conformance to the standard, management, and safety assessments
2. Requirements for electrical/electronic/programmable electronic safety-related systems: define the general requirements of Part 1 in the context of hardware
3. Software requirements: define the general requirements of Part 1 in the context of software
4. Definitions and abbreviations: gives definitions of the terms used
5. Examples of methods for determination of safe try integrity levels: provides risk-analysis examples and demonstrates the allocation of safety integrity levels
6. Guidelines on the applications: offers guidance as per its title
7. Overview of techniques and measures: provides brief descriptions of techniques used in safety and software engineering

This standard helps develop safety functions by

- Identifying and analyzing risks
- Determining the tolerability of each risk
- Determining the risk reduction necessary for each intolerable risk
- Specify the safety requirements for each risk reduction, including their safety integrity levels
- Design safety functions to meet the safety requirements
- Implement the safety functions
- Validate the safety functions

Other regulations and requirements just outside of the top 11:

IEC 60529 Degrees of protection provided by enclosures (IP Code) Edition: 2.2 (2013)

- This IEC standard regulates the IP rating of battery enclosures

DNV GL CP-0418 Type Approval of lithium batteries

- This DNV GL certification is for regulating lithium ion battery cells used on marine vessels, similar to UL 1642 or IEC 62133

IMO MSC.1/Circ. 1455 Guidelines for the Approval of Alternatives and Equivalents as Provided for in Various IMO Instruments

- This risk based approach enables innovation that is feasible in design but is not adequately controlled by prescriptive regulations. It is being applied to approval of lithium ion battery system for marine power system.

Regulations can be tricky, but we can help you with them. Start working with one of our battery safety experts while you navigate the waters.

Contact us to learn more about lithium ion battery regualtions and how you can increase the safety of lithium ion batteries and systems.

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