Risk Bulletin

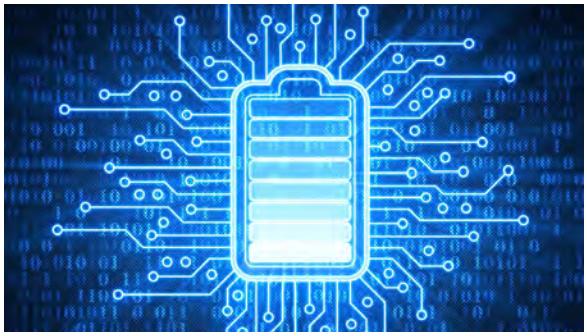
2017

Allianz Global Corporate & Specialty®

Lithium-Ion Batteries

Allianz Risk Consulting

Introduction



Source: iStock

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices. A battery may contain one or multiple cells that convert chemical energy into electrical energy. **Lithium-ion batteries** are a member of a family of rechargeable battery types in which lithium-ions move from the negative electrode to the positive electrode during discharge and back when charging. They are the most widely used type of rechargeable batteries today and are common in home electronics, mobile electronics, medical applications and industrial applications. Beyond consumer electronics, lithium-ion batteries are also growing in popularity for military and electric vehicles as well as aerospace and marine applications.

This risk bulletin is issued in support of raising the awareness of businesses involved in the manufacturing, packaging, transporting, usage and storage of these types of batteries, as well as products containing these types of batteries.

Advantages and disadvantages

Lithium-ion batteries are popular for the following reasons:

- They are lighter than other types of rechargeable batteries of the same size, due to electrodes, which are made of lightweight lithium and carbon
- Because lithium is a highly reactive element, a lot of energy can be stored in its atomic bonds, thus lithium-ion batteries carry a very high energy density
- They have a low self-discharge over time compared to other batteries
- They have a small memory effect there is no need to completely discharge the battery before recharging, as required by some rechargeable batteries
- They can handle hundreds of charge/discharge cycles over their lifetime

Despite the huge advantages of lithium-ion batteries, there are disadvantages that should be noted:

- Lithium-ion batteries begin degrading soon after being manufactured and will typically last 2 to 3-years from the date of manufacture, whether used or not
- Heat causes lithium-ion batteries to break down faster than normal, so their sensitivity to high temperatures must be considered. Storage in a cool place slows the aging process of lithium-ion batteries. Manufacturers recommend storage temperatures of 15°C (59°F)
- A lithium-ion battery pack requires an on-board computer (battery charge state monitor) that handles the entire charging process to make sure the batteries charge as quickly and fully as possible. This on-board computer draws power from the batteries, causing the batteries to lose power over time

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- If completely discharged, a lithium-ion battery is ruined
- If a lithium-ion battery pack should fail or be damaged, it could ignite or explode, due to the flammable electrolyte contained and pressurized in these batteries. Over the past several years, in response to reported accidents and failures, there have been several lithium-ion battery-related recalls

Source: iStock

Potential safety issues

Battery manufacturers and manufacturers of battery-powered products design their products to deliver specified performance characteristics in a safe manner under anticipated usage conditions. As such, poor performance or safety failures can be caused by poor design, or an unanticipated use or abuse of the product. The lithium-ion cell is safe if carefully controlled. If not controlled, serious problems can occur. Lithium-ion batteries are more energy dense, meaning they have more stored energy and are potentially more dangerous. Potential causes of safety events involving lithium-ion batteries can be grouped into three categories:

- Over-charging
- Over-temperature
- Mechanical abuse

Over-charging of a lithium-ion cell is the most serious of potential events, although least likely. Charging systems are well controlled, and those operating with lithium-ion batteries typically have a communication link through which the battery can send alarms related to overcharging and other conditions. If the charger fails to respond to such alarms the battery will open switches to isolate itself.

Over-temperature results when Lithium-ion batteries are subjected to high temperatures, which would be caused by one of the three following sources: from high ambient temperatures; internal heating of the cell during use and internally generated heat from a short-circuit cell failure. Above 100°C (212°F) internal breakdown can occur, causing a thermal runaway event. If a battery gets hot enough to ignite the flammable electrolyte, a fire and/or explosion is likely.

Mechanical abuse is generally in the form of crushing or penetration of the lithium-ion cells, both of which can result in short circuits. Such abuse is most likely to occur during transportation and installation. Many lithium-ion batteries are shipped in a partially charged state to limit the possible safety consequences.

Transportation

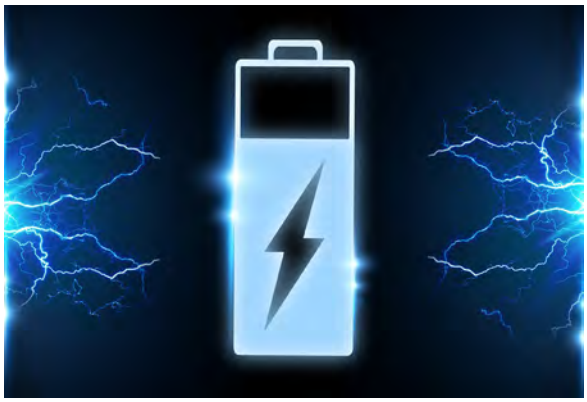
Both from an engineering standpoint in the operation of marine vessels as well as cargo being transported on vessels and other modes of transportation, Lithium-ion batteries have proven to be dangerous and a risk to public health and property when improperly cared for. Numerous incidences over the past few years have been documented involving Lithium-ion batteries and have negatively affected businesses from both the loss itself as well as from a loss to their reputation and brand name. Examples include the new 787 Dreamliner aircraft, fire damage to a marine vessel's engine room, various makes of hovercrafts, e-cigarettes, laptop computers and recent smartphones, just to name a few that have made news headlines.

According to a US Federal Aviation Administration (FAA) report[1], a total of 80 aviation incidents have occurred involving lithium batteries since 2011. Of the 80 aviation incidents that have been documented over the past 6 years, 31 of them occurred in 2016, which amounts to almost double the incidents in 2015. In order to reduce this increasing incident rate, both the US FAA and the Pipeline Hazardous Material Safety Administration (PHMSA) have issued numerous advisory bulletins and posters in an effort to alert the general public of the safety issues and ongoing regulatory changes. The transportation of lithium-ion batteries in commerce is regulated as a hazardous material (dangerous goods) for all modes of transportation in both the international arena, as well as domestically here in the United States.

The regulations governing shipments of lithium-ion batteries by aircraft between countries can be found in the International Civil Aviation Organization's (ICAO) set of instructions and annexes that are developed by The Dangerous Goods Panel within ICAO. For international vessel shipments, the International Maritime Organization's (IMO) International Maritime Dangerous Goods Code (IMDG) would take precedence. Both of these organizations are specialized branches of the United Nations (UN). Based on recent experiences, it can be expected that these regulations will continue to be

1. Lithium Batteries and Lithium Battery-Powered Devices, FAA Office of Security and Hazardous Materials Safety, Bulletin, Dec. 22, 2016

amended as additional research is completed (providing more knowledge about the hazards associated with transporting these batteries) and, unfortunately, as new incidents come to light. Within the US, the regulations governing the transportation of lithium-ion batteries can be found in Title 49 of the Code of Federal Regulations (CFR), which governs shipping.



Source: iStock

Although it is not within the scope of this risk bulletin to go into all of the detailed requirements found within those regulations (in order to be in compliance with the hazardous materials (hazmat) regulations), it is within this bulletin's scope to provide the following general information:

- Formal training and record keeping is required of all employers who are involved in the transportation of hazardous materials, including lithium-ion batteries, whether being shipped as standalone batteries, or contained or packed in equipment
- Hazmat regulations also apply to lithium-ion batteries used in battery-powered vehicles, such as wheelchairs, golf carts, lawn vehicles, motor scooters and even hover boards
- Manufacturing and packaging of lithium-ion batteries must meet all of the recommendations found in Section 38.3 of the United Nations Manual of Tests and Criteria . Testing of lithium batteries under this standard is required by US regulation for transportation
- Packaging and quantity limits (if applicable) of lithium-ion batteries being transported must be in compliance with the mode of transportation being used. Specific declarations on way bills or bill of ladings must be appropriate for the shipment
- All required markings and labels must be applied to the packaging as required by the regulations
- All packages must be adequately secured to prevent movement while being transported
- Specific exceptions or exemptions may apply to certain shipments

Manufacturing and packaging processes are keys to keeping lithium-ion batteries safe during transportation. Lithium-ion batteries may become a source of ignition if overcharged, mishandled, short circuited, heated to high temperatures or if produced with manufacturing defects. If damaged during transportation some lithium-ion batteries may release a flammable electrolyte mixed with other flammable gas compounds. It is for these reasons that importers as well as shippers of lithium-ion batteries must be keenly aware of these compliance issues and ensure that their shipments meet all regulations that apply.

Marine Applications

As lithium-ion batteries continue to grow in their usage and evolve to suit the demands of our society, so will the need for continued research and development.

We have already begun to see an increase in the application of this energy resource in the maritime industry from an engineering point of view on both large commercial vessels as well as small private vessels. According to a recent US Coast Guard (USCG) article[2] the Marine Safety Center has reviewed plans for vessels having all-electric and hybrid-electric propulsion systems.

Lithium-ion batteries in a rack on a marine vessel. Source: USCG

With these systems comes the need to store the electrical power and lithium-ion batteries are among the quickly advancing energy storage system options. There are various reasons for the growth in popularity in the marine industry as previously discussed, however the USCG feel that the safety margins have not kept up with the rapid growth and changes in their application. The thermal runaway event which led to a lithium-ion battery fire on a US flagged hybrid-electric towing vessel in the port of Los Angeles in 2012 is an example of the lack of safety of Lithium-ion batteries.

2. LT Stephen Lewis, Lithium-ion Batteries are Heating Up, Marine Safety Engineering, Dec. 2016.

Currently, the regulations found in Title 46 CFR do not address this type of battery and therefore the USCG is in the early stages of developing a policy to address the associated hazards. The USCG's Marine Safety Center is currently evaluating any new battery installations on a case-by-case basis.

Burned out lithium-ion battery
Source: USCG

The USCG however, is not the only entity with a vested interest in the research and development of this growing technology. The US Department of Defense (DoD) also sees a multitude of applications for the battery's technology and has been involved in their own research and development at various commands. The Naval Surface Warfare Center's (NSWC) crane division has invented a new battery charger and power reduction system and method that may resolve some of the hazards associated with the battery. This new Battery Charger[3] is a "shunt-type, lithium-ion battery-charging device that is designed to reduce the likelihood of overcharging and the possible deleterious effects (and cooling requirements) that are associated with the generation of heat during the charging process".

As marine applications continue to grow in this area, so should the safety measures as well as the regulations and the best practices, in order to reduce the risks associated with the lithium-ion battery.

Loss Prevention

Since the rapid growth of lithium-ion batteries into commercial and industrial applications, little data exists relative to storage and fire response guidelines. Ongoing research will eventually present guidelines relative to the safe storage, fire management and fire suppression issues of these types of batteries. Proper planning, risk assessment, storage methods and response protocols can help to manage the fire risks of lithium-ion batteries.

1. Storage/Transport

In 2016, FM Global along with the Property Insurance Research Group (PIRG) and the National Fire Protection Association's (NFPA) Fire Protection Research Foundation[4] released data and guidance relative to flammability characteristics of lithium-ion batteries. The report, which detailed large-scale fire tests of lithium-ion batteries in warehouse storage, represents the first sprinklered fire tests of lithium-ion batteries. The test results confirm the following:

- Bulk storage of small-format lithium-ion batteries (i.e., 2.6 Ah) exhibits similar fire growth as cartoned commodities
- The time required for involvement of lithium-ion batteries in a fully developed fire is on the order of 5-minutes
- Lithium-ion batteries present several unique fire hazards when involved in a fire, due to the ignitable electrolyte liquid contained within such products
- Densely packed lithium-ion cylindrical cells behave differently than lithium-ion power tool packs in such fires
- Early fire extinguishment and cooling of the lithium-ion batteries in bulk format is imperative to properly protect a facility
- Existing protection solutions used for other types of high hazard products and materials can be effective for protecting lithium-ion batteries stored in bulk arrangements

These conclusions provided the basis for sprinkler protection recommendations for small-format lithium-ion batteries in bulk storage. **Caution should be taken when extending these guidelines to lithium-ion storage arrangements that are different in packaging, battery size, configurations, etc.**

Though formal standards and guidelines by which to manage the lithium-ion battery fire issues have not been completed, storage and transport strategies have been developed that help manage the associated risks. An effective strategy for storing lithium-ion batteries is to provide fire containment and suppression systems that would deal with the battery fire event. Primary consideration in this approach is that batteries are housed in environments that feature fire suppression systems that extinguish through cooling. Suppressing a lithium-ion battery fire is best accomplished by cooling the burning material.

3. Battery Charger and Power Reduction System and Method – Market Overview, FirstLink, DoD National Center of Excellence for First Responder Technology Transfer, NSWC – Crane Division (ND).
4. Flammability Characterization of Lithium-ion Batteries in Bulk Storage, Research Technical Report, FM Global 2016.

Another strategy is that lithium-ion batteries should be isolated from other battery chemistries and commodities (storage, transport, etc.). They should be stored (shipped) in environments that would effectively contain fires and toxic burn by-products. This is essential to health, safety, and preservation of property. Close attention should be paid to isolating batteries from general facilities by developing external storage or "satellite" storage. Battery storage farms would allow for storage off-site with just-in-time (JIT) delivery of batteries to a facility when needed. Batteries should be partially charged during storage. Most manufacturers recommend a 40% charge.

The storage of equipment that incorporates lithium-ion batteries (power tools. cell phones, laptops, etc.) does not present the same hazard as battery storage because the equipment that typically encases the batteries significantly delays their involvement in a fire incident. Therefore, protection for the storage of these items can usually be based on the commodity classification of the product. This will typically be driven by the housing of the product, the packaging and the pallet.

2. Training

Since lithium-ion batteries present critical challenges to facilities that possess them, it is recommended that training be included in any risk management strategy. Facilities and individuals alike should be aware of the unique hazards that these batteries present.

Companies that possess lithium-ion batteries in high quantities should work with experts to develop training that seeks to mitigate the fire issues and ensures additional layers of safety. Training might address issues like battery awareness or include more detailed situational training such as battery fire behavior, emergency response procedures and fire extinguisher use (lithium-ion battery focus). This type of training lends itself well to the preservation of property, as well as life.

3. Standard Operating Procedures

Effective lithium-ion battery standard operating procedures (SOP's) should include processes that guide shipping and receiving, handling, daily use, storage and other functions involving the batteries. Proper SOP's should address every facet of the battery life cycle. Businesses that are involved in the storage and transportation of lithium-ion batteries would be well advised to develop a unique SOP.

4. Emergency Response Procedures

Lithium-ion battery fires shouldn't be treated like common fires as the burn characteristics and toxic by-products released are different than fires involving other materials. The level of risk should be determined through proper assessment and businesses should create emergency response procedures based on sound response and battery handling data.

Close attention should be paid to Safety Data Sheets (SDS, formerly MSDS) and other suggestions from manufacturers and distributors. These documents prescribe possible methodologies for proper storage, handling and emergency response. It should be noted that SDS recommendations can sometimes vary widely and at times are quite different, ultimately adding to some confusion, although some of the suggestions can be used to develop a strong lithium-ion battery management process.

Technology Moving Forward

It should be noted that as this bulletin was being prepared, the US Public Broadcasting System (PBS) aired an episode of the popular science-based television program called "NOVA" entitled "Search for the Super Battery[5]" which discusses the rapidly evolving field and explores a new technology (solid plastic electrolyte) which may eliminate the common hazards and risks associated with Lithium-ion batteries.

Lithium-ion battery on bike luggage carrier
Source: iStock

5. Search for the Super Battery, NOVA, Feb. 1, 2017 - http://www.pbs.org/wgbh/nova/tech/super-battery.html

For further information:

Captain Randall Lund
Senior Marine Risk Consultant
Allianz Risk Consulting
randall.lund@agcs.allianz.com

Justin Kersey
Senior Marine Risk Consultant -
Inland Marine & Related Property
Allianz Risk Consulting
jkersey@aic-allianz.com

Design: **AGCS Graphic Design Centre**