Sunderland Marine

Safe Home

Lithium-ion battery fire risk

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Introduction

The use of lithium-ion batteries is becoming increasingly widespread in our life and work. From personal devices to vehicles to even vessel propulsion, the technology is constantly improving, resulting in batteries packing more power.

However, this rise in the use of lithium-ion batteries has brought with it new risks, in particular fire.

The Lithium-ion Battery

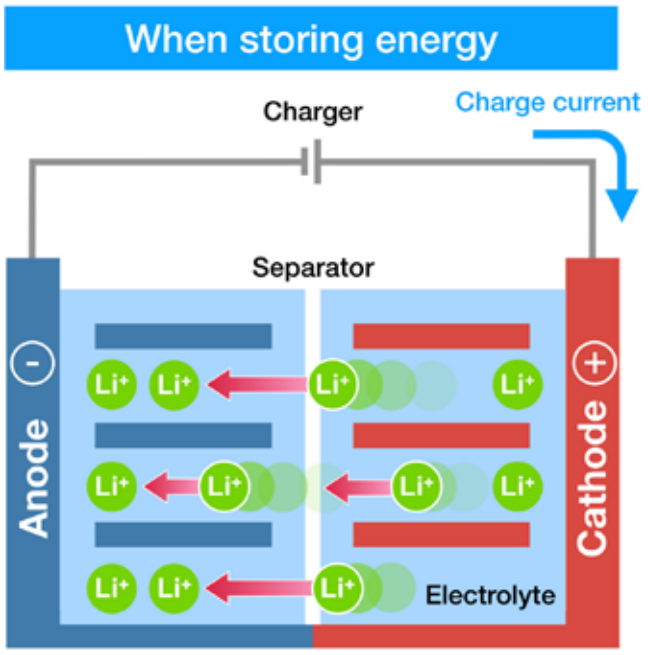
Lithium-ion (Li-ion) batteries are rechargeable batteries which are popular due to being light in weight and their high energy density (i.e., the amount of energy it can store in a given space).

In simple terms, the battery is made up of lithium-ion cells connected together, each cell consisting of an anode, cathode, electrolyte, and a separator.

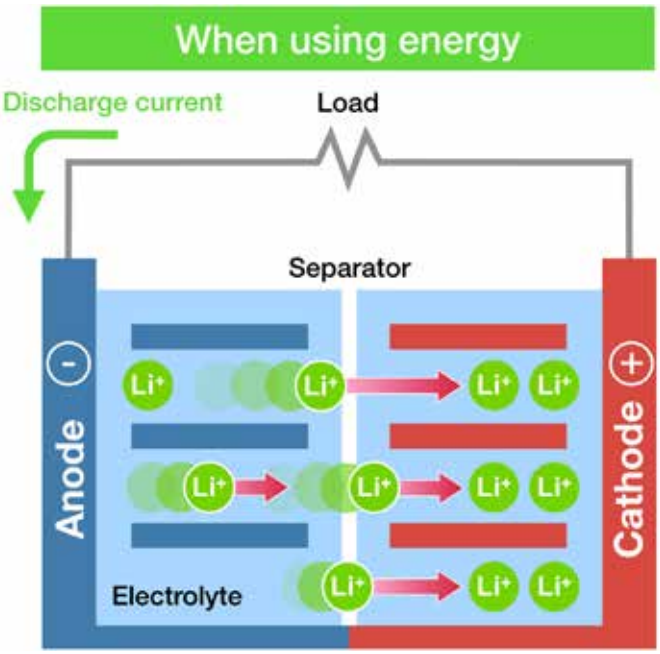
When in use (discharging), lithium ions are carried by the electrolyte between the cathode and anode. This generates a flow of electrons in the external circuit (outside of the battery) which delivers power to the device connected to the battery. When charging, the opposite occurs.

The separator, which is a porous film, has an important role as it blocks the flow of electrons inside the cell, while still allowing the lithium ions to pass through. It also prevents the anode and cathode coming into physical contact with each other. If this separator fails or is damaged, the consequences can be severe, as we will see.

How batteries work



1. The charger passes current to the battery.
2. Lithium ions move from the cathode to the anode, through the electrolyte.
3. The battery is charged by a potential difference between the two electrodes.



1. A discharge circuit is formed between the anode and the cathode.
2. Lithium ions, stored in the anode, move to the cathode.
3. Energy is used.

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Lithium-ion battery fire risk (cont.)

When lithium-ion batteries go wrong

Lithium-ion battery fires and explosions are typically caused by an internal short circuit which results in a process called 'thermal runaway'. This a chain reaction of uncontrollable temperature and internal pressure inside of the cell or pack, ultimately leading to gas leakage, fire, and explosion.

There are four main ways that a fire can start leading to thermal runaway:

- **Manufacturing defect –** e.g., a defect or breakdown in an internal component or its construction
- **Mechanical –** e.g., collision or crushing, nail penetrations, compression.
- **Electrical –** e.g., overcharging, over discharging, external short-circuit.
- **Thermal –** e.g., overheating, high ambient temperature, external fire.

A further hazard with batteries in the fishing and maritime environments is exposure to water. As reported in this **IMCA Safety Flash,** water can corrode or damage the internal battery safety devices and cause it to overheat, ignite, rupture or leak.

Thermal runaway is a self-sustaining reaction; it is very difficult to stop once it has started. The cell temperature can rise incredibly fast (in a matter of milliseconds) and generate extremely high temperatures. Because of the self-sustaining chemical nature of the fire, it can produce its own oxygen and therefore make it almost impossible to extinguish.

There is also the risk posed by the release of toxic and flammable vapours; the resulting vapour cloud could lead to an explosion.

The occurrence of lithium-ion battery fires is low, and it shouldn't be sensationalised. However, the consequences of such fires can be high, which is why it is a risk that cannot be ignored.

Battery Fire on S-Trust

In November 2023, the United States National Transportation Safety Board (NTSB) released its report on the incident investigation into the fire on board the oil tanker S-Trust. The incident may have occurred on an ocean-going oil tanker, but the circumstances are relatable to anyone serving on any type of vessel.

The vessel was berthed alongside at the port of Baton Rouge, Louisiana a fire started on the bridge. The fire was caused by one of the cells in a lithium-ion battery for an ultra-high-frequency (UHF) handheld radio exploding.

The batteries and chargers for the handheld radios were located on the communications table on the bridge, which was unmanned at the time of the incident. The fire was discovered when the master arrived on the bridge to investigate why the camera feed to his office failed.

The vessel's crew extinguished the fire using hoses. The S-Trust's navigation, communication and alarm systems were damaged beyond use. Thankfully, no injuries were reported.

Video footage from the closed-circuit camera positioned on the bridge caught the start of the incident, showing an orange flash that was immediately followed by a puff of smoke by the communications table. Following the initial flash, the video showed smoke rising up and increasing in volume and thickness. The footage then showed another orange flash, followed by an object on fire, which flew from the area and landed on the deck and continued to burn.

Very quickly the camera lens became covered in ash and started to deform, preventing any further view of the fire within the bridge.

Photos from the bridge closed-circuit camera showing (1) a second explosion occurs, (2) an object is propelled on fire into the air (circled), and (3) the object, still on fire, landing on the floor. *(Source: Stalwart Management Ltd and NTSB marine accident report MIR-23-23)*

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Lithium-ion battery fire risk (cont.)

The damage to the bridge. *(Source: United States Coast Guard and NTSB marine accident report MIR-23-23)*

The NTSB determined that the probable cause of the fire was the thermal runaway of one of the cells in a lithium-ion battery for a UHF handheld radio.

Fire on fishing vessel

Investigations into the cause of a fire that broke out in a bosun's locker on a factory trawler suggested the likely source was a lithium-ion battery.

As is quite typical after a fire, the extent of the damage can make it difficult to determine with certainty what was the trigger. In this instance, it was noted that a battery charger, a battery-powered grinder, a vape unit, a mobile phone charger and a Bluetooth speaker were found in the fire-affected region.

Bosun's locker

Battery Charger

Battery in the grinder

Preventing battery fires

An internet search for lithium-ion battery fires will produce many instances of video footage showing vehicles, electric scooters and bikes, and small devices being rapidly consumed by a raging fire, sometimes with a catastrophic explosion. But these fires are thankfully rare, and the risk can be controlled by taking some simple precautionary measures.

- Take care when purchasing tools and devices with lithium-ion batteries, battery chargers and replacement batteries. The cheapest offer might be financially attractive, but it might contain unregulated or poor-quality parts that increase the risk of fire.
- Know what lithium-ion battery devices and chargers are on board your vessel and where they are.
- Make sure used or damaged batteries are properly disposed of. Do you have a battery bin, and if so, is it protected by a fire-rated enclosure, or is it in an appropriate location and is it emptied at the earliest opportunity?
- Handle batteries and devices with care - if a device, such as a radio, is dropped or is wet, make sure it is properly inspected before re-charging.
- Use the correct charging station for the device.
- Follow manufacturers' instructions for the care and maintenance of lithium-ion batteries.
- Keeping batteries and chargers away from heat sources and flammable materials.
- Make the crew aware of the risks of charging personal devices, such as their smartphone, on their bed or pillow.

A final recommendation by the NTSB is to avoid unsupervised charging of lithium-ion batteries.

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Lithium-ion battery fire risk (cont.)

Fighting the fire

The action to take in the event of a fire can depend on its stage of development.

If at an early stage, an attempt to extinguish the fire can be made with water, foam, CO2, or other dry chemical agents. Isolate any mains power source. Containment bags, which are typically used by cabin crew in the airline industry for battery fire incidents, may be a suitable quick-response action for smaller items.

However, if the battery fire cannot be extinguished and/or the battery is undergoing thermal runaway, then efforts can be focused on allowing the pack to burn out in a controlled manner. This includes:

- Fighting the fire with water – bearing in mind that excess water can impact the stability of the vessel, especially if freeing ports and scuppers become blocked.
- Containment – close down the area and isolate any other flammable or explosive materials.
- Establish boundary cooling.

Be aware of the risk of secondary fires. If, after extinguishing, the battery retains a state of charge, its internal temperature could rise again and re-ignite the fire.

Remember, the vapour released by a lithium-ion battery on fire is both toxic and explosive. Ensure those attempting to fight the fire are properly protected.

Acknowledgements

NTSB investigation report MIR-23-23

www.ntsb.gov/investigations/AccidentReports/Reports/MIR2323.pdf

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