Lithium-ion battery fires – industry guidance and conference address risks

Lithium-ion (Li-ion) battery fires can be difficult to extinguish. Additional, although infrequent events, can result in Li-ion batteries experiencing thermal runaway, a chain reaction leading to a violent release of stored energy and flammable and toxic gas, potentially resulting in large scale thermal events with severe consequences.

Published 11 December 2024

Written by Mark Russell

In certain circumstances ignition may be delayed and the potential for a vapour cloud explosion may be created, which can be more damaging than a fire. Li-ion battery fires can continue to burn without access to additional oxygen. They may also continue to generate high amounts of heat following fire-extinction and are at risk of re-ignition.

Industry guidance

The shipping line members of the Cargo Incident Notification System (CINS) have recently published a new set of guidelines for the carriage of Lithium-ion batteries in containers. The guidelines are the product of collaboration with the International Group of P&I Clubs (IG), the International Cargo Handling Coordination Association (ICHCA) and the TT Club, together with input from relevant industry experts. The guidelines can be accessed here.

The guidelines identify risk and prevention measures and provide recommendations for all stakeholders in the supply chain to enhance safe carriage. They are not intended to address waste or damaged batteries. The guidelines describe how Li-ion batteries operate, how they are regulated for carriage and their hazardous properties. The risk of thermal runaway is explained and can be triggered by over-heating, charging abuse, short circuiting, a defect within the battery or damage to it. In other words, thermal runaway can start within the battery without warning or due to an external event such as impact damage or a fire.

Cargo packaging is also covered and the stresses to be withstood during sea transport are explained. A shift of stow within the container should be avoided, but if it were to occur proper packaging still ought to provide some protection, thereby reducing the risk of battery damage and thermal runaway. The state of charge and health of the battery are also addressed. Notably, the guidelines reference research that associates a higher state of charge to greater energy release and more intense fires, whereas a lower state of charge creates a greater risk of vapour cloud explosion. Air carriage regulates a maximum 30% charge, and the guidelines recognize the value and relevance of such limitations.

Stowage of the container on the ship above or below deck is subject to certain IMDG code requirements. The guidelines consider stowage away from sources of heat, separation from other dangerous goods and in a location where effective firefighting can be deployed.

There is a detailed section on the evolution of Li-ion battery fires and what that means for detection, response, and suppression. Final sections on loss prevention cover training, procedures, the importance of knowing your customer, as well as proposals for future safer carriage. The guidelines will be subject to revision as knowledge, experience and technology evolves. The guidelines are essential reading for those involved in the carriage of Li-ion batteries, especially crew, who should better understand what they are carrying.

Further CINS guidance is expected - Part B Checklists and Compliance, Part C Risk Assessment and Emergency Response, Part D Training and Awareness program.

Industry conference

The IG, CINS and the TT Club also jointly hosted an industry conference in London on 15 March entitled “Lithium-ion batteries in the logistics supply chain” which was attended by over 130 delegates representing regulators, container and vehicle carriers, fire investigation and fire-fighting experts as well as other stakeholders. The presentations and discussion covered many of the aspects mentioned in the guidelines and further below. It is expected that this collaboration will pave the way for making more informed decisions on addressing and controlling risks involved with Li-ion batteries.

Growth in demand and carriage on ships

Li-ion batteries have a higher energy to weight ratio than conventional batteries and a lower discharge rate meaning they last longer before re-charging becomes necessary. The demand for

Li-ion batteries has been increasing in conjunction with a mobile technology led world, such that these batteries are widely used in most portable electronic devices. These devices, as well as the batteries themselves, represent a common cargo carried in containers. The most rapid increase in forecast demand is for use in propulsion as part of the green transition, notably electric vehicles that will be carried on vehicle carriers and ro-ro passenger vessels. Global demand for Li-ion batteries is expected to surge more than five-fold by 2030.

Fire incidents and the risk on ships

Any fire on a ship is serious and many fires can be difficult to contain and extinguish, whatever the source. There is limited knowledge of Li-on batteries being a confirmed source of fires involving the carriage of electric vehicles and there have been many serious fires on vehicle carriers and ro-ro passenger ships involving only conventionally fuelled vehicles. The risk however is increasing with more electric vehicles carried and a potentially more intense fire should such vehicles become affected by another fire source. There are numerous examples of electric vehicle fires on land with alarming visuals (see links below).

The risk in container carriage is similarly increasing. The number of container contents including Li-ion batteries is not only increasing but also the potential for mis-declaration. Mis-declared batteries are among the most common source in recent container ship fires. It is also worth noting that the ships themselves carry many more units (container ships over 24,000 TEU and vehicle carriers heading to over 9,000 CEU), only one unit of which is needed to start a fire.

Fire detection and firefighting complications

Best practice for fire detection and firefighting Li-ion battery fires is the subject of ongoing research, some of which is referred to in the above guidelines and below links. The initial signs of a Li-ion battery reaction, that can lead to thermal runaway, may include white vapour (off-gas) and popping sounds, so video and audio monitoring of vehicle decks could become even more important as detection speed is key to containing any fire. Traditional smoke detection devices may be less effective. The batteries will be well encased, either within a vehicle or a container.

There are questions over the effectiveness of existing extinguishing mediums, such as CO2, due a lack of cooling effect. Thermal runaway continues to produce heat and combustible gases and effective containment may require large quantities of water. However, that can give rise to stability risks on ships, notably on vehicle carriers and ro-ro passenger ships. Shore fire fighters may need reminding of those risks. Operators also question the best use of “one-shot” systems and whether for example to inject all CO2 leaving nothing left for the reignition risk. One containership operator is in discussion with Class about using the CO2 system for water if CO2 itself is ineffective. Ships may be particularly vulnerable when doors or hatches are opened in port, and which will slow the ability to close a space and use a fixed system. The firefighting capabilities on larger container ships has been a growing concern and Gard has been working to have this addressed.

What is extremely important is to avoid putting people in harm’s way, which is why knowing that a fire can involve Li-ion batteries is key. As mentioned above, a vapour cloud explosion risk can sometimes develop, and toxic gases will be present. The vapour should not be mistaken for smoke associated with more conventional fires. Crew are not professional fire fighters and the use of handheld firefighting gear or large fire blankets (used in some research tests to cover vehicles) may be considered too dangerous. It should certainly not be attempted without suitable fire suits and breathing apparatus. One has to factor in that time is limited when using such apparatus and crew must also be able to safely evacuate a space which may be difficult to navigate in smoke with small gaps between vehicles. Many containership operators are investing in firefighting equipment beyond statutory requirements, such as devices that penetrate a container (also at heights) with the crew spending minimal time in danger zones attaching the device to the container. Classification Societies are also providing additional Class notations which provide for extra water monitors and water curtains.

Ultimately, a ship's master may feel that the safest course of action, especially in enclosed cargo spaces, is to use fixed systems to try and contain the fire until professional help can arrive. The maintenance and testing of these systems are important, as is the cooling of surrounding areas to limit heat spread. Preparedness though fire drills remains key and the mindset onboard ships facing Li-ion fires may need to adapt more towards fire containment than firefighting. Given that statutory fire training is rather generic, operators may find that crew need immediate advice on responding to fire situations from experts ashore.

Regulatory challenges

The regulations surrounding the risks associated with Li-ion batteries also represents some challenges. Part of the problem is that the risk landscape (notably because of technology and environmental drivers) is changing quicker than it takes to put controls in place. This is especially the case for regulatory controls, which take years to scope, debate, agree and implement.

Regulation for ships

In 2021 the IMO MSC103 agreed on the need to make changes to SOLAS for better fire detection, containment, and suppression on container ships. The work program aims to amend requirements for firefighting detection and control on new ships from 2028.

Draft amendments to SOLAS for fire protection of ro-ro passenger ships constructed from 2026 will be submitted to MSC 107 in June 2023. Fixed detection and firefighting systems will be required for weather decks and video monitoring will be required for all vehicle spaces.

There are currently no statutory fire safety requirements for ships specific to electric vehicles. Some member states of the IMO, who also represent large manufacturing bases, have submitted proposals to the IMO to revise the fire safety requirements for ships carrying electric and alternative fuel vehicles. Fire tests referenced by one state point to some success with deluge spray systems, another with high-expansion foam. At MSC 105 the IMO approved further work to address the SOLAS fire safety gap for these vehicles.

The charging of vehicles onboard ro-ro passenger ships poses additional risks as over-charging can be a trigger for thermal runaway. Onboard charging is currently unregulated, and passengers with EVs will have increasing expectations for such services.

Regulation for goods

The IMDG Code is already a complex and challenging code setting the baseline for safe carriage. It requires a level of competence and expertise to navigate and interpret its provisions. There is a constant challenge to amend the Code, which is a biannual process. There is a particular challenge with special provisions, which shippers may use to avoid treating and declaring some goods as dangerous. SP188 is meant to apply to less dangerous Li-ion batteries and is based on the weight and power outage of the cell or battery, though additional conditions apply. There is more a fundamental view that Li-ion batteries are not properly categorized in the IMDG Code (as the lowest risk Class 9 - Miscellaneous DG) given the risks they can represent.

SP961 of the IMDG Code states that the Code shall not be generally applicable for electric vehicles carried in vehicle and ro-ro spaces (not therefore when stowed in a container) when certain conditions are met. IMO CCC 8 discussed a member state proposal to replace that special provision and established a Correspondence Group to consider amendments and measures to address the hazards.

Unlike air transport, there are currently no regulations on the state of charge for Li-ion batteries on ships. A member state submission to the IMO recommended a 30% limit for electric vehicles.

Damaged or defective Li-ion batteries are at greater risk from short-circuiting, which can lead to thermal runaway. They should not be shipped, but in the years to come there will be many more

used, reconditioned and second-life Li-ion batteries, including those in second-hand electric vehicles. The lack of regulation surrounding them means that some carriers simply ban their carriage. That however may only serve to encourage some unscrupulous shippers to mis-declare.

Transportable battery energy storage systems (BESS) with megawatt-hour capacities vary in size but can be of container size. They enable large amounts of energy from renewables, like solar and wind, to be stored and then released when customers need power most. Classification societies are already being approached to assess the special risks posed by their carriage on ships.

Conclusions

The carriage of Li-ion batteries is increasing at a tremendous rate. Carriers, insurers, industry bodies, and experts are reacting to the rapidly changing risk landscape. Most importantly, they are collaborating to better understand the risks, increase risk awareness and share effective risk controls. That work is vital given the time it takes for regulatory change. Regulation still has an important role to play, but the guidance and conference mentioned above are excellent examples of the industry coming together to better protect itself in the meantime. Knowing your cargo, your customer and the controls that can be put in place will be key.

The pace of change will hopefully also see new technologies which will serve to better control the risks. Ideally that will come with the equipment or device itself so that battery management systems can more effectively contain adverse reactions before they get onboard ships or at least alarm those on board of a problem developing. Sensors on ships and in containers, as well as new extinguishing mediums will also hopefully become more sophisticated and effective, should they be needed. The supply chain should not however leave it to ships and their crews to tackle problems that in many ways society has created.

Further reading/Useful links

Reports

MCA guidance on the carriage of electric vehicles:MGN 653 (M) Electric vehicles onboard passenger roll-on/roll-off (ro-ro) ferries

EMSA guidance on the carriage of alternatively fuelled vehicles:Guidance on the carriage of AFVs in RO-RO spaces

NTSB report on Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric VehiclesSafety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles

ABS Classification Society best practice for electric vehicle carriageBest Practices for the Transport of Electric Vehicles on Board Vessels

USCG safety alerts

Lithium battery fire container illegally loaded with discarded lithium batteries:US Coast Guard Marine Safety Alert Lithium battery fire

Saltwater intrusion causes damage to electric vehicle batteries:US Coast Guard Marine Safety Alert Saltwater instruction causes damage to electric vehicle batteries

Research

EMSA Cargosafe project to identify cost-effective risk control options for cargo fires based on a safety risk study on containerised cargo fires.Containership safety

LASH FIRE international research project aiming to significantly reduce the risk of fires on board ro-ro ships.<span data-ccp-props="{"134245417":false,"201341983":0,"335559739":0,"335559740":240}"> CFIS 2023 conference on fire safety at sea<span style="font-style: italic;" data-ccp-props="{"134245417":false,"201341983":0,"335559739":0,"335559740":240}">

Danish Institute of Fire and Security Technology testing into the detection and extinguishing of battery fires in electric cars on vehicle decks in ferriesDBI new knowledge about battery fires in electric cars on ferries