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Lithium-Ion Batteries The writing on the wall (Part one)

Eloquent and timely are the words of a leading academic who concludes in no uncertain terms that "*Micromobility devices [incorporating lithium-ion batteries] should NOT be charged or stored indoors*"[1]

That, in the domestic setting. Translate to the marine setting, and it begs the question: are alarm bells not ringing for owners of yachts, their managers, their crews, marina owners, the financing banks, the yards, the manufacturers in the yacht sector, to say nothing of the original manufacturers of the batteries who may feel they can hide away behind the scenes at the end of complex supply chain contracts, and the insurers of all of the above? We unhesitatingly say "*yes, they should be*"; and we should know, having experience of one of the most significant reported yacht fires involving batteries and having followed the topic now for some years. The uptick in attention on the topic is consistent with that view. Yes, there is much armchair commentary and misconception surrounding the topic, but that by no means diminishes the real issues that are known and pressing.

In short, the problem is that not enough is being done quickly enough or in a joined-up fashion to address and mitigate the risks. Whilst progress is being made, lithium battery usage continues to grow, with the ever increasing risk – which is still in too many quarters just dismissed as overreaction – falling to insurers. That is unsustainable and dangerous. What is needed is a concerted industry-wide drive, from the manufacturers (where it all starts, after all, as so often is forgotten in the aftermath) through to end-users, to improve understanding at all levels to reduce the risk of loss, to understand those risks and mitigate against them, and then ensure the risk is properly allocated and priced.

As we explore below, green shoots are appearing in this respect, not least with the UK Maritime & Coastguard Agency stating in its draft guidance MGN 681 (regarding "Fire Safety and Storage" of Lithium batteries on yachts) that "*Increased understanding of the fire risks from Li-ion batteries among yacht crew, designers and owners should lead to better practice and increased fire safety*". And there are insurers out there trying to challenge the status quo and rightly seeking to raise the bar to encourage, through proactive underwriting, education, awareness and risk mitigation. So for example Beazley are proactively offering to help owners and their crews to manage the risks by e.g. providing concrete, practical guidance. However, it is critical that all stakeholders collaboratively and openly maintain the pace.

Context

According to Superyacht Times 2022 Market Report there were some 5,478 superyachts over 30m in service. Boat International reports that there were 600 yachts over 30m *on-order* in 2022. Each of these yachts – to say nothing of the tens of thousands of other, smaller yachts in service – will utilise battery technology in some form, each giving rise to its own distinct issues: be that toys (seabobs, electric surfboards, drones etc) or the use of batteries as an alternative propulsion power source (whether newly-constructed hybrids, or retrofits).

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[1] Prof Paul Christensen (Pure & Applied Electrochem, Newcastle University, from his 160+ page presentation as part of the 2022 knowledge event series – Operations response and lithium-ion batteries.

And lest anyone suggest the fires reports in our last article were just a fad, check out the nightmare in Marbella with over 80 yachts destroyed in one hit.

So, this is real. And it's big.

Before looking at the distinct issues which arise depending on the use case, don your lab coat and goggles: it's time for some science.

Li-ion, LiPo, LIFePO4…Decoding it all

Lithium batteries come in various shapes and sizes, using different materials and chemical combinations each with their own pros and cons (size, longevity and stability being the principal considerations).

A lithium "battery" (in the context of this article, generally) consists of multiple "packs", which comprises a number of "cells", usually around the size of an AA battery.

A lithium cell is, at its most basic, a metal case containing a negative and a positive electrode (the anode and the cathode, respectively). The cell contains an electrolyte – in a traditional lithium-ion ("Li-ion") cells that is a liquid; in lithium polymer ("LiPo") cells it's a polymer-gel.

Lithium iron phosphate batteries (LiFePO4) build on traditional Li-ion technology but incorporate iron (Fe) for the cathode meaning they have a higher discharge current, are less prone to explode under extreme conditions, and weigh less, but have lower voltage and energy density than normal Li-ion cells. There are other variants, which it is beyond the scope of this article to go into.

Regardless of the materials used, stripping it back to the basics, the process involves the transfer of ions within the cell from one end to the other, enabling the concurrent movement of electrons within the circuit which produces the charge and makes whatever the battery is connected to "go".

Risks

"*So what*?", you may be thinking. "*What's new here?*". We all use batteries without a thought and then toss them in the recycling bin in the local supermarket once they're flat or leave them recharging unattended if they are rechargeables. Indeed, many of you may be thinking our phones, laptops etc use *lithium* batteries of one form or another and we all use them without a second thought.

The answer can be most obviously seen – on a small scale – by comparing a standard AA (alkaline) battery and a small, single cell ("1S") LiPo battery. Although roughly the same size, the latter will typically be lighter and pack almost three times the voltage. But what really tells its own story is the difference in instructions: for AA batteries – a few lines on the back of the pack; for a 1S LiPo, text of Tolstoian length – literally pages of (dire) warnings.

The spectre of "thermal runaway"

The difference between them is the inherent risk that Li-ion and LiPo batteries may experience catastrophic "thermal runaway", which doesn't occur in alkaline batteries given their different chemical composition. Any mention of thermal runaway should rightly set your nerves on edge. This phenomenon occurs when there is an initial temperature rise within a battery cell which causes an exothermic reaction (i.e. one that produces heat) that leads to the temperature and pressure increasing uncontrollably. If the pressure reaches an excessive level within the individual battery cell then it will burst open and the flammable electrolyte liquid can be ejected and catch fire in spectacular fashion. This explosion and fire will almost inevitably then damage and heat up adjacent cells within the battery pack, possibly causing another thermal runaway event until an entire battery, or even bank of batteries, is ablaze.

A range of factors can cause the initial temperature increase, such as internal defects during manufacture of a cell; over-charging or over-discharging; a short circuit in the equipment to which the cell is attached; crushing or puncturing of a cell; and external heat sources such as fire. It should also be fairly obvious that the risk of such damage is far greater where the batteries are used in toys in a marine environment: they will be knocked about, affected by saltwater, exposed to heat from the sun over long periods, and constantly charged and recharged, so heightening the risk of damage and thermal runaway. Also, while some of the above risks are familiar to us all from more conventional battery use, it is the risks associated with incorrect charging which are – as anyone who has handled these batteries will know – considerably more complex. What is more, the circumstances leading to thermal runaway can be difficult to detect as the cause may not manifest for some time, so batteries which are damaged but appear safe may, for example, be stored away during a voyage only to combust mid-transit or during charging at a later date.

Even this brief summary of the risks is already a stern indicator of the catastrophic consequences if batteries are mishandled, inadequately inspected or stored, or are simply of poor quality. As we made clear in the opening to this article, it is about time that *all* stakeholders, not simply insurers, sit up and take notice of the issues and take real action to mitigate them. We will be looking into this point next time.

Safer alternatives?

So as not to finish this first of our series of articles on a sour note, it is important to highlight that there *are* safer alternatives out there, to say nothing of the risk mitigation that if properly implemented goes a significant way to addressing the situation, as we will discuss in our next article.

We mentioned LiFePO4 (lithium-ion iron phosphate) batteries above, and these are reported to be significantly safer than LiPos; it is perhaps for that reason that they are increasingly widespread in the marine world, despite their drawbacks (form / weight / voltage). A study conducted by the US Department of Transportation in 2017 indicated[2] that LiFePO4 batteries have a lower risk of thermal runaway by comparison to standard Li-ion batteries, even when quite literally blown up, so the prospect of fires breaking out when such batteries are damaged is lower. This also appears to be the sentiment held by many owners of smaller yachts who, whether based on anecdotal evidence or otherwise, are increasingly shifting towards using LiFePO4 batteries. In addition, that DoT study found[3] that when LiFePO4 cells experience thermal runaway, their temperature increases less significantly than in other compositions of battery (e.g. lithium or lithium cobalt oxide). As a result, they are far less likely to heat up adjacent cells and damage them. In short, thermal runaway is less likely to spread between LiFePO4 cells.

This matters because – just as with the use-case analysis we will turn to in part two of this series – there are important distinctions to be made across all aspects of this topic, and tarring all lithium batteries with the same brush is unhelpful and stymies progress in understanding and regulating this area. All the more reason for increased education. Ignorance, in this case, is not bliss.

Whilst there is much focus (rightly) on risk-mitigation, there is also a significant question which we anticipate will come into sharper focus in respect of risk *prevention* and the role that the manufacturers (where it all starts, after all) have to play in that respect.

See you next time when we will be looking into the various uses in the yacht context for lithium battery tech before turning on our crystal ball and looking to the future...

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[2] US Department of Transportation, Federal Aviation Administration) "Fire Hazard Analysis for Various Lithium Batteries", Figure 14.

[3] "Fire Hazard Analysis for Various Lithium Batteries", Figure 15.

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