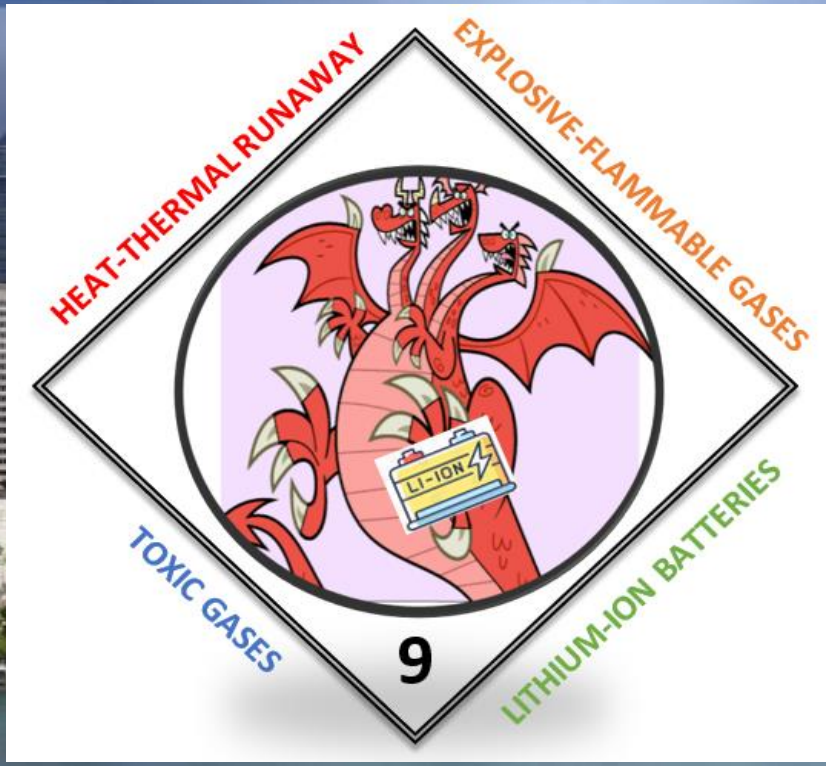
Li-ion Batteries: Risks and Mitigation
H.O.S.T. Advisory Board Meeting

December 8, 2022



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Who am I?

Greg Jenkins

-Matson-Dangerous Goods Specialist, SQES-DG
-35 Years in Fire Service
-Retired-Captain Maui County Fire Dept.- HazMat 10, Kahului., 26 Years
-Certified HazMat Specialist
-BA Public Administration, Summa Cum Laude, University of Hawaii

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What is a lithium-ion (Li-ion) battery and why are they so popular?

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What is a lithium-ion (Li-ion) Battery?

A lithium-ion battery or Li-ion battery is a type of rechargeable battery composed of cells (*within modules) in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and back when charging.*

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What is a lithium-ion (Li-ion) Battery? Individual or Larger…

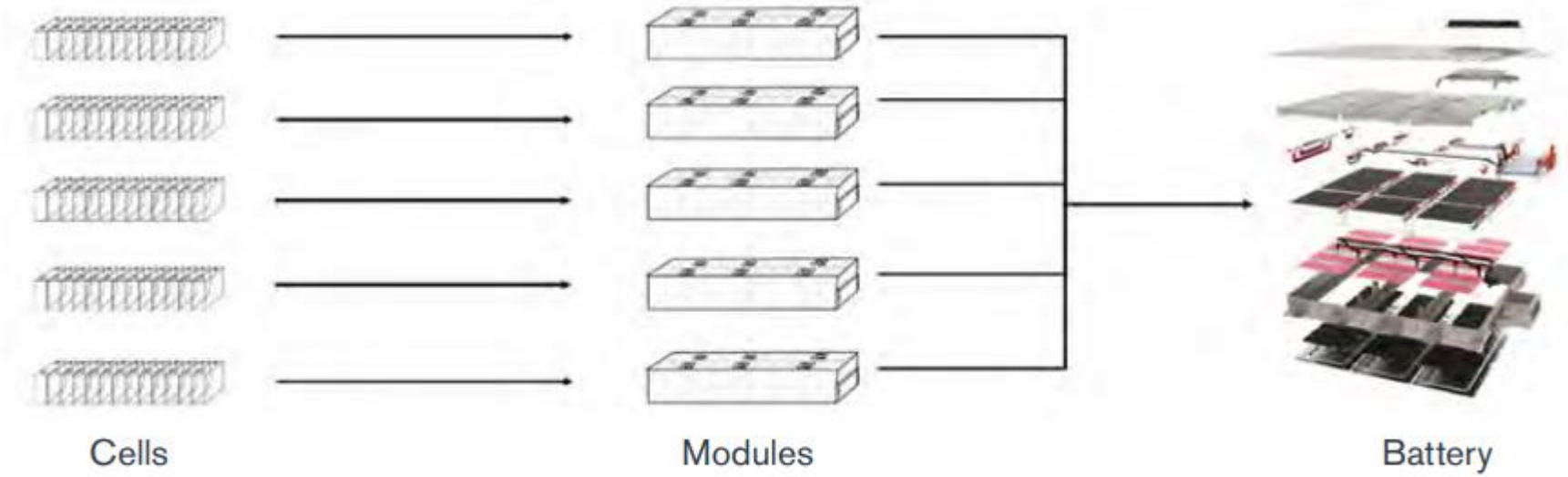

Figure 1 *- Schematic showing how cells are arranged into modules as a component of a complete battery. [Journal of Energy Chemistry, 2021, 59, 83]*

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What is a lithium-ion (Li-ion) Battery? Individual or Larger…

Examples of EV battery packs are shown in Figure 3.

Figure 3 *- Examples of the positioning of the battery packs in EVs, which is found in the chassis..*

Tesla Model Y has approximately 4,416 cells

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What is a lithium-ion (Li-ion) Battery? Shapes & Characteristics

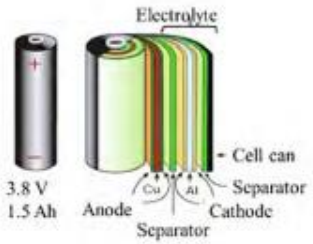
Battery type	Physical characteristics	Picture	Typical uses
Cylindrical 	The separator and electrodes are wound into a tight cylinder and placed in the casing; the electrolyte is poured in and the battery is sealed. Battery packs of cylindrical cells are less space efficient, due to their shape, but are easier to cool.	 *[Journal of Energy Chemistry, 2021, 59, 83]*	E-bikes, medical devices, power tools, Electric vehicles.
Prismatic 	Made up of large sheets of electrodes that are sandwiched between separators and rolled up before flattening so that they fit into a cubic housing. They can also be assembled by stacking the electrodes in layers rather than rolling. Prismatic cells are thinner and more space efficient but have poor heat dissipation.	 *[Journal of Energy Chemistry, 2021, 59, 83]*	Mobile phones, tablets, and other lightweight electronic devices. They are also used in electric vehicles and scooters.
Pouch 	The electrodes and separators are stacked in the cell container, which is a sealed flexible foil, usually an aluminium plastic film. Pouch cells offer greater flexibility over cylindrical and prismatic cells for fitting the cell to a particular device shape but they can withstand less pressure than a metallic shell casing.	 *[Nature Reviews Materials, 2016, 1, 16013]*	Used in laptops, tablets and electric vehicles.

Table 1 - Types of battery cells.

Lithium batteries whitepaper, 2022

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What is a lithium-ion (Li-ion) Battery?

A Li-ion battery cell is made up of an anode, cathode, separator, electrolyte, and two current collectors (positive and negative)

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What is a lithium-ion (Li-ion) Battery?

The anode and cathode store the lithium. The electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator.

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What is a lithium-ion (Li-ion) Battery?

The Anode is the negative or reducing electrode that releases electrons to the external circuit and oxidizes during an electrochemical reaction. The Cathode is the positive or oxidizing electrode that acquires electrons from the external circuit and is reduced during the electrochemical reaction.

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What is a lithium-ion (Li-ion) Battery?

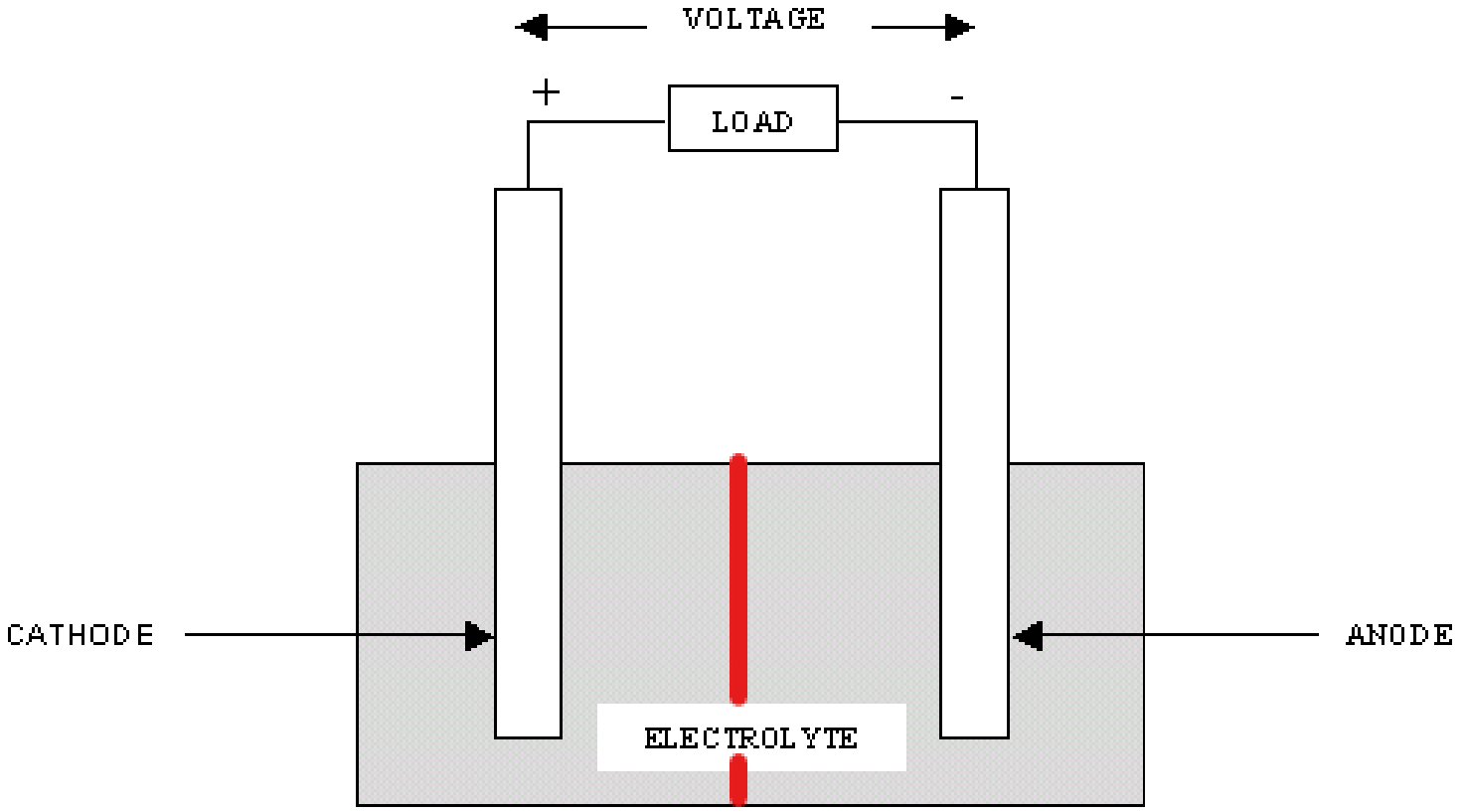

Figure 1: Components of a Cell

https://depts.washington.edu/matseed/batteries/MSE/components.html

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What is a lithium-ion (Li-ion) Battery?

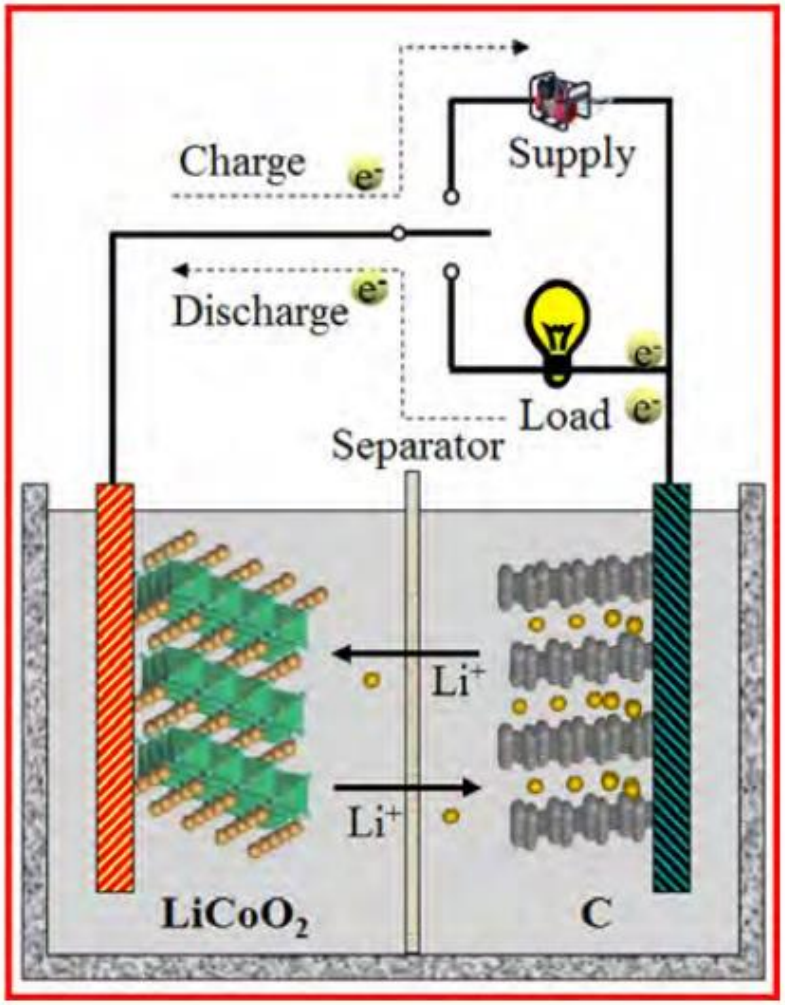

Figure 2 *- Schematic diagram of the fundamental structure of Li-ion batteries. The anode is carbon, and the cathode is $LiCoO_2$ in this image. [Energy Science and Engineering, 2015, 3, 385]*

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Why are lithium-ion (Li-ion) Batteries So Popular?

Li-ion batteries are popular due to "High Energy Density" = amount of energy that a system stores in an amount of space. (M$,C,E!)

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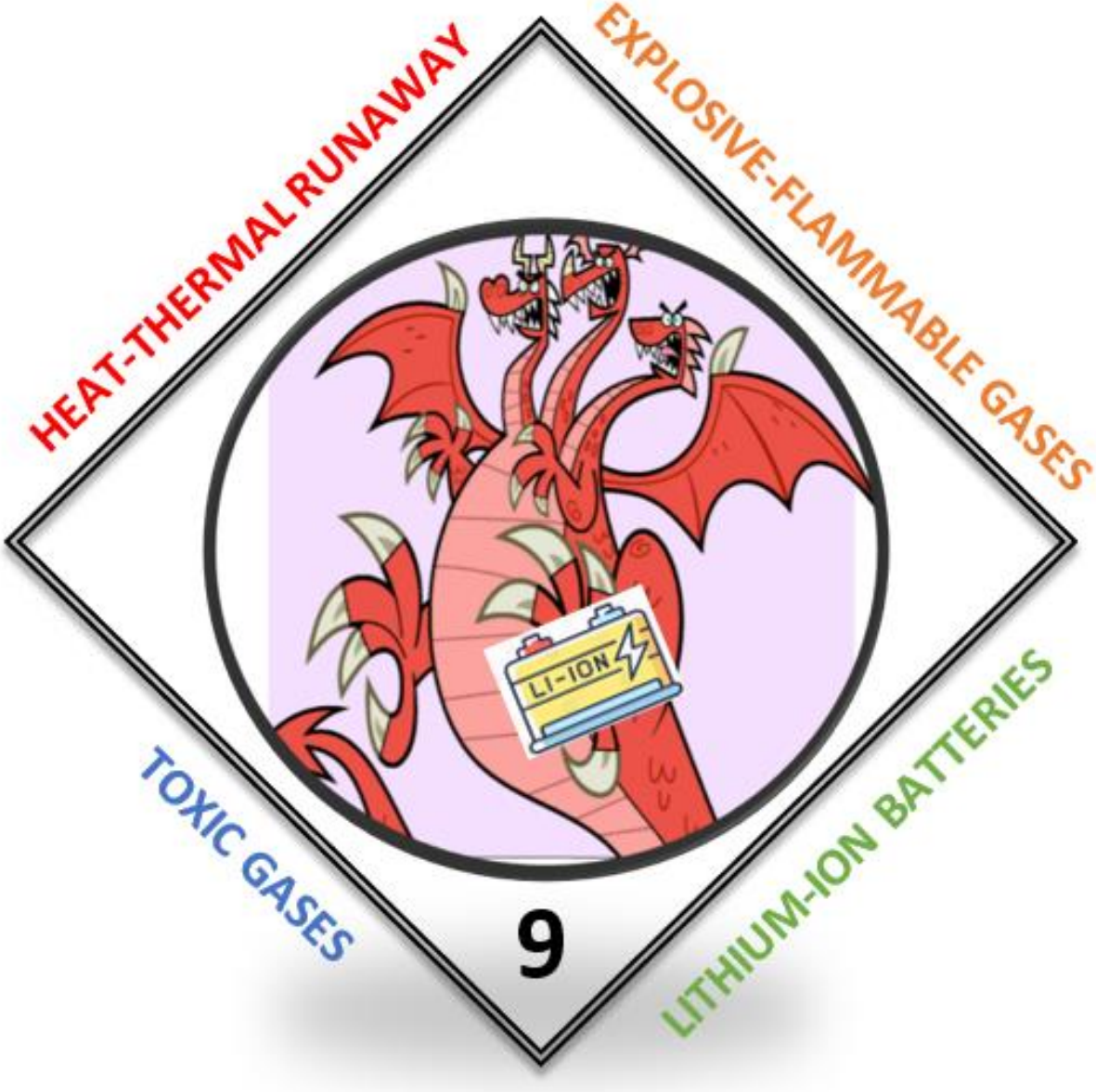
Types of Lithium Batteries

- Lithium ion (Li-ion)
- Lithium Polymer (Li-Po)
- Lithium Metal (LiM)
- Lithium ion (Li-ion **rare earth** metal materials):
  - Cobalt
  - Graphite
  - Lithium
  - Nickel
  - Manganese
  - Iron
  - Future (Sodium-ion, lower energy density, larger size, cycling stability issues?)

How & What Does Matson Carry?

- All types of Lithium Batteries such as EV, BESS, Other
- New
- Used
- Defective (complicated)
- No Damaged at this time
- Jone’s Act and local impacts, where do they go!

How and What Goes Wrong?



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How & What Goes Wrong?

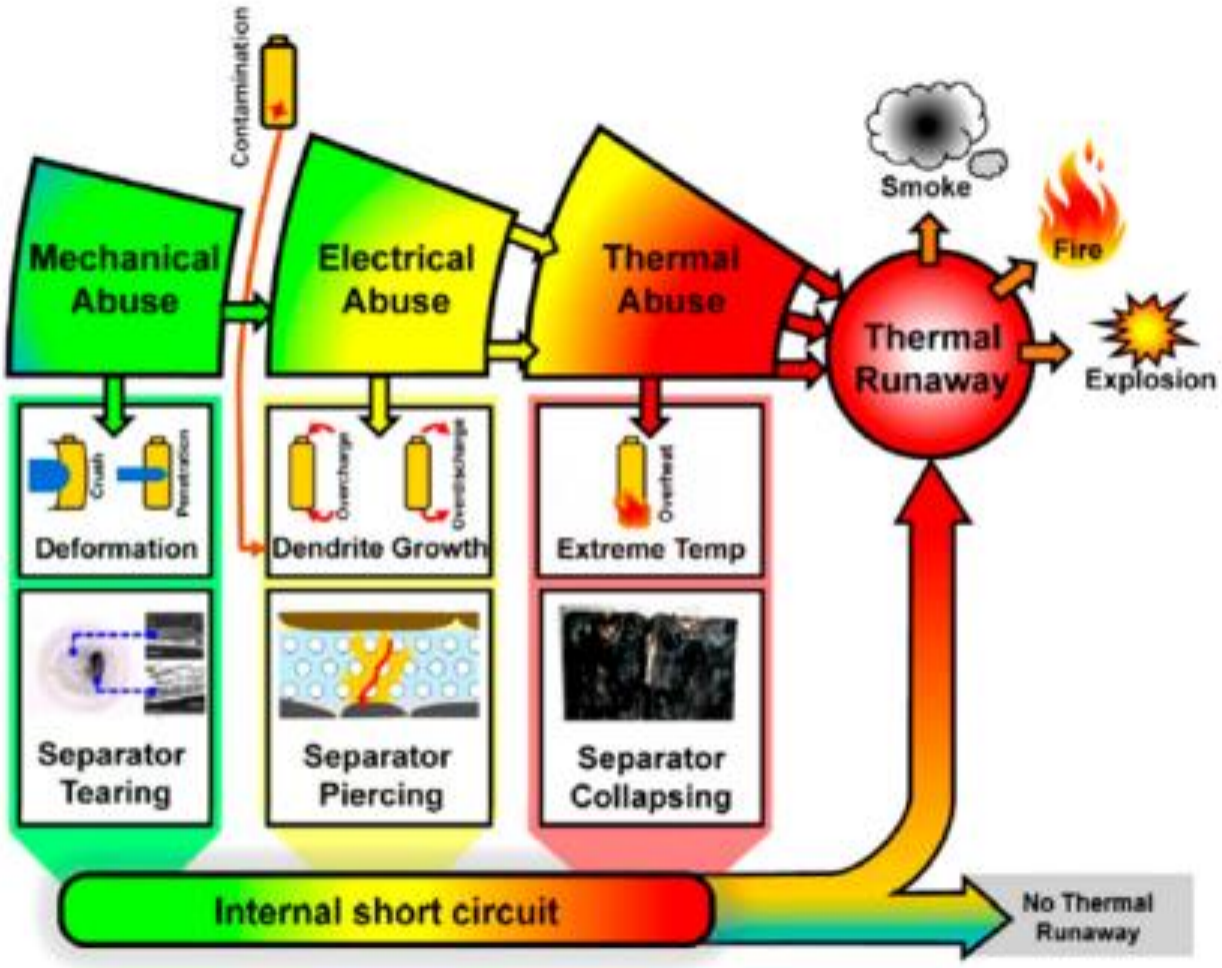


Figure 4 *- The possible consequences of the various types of abuse. [Ghiji M, Edmonds S & Moinuddin K (2021) A Review of Experimental and Numerical Studies of Lithium Ion Battery Fires, Applied Science, 2021, 11, 1247]*

How & What Goes Wrong?

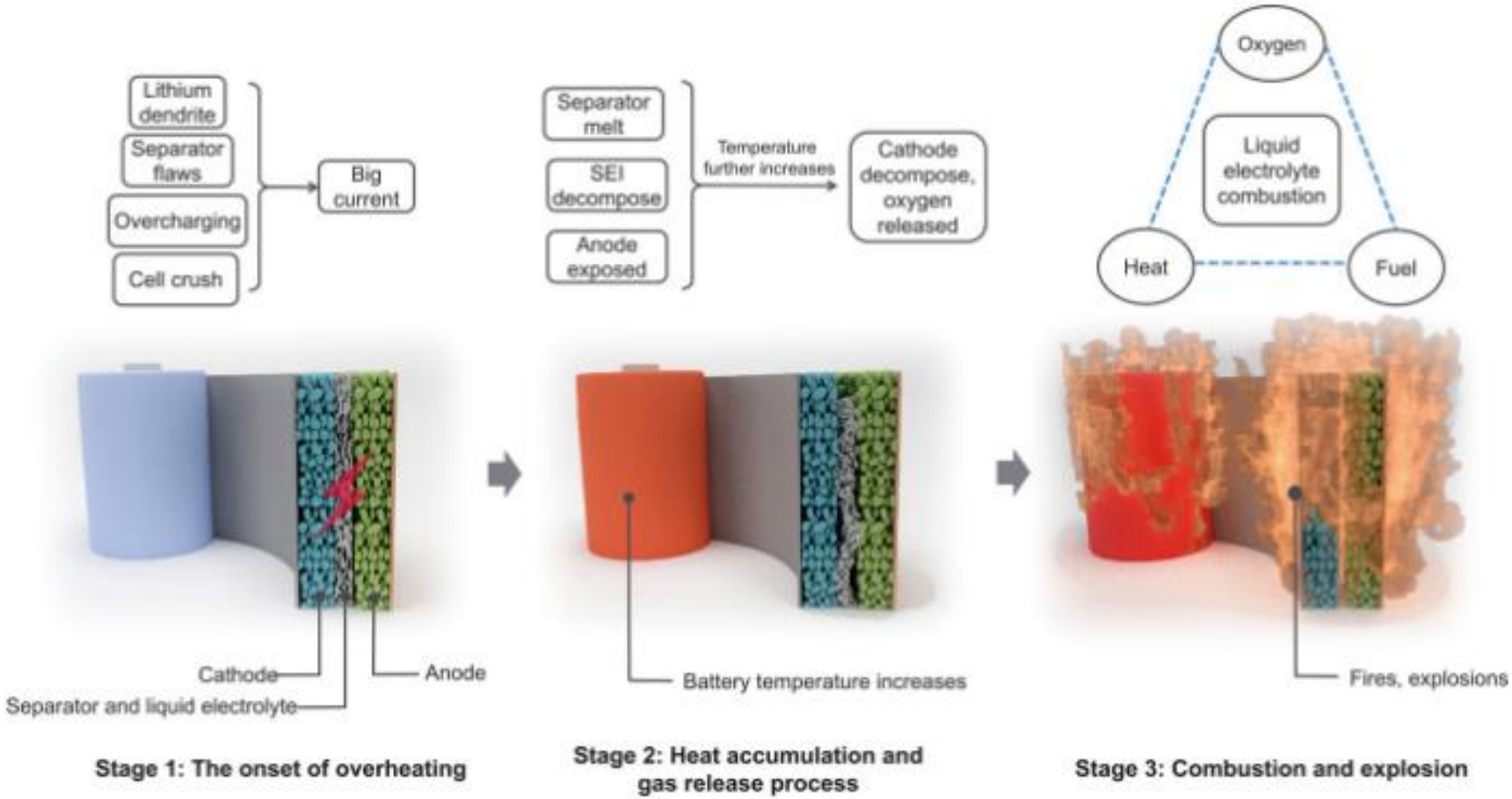


Fig. 1 Three stages for the thermal runaway process.

Stage 1: The onset of overheating. The batteries change from a normal to an abnormal state, and the internal temperature starts to increase. Stage 2: Heat accumulation and gas release process. The internal temperature quickly rises, and the battery undergoes exothermal reactions. Stage 3: Combustion and explosion. The flammable electrolyte combusts, leading to fires and even explosions.

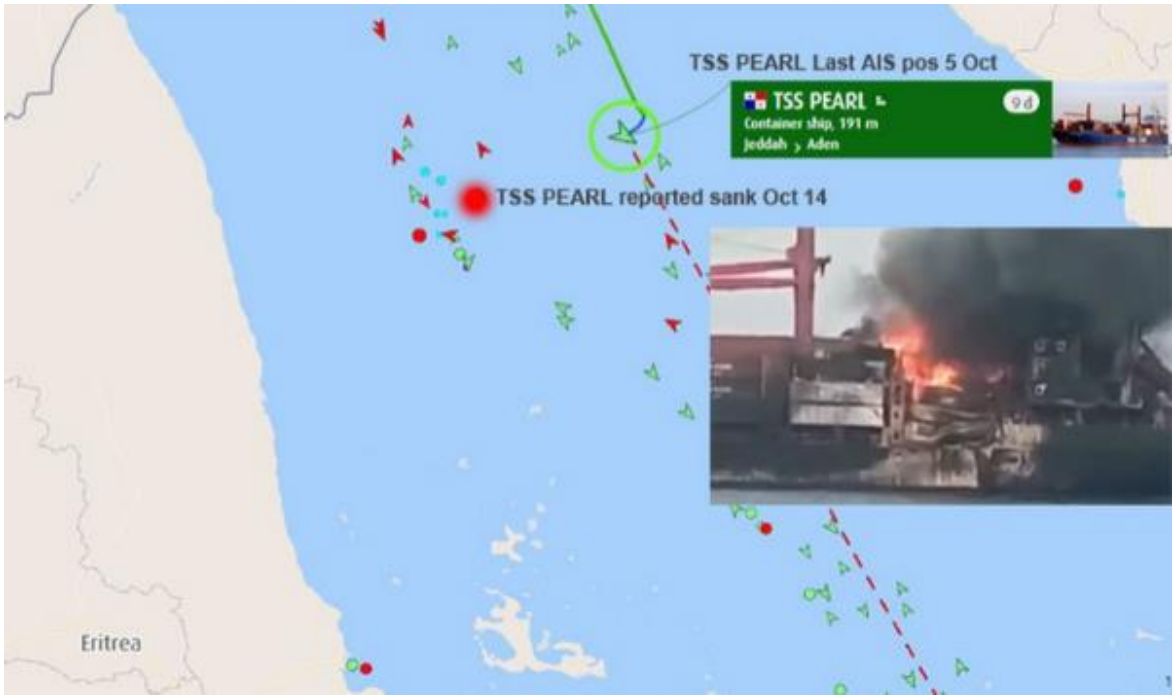
https://www.science.org/doi/10.1126/sciadv.aas9820

How & What Goes Wrong?

Figure 5 *- Example of the different gases emitting from a battery during a thermal runaway event.*

Lithium batteries whitepaper, 2022

Recent Notable Fires



October 2022

As of Oct.14th,*TSS Pearl* sank in the Red Sea after being disabled by a major fire. 25 crew abandoned the ship and were rescued. (*X-Press Pearl* carrying 1,486 containers burned for two weeks then sank in 2021,Nitric acid leak.

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Recent Notable Fires

August 2022

Fire rips through 8,586 TEU *Zim Charleston* in the Indian Ocean with the ship showing no signs of leaving its mooring at Colombo port. Blaze being investigated. Fire erupted under deck in a dangerous goods cargo hold and up to 300 containers may have been damaged in the fire.

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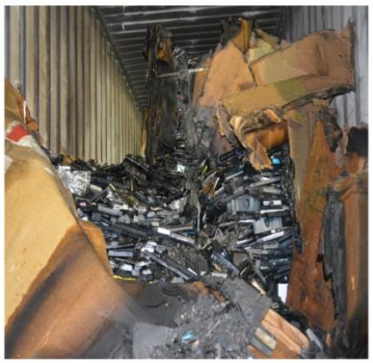
Recent Notable Fires

February 2022

The *Felicity Ace*, traveling from Germany to R.I., USA, burns near Azores islands from possible EV fire. Estimated $500m in cargo plus vessel costs!



Burnt lithium batteries in fiberboard boxes.

August 2021

Container Fire on Highway enroute to Port of Virginia, intended for maritime voyage to China.

April 2019

Firefighters seriously injured as a result of cascading thermal runaway within a 2.16 MWh BESS that led to a deflagration event in Surprise AZ. Over 6 months to render BESS safe.

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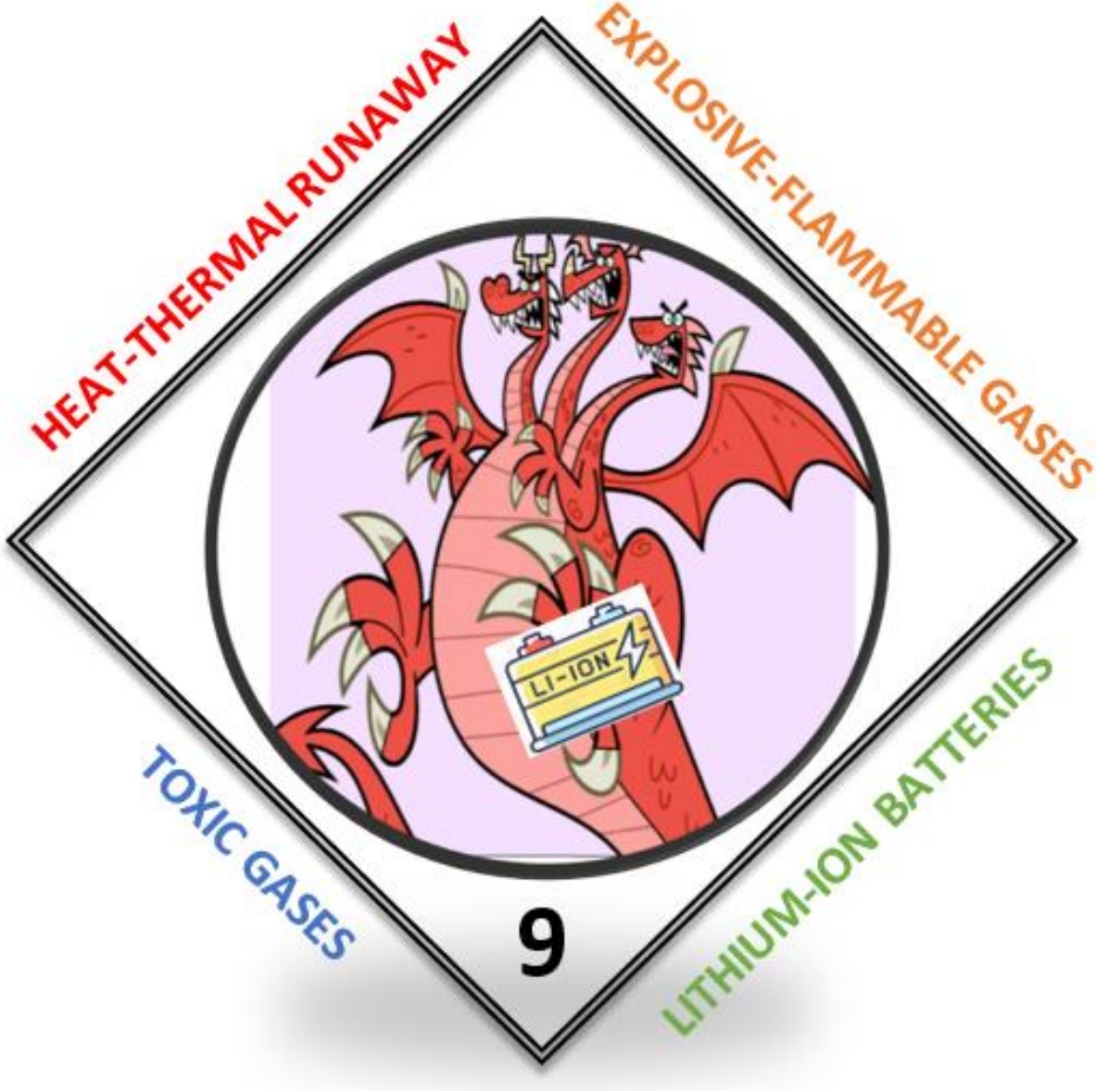
Videos…

- News Segment Li-ion Batteries
- Felicity Ace
- Contaier Fire Containing Li-ion Batteries
- Li-ion Thermal Runaway and Fire Camp Site
- Scooter Fire

Li-ion Batteries: Risks and Mitigation

(Chicken Little, The Feasance Brothers, and Snake Oil)



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Li-ion Batteries: Risks and Mitigation-What Are We Doing?

- Matson EV Fire Working Group
- External Working Groups
- ABS Review for BESS Cargo On Vessels and Barges
- SQES-DG Equipment RnD, Equip. Demos and New Tech Research
  - Early Detection Leads to Early Decision!
    - Linear Heat Detection; CCTV Video Smoke and Fire Analytics; Flame Detectors
  - Early Decision (Containers and RoRo!)
    - HydroPen; BEST Nozzle; Fire Blankets; Matson Nozzle; Master Streams/Deluge Guns; Dewatering Upgrades by Class Spec.
    - Retrofit and New Builds Water Sprinklers or Mist Systems (Mid to Long Term, Targeted Locations Only!)
- Collaborative Team Approach to Address Problem:
  - SQES, CARS, Vessel Operation (including Vessel Master and Chief Mate), Risk, etc.
  - RoRo Space improvements for Safe Access and Suppression Deployment.
- Internal Policy review and development based on practicable solutions derived from feedback.
- Insurance/Underwriters Club, Risk Driven!

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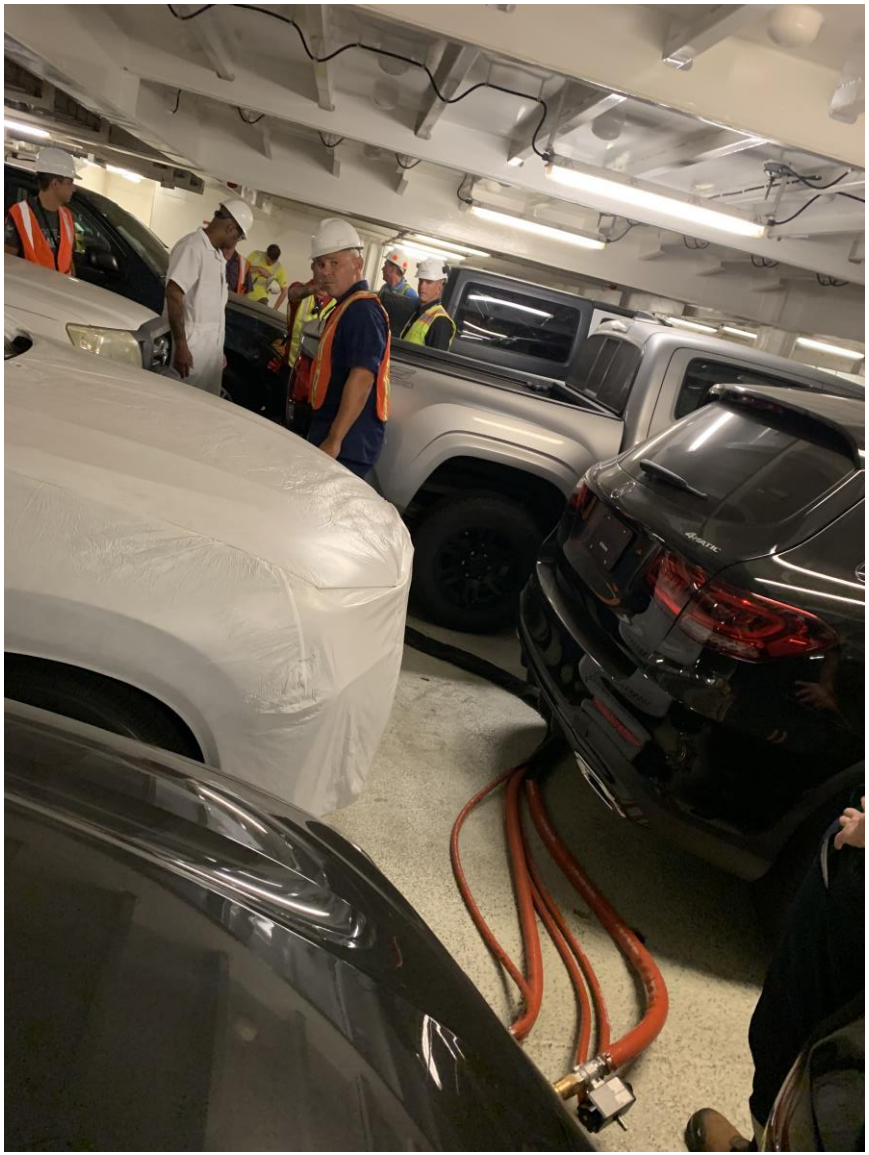
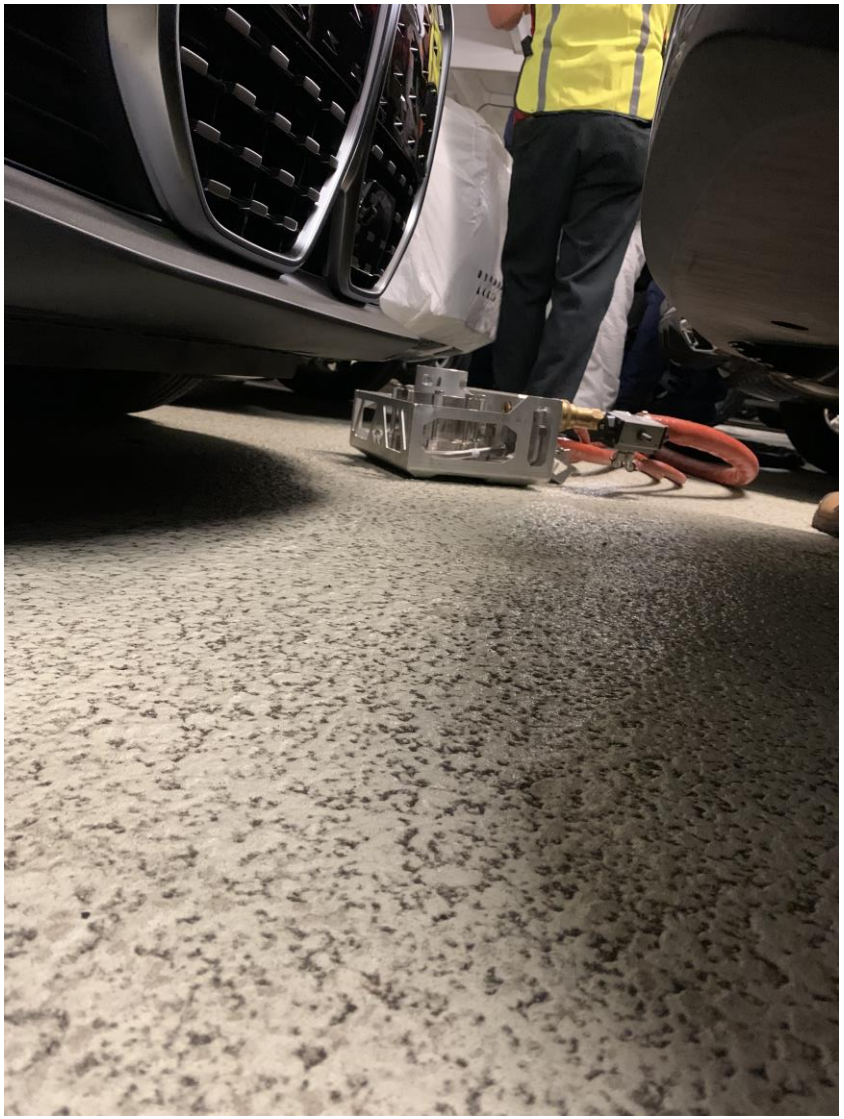
Rosenbauer BEST-HNL 8.18.22





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Rosenbauer BEST-HNL 8.18.22

- Practical with challenges shoreside (FD)
- Not practical or safe for vessel deployment (Complicates Risk Mitigation, Next Steps)

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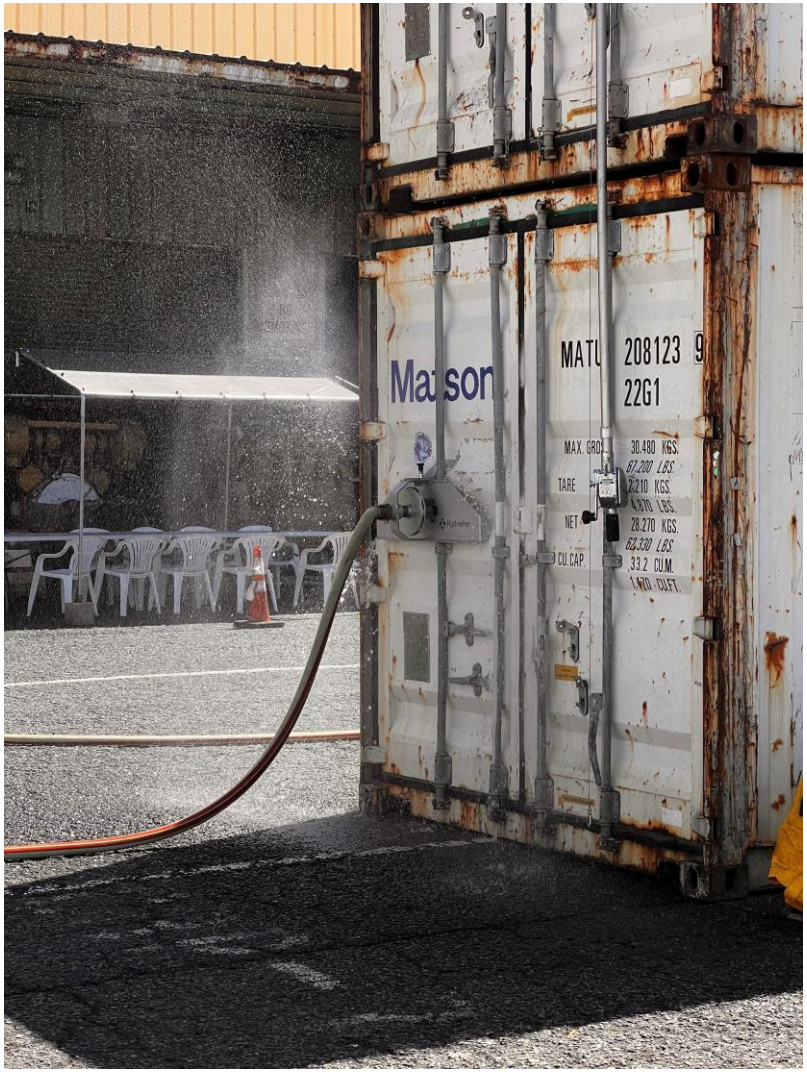
HydroPen-HNL 8.19.22



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HydroPen-HNL 8.19.22

VIDEO HydroPen Demo HNL 2022

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HydroPen-HNL 8.19.22

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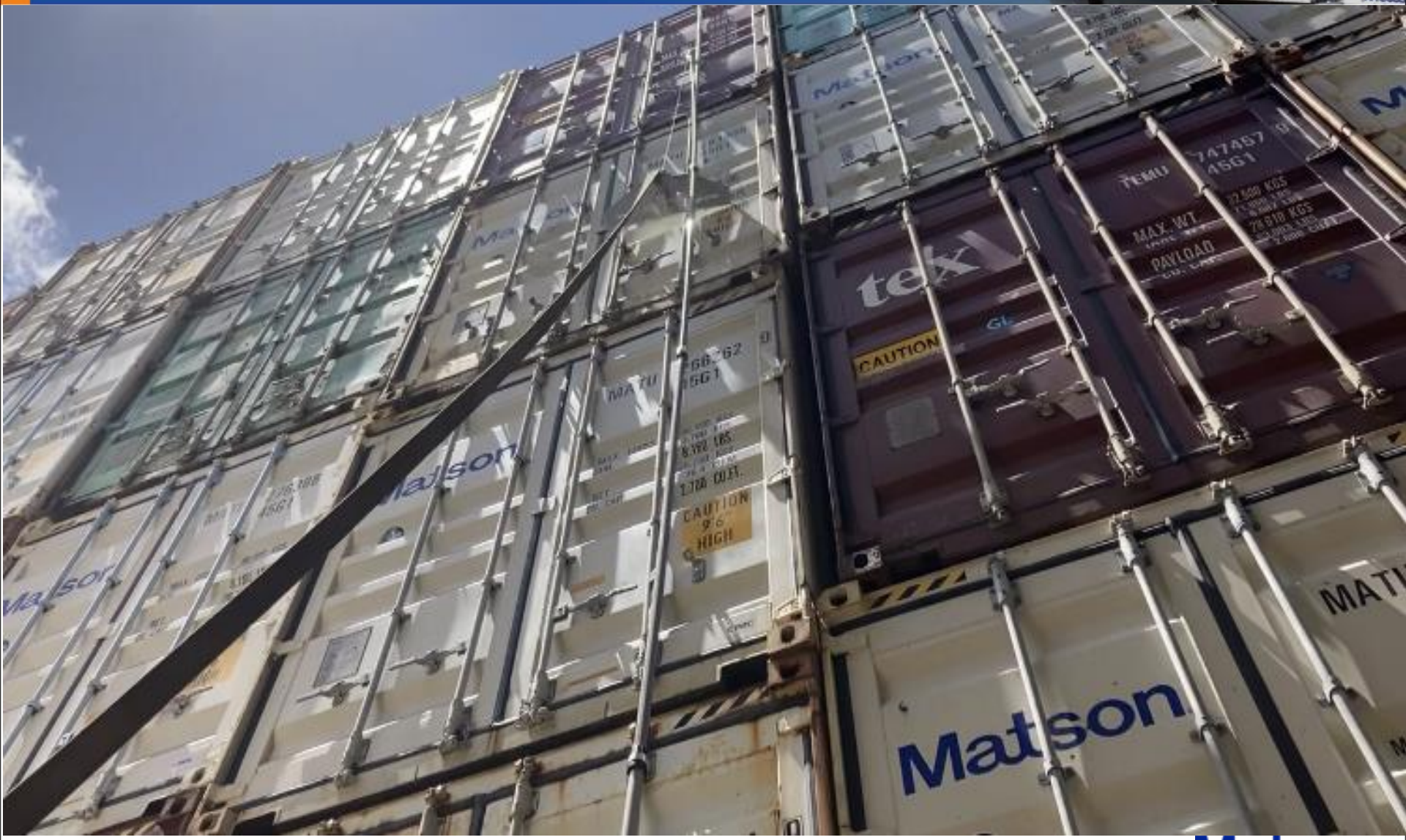
HydroPen-HNL 8.19.22



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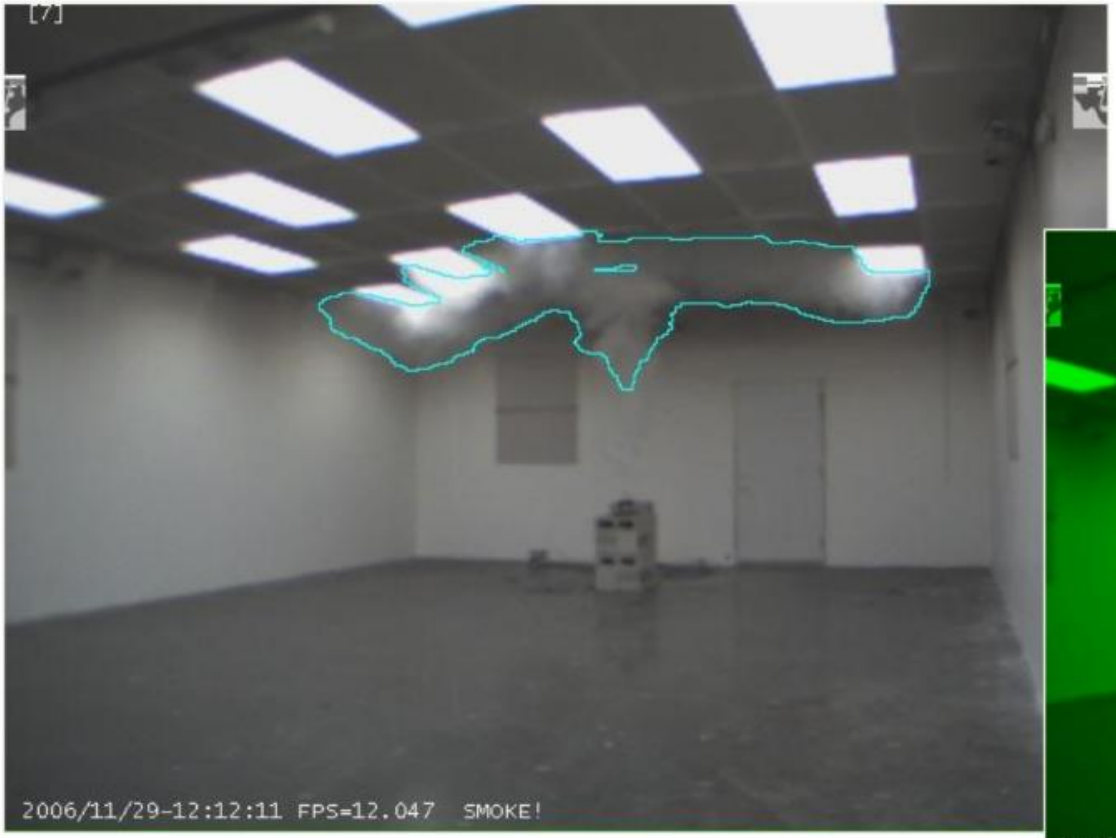
Fike-Matson-USCG HQ 11.4.22

Smoke Signature Recognition



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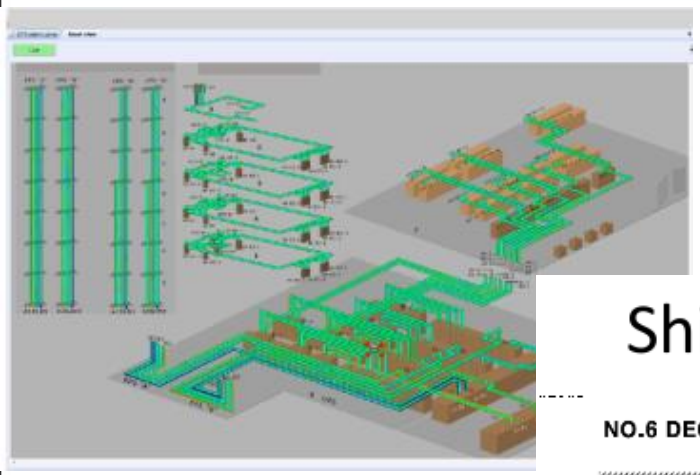
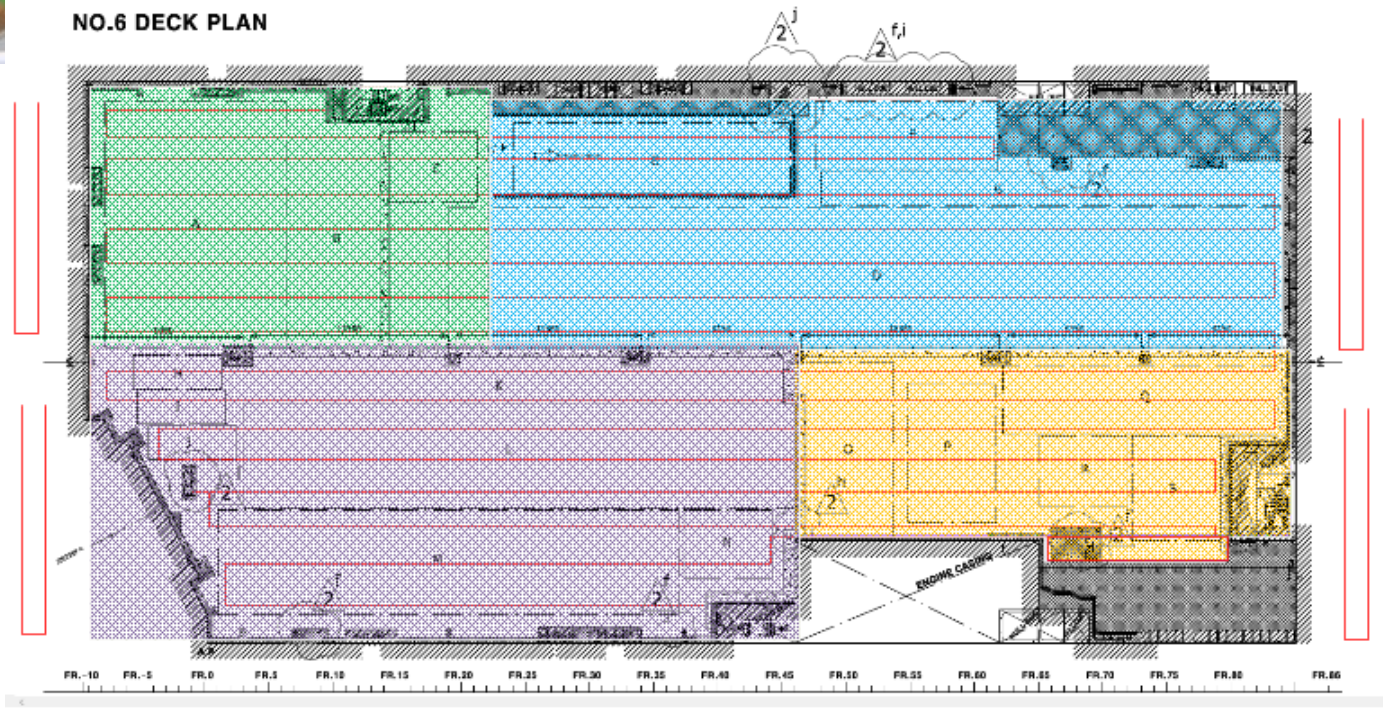
Fike-Matson-USCG HQ 11.4.22



Ship design fiber linear heat detection



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Other Ongoing & Future State Action Items

- Tesla Product and Fire Protection Engineer Collaboration
- USCG HQ and ABS Review, Collaboration, and Approvals
  - Class Spec, 46 CFR Sub. Chapter Q: Additional or Supplemental Equipment or Strategy
- Review & Upgrade of Current State of Vessel Fixed Fire Protection Using Water and Dewatering Capabilities by Class Spec.
- Review & Install Early Detection Technology
- Invent and Build a New Perimeter Cooling Nozzle For RoRo, “Matson Nozzle”
- Donate HydroPen w/TRN to Local FDs Serving Matson Terminals
- Implement Recommendations for Vessel New Builds and Retrofit Existing Vessels.
- Equipment Implementation Balanced With Crew Trust/Training!
- Coordinated Fire Plan/Strategy Development with External Stakeholders (Local Fire Dept., State AHJ, USCG, EPA)

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Allianz

Allianz Global
Corporate & Specialty

Safety and Shipping Review 2022

An annual review of trends and developments
in shipping losses and safety

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Greg Jenkins | Dangerous Goods Specialist
Safety, Quality, Environment, and Security (SQES)
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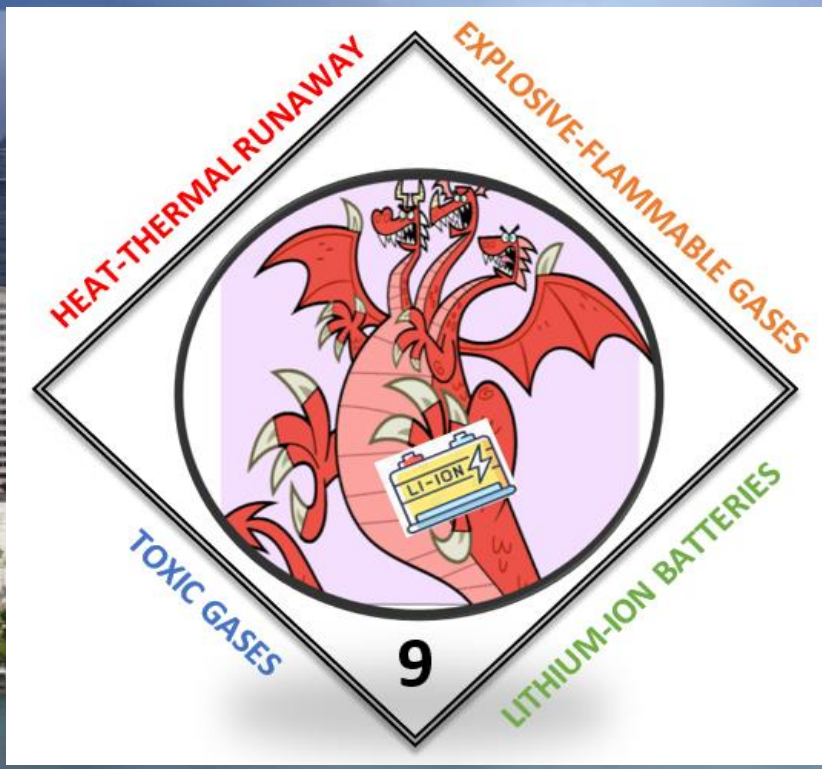
Mahalo Nui Loa!



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