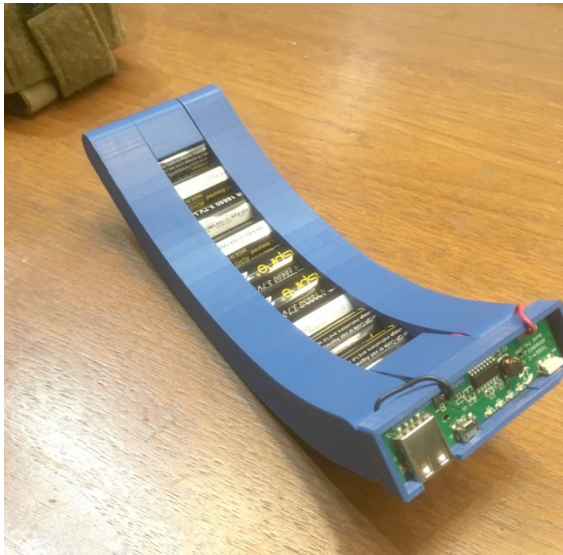# Rechargeable lithium battery fire risks

Fathom Engineering

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# Fathom Engineering

- Engineering consulting
  - Laboratory testing
  - Failure analysis
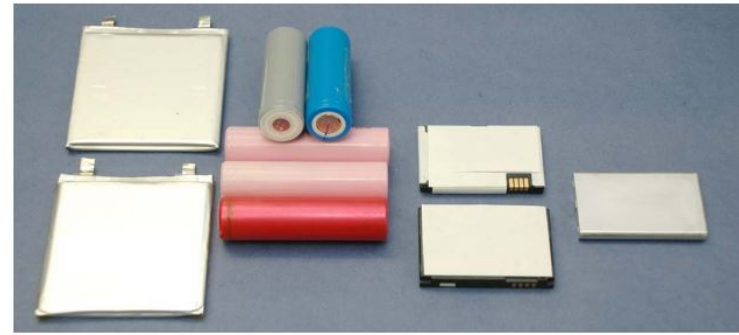 - design

Lithium battery fire statistics

- There is no epidemiological data available on e-bike fire risk
- There is data on electric road vehicles
  - This data is not useful for e-bikes
- There is recent data on vaping device fires
  - Applicable to e-bikes because the cells are the same and are used in similar ways
- Most common time for fire is during charging and discharging
  - This is true for almost all consumer applications
  - Charging is an issue for all applications
  - The discharge problem applies to high-current devices like e-cigs, EVs and e-bikes
  - Fire risks during storage and transport are specific to each application
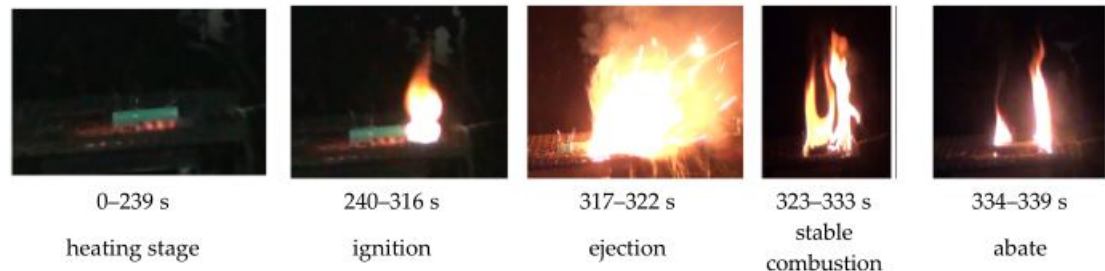
Lithium battery fire statistics
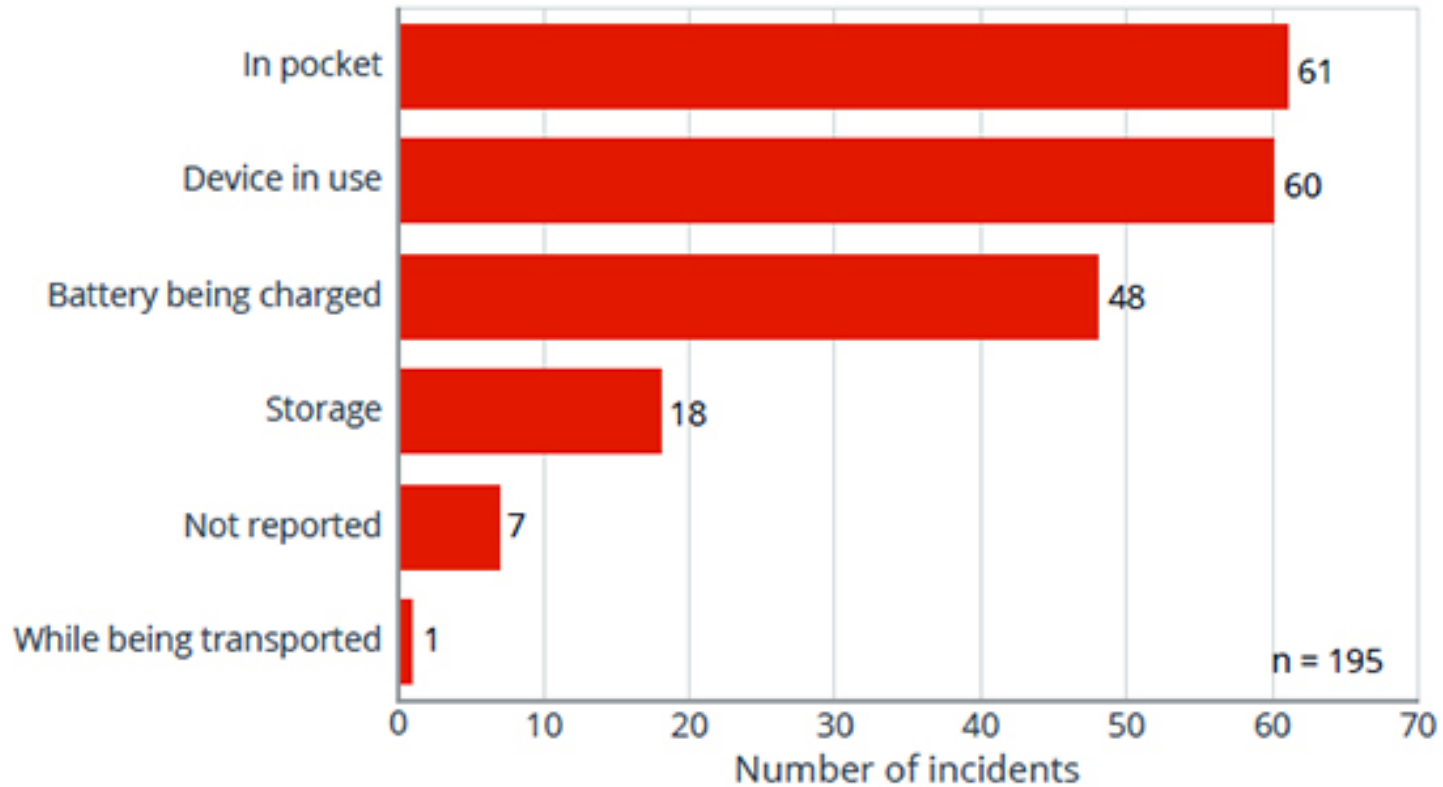
How does Li-ion cell chemistry affect the risk of fire and explosion?

- Cell vs battery
  - Cell is an individual electrochemical cell that produces a specific voltage
    - Lead-acid 2V
    - Ni-Cd 1.2V
    - Alkaline 1.5V
    - Lithium 3.5 to 4.5V
  - A battery is an electrical and mechanical combination of cells to produce a higher voltage or grater output current.
    - Cells: AA, C, D, 18650
    - Battrey: 12V car battery, 9V battery, 48V e-bike battery
  - types of rechargeable batteries in e-bikes (and cars)
    - sealed lead-acid
    - NiCd
    - Lithium

- Lithium itself is many different chemistries such as Li-NiMn and Li-FePO
  - Li-FePO is stable and does not self heat but it has a low discharge current. It is commonly used in some power tools, solar storage, and marine.
  - The Lithium chemistries used in e-bikes allow high discharge currents and fast charging, similar to electric car requirements. This is usually Li-NiMn or Li-MnCo chemistry
  - The electrolyte in these lithium chemistry batteries is a liquid hydrocarbon mixture

How does Li-ion cell chemistry affect the risk of fire and explosion?

- Because of the vulnerability of lithium cell design, self-heating of the cell during charge or discharge is the leading cause of fires.
  - more than other types of chemistry because of high energy density and high discharge current
  - Because the liquid electrolyte vaporizes and build pressure in the cell
  - high charge current is design choice
  - Self-heating can lead to thermal runaway, where the excessive heat itself can further damage the cell (or adjacent cells)
- lithium can burn without oxygen
  - extinguishing is difficult
  - can heat adjacent cells
  - the electrolyte is flammable

| 0–239 s | 240–316 s | 317–322 s | 323–333 s | 334–339 s |
| heating stage | ignition | ejection | stable combustion | abate |

How does Li-ion cell affect the risk of fire and explosion?

- Defect in a cell is the other main cause of fires
- Defect creates an internal short
  - Can be an inclusion
  - Thin area in insulator
  - Internal short
- Defects in cells can come from
  - cell manufacture
    - Hand made vs machine made
    - QC testing
  - damage during battery pack mfg
  - damage during transport
  - damage during use
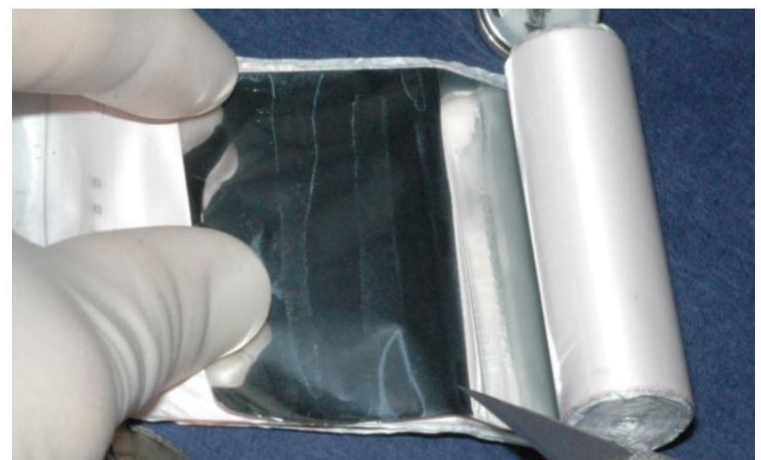
How does the manufacturing process of batteries and e-bikes, and the chain-of-commerce for both products affect the risk of Li-ion battery fire?

- E-bikes tend to use 18650 cells in a S-P battery pack configuration to get 48V DC output
- hand-made vs machine made cells
  - Depends on form factor – these days 18650s are machine made
  - QC on cells; has the cell been screened for defects?
  - counterfeit cells
- cell maker vs batter pack mfg
  - Quality cells are made by Panasonic, Sony and Samsung
  - cell sourcing (counterfeit or untested)
  - thermal management
  - battery charge/discharge management/protection

How does the manufacturing process of batteries and e-bikes, and the chain-of-commerce for both products affect the risk of Li-ion battery fire?

- kit bike vs manufactured product
    - A complete manufactured e-bike might be tested and use approved products
    - A kit may contain COTS parts assembled overseas or locally
    - There are engineered kits that are different from COTS parts; these are often reversible kits
- How is the e-bike imported?
    - direct by end-user can bypass many import controls and retail risk-management controls
    - local bike shop
    - larger retailer risk management requirements

What are the common specific risk factors of battery fires that are potentially under the control of the end-user of the bike and battery?

- Good practices in choosing a cell or battery pack
  - Watch out for too-good-to-be-true prices for 18650 cells or battery packs
  - There is almost no way to know the source when buying direct from another country and self-importing
  - protect cells and batteries from mechanical damage and heat
- Good charging practices
  - do not upgrade cells in a battery pack or change charging method
    - For example, removing an internal battery pack and charging it externally
    - Using an advertised faster charger
  - Where to charge the battery?
    - charge in your fireplace

What are the common specific risk factors of battery fires that are potentially under the control of the end-user of the bike and battery?

- Good practices in choosing an e-bike
    - buy from a retail chain with legal imports and insurance protection
    - Avoid products with removable batteries or external battery charging
    - use the supplied charger with the e-bike
    - Watch out for kit bikes unless you know what you're doing

What can the AHJ (authority having jurisdiction) do to affect battery fire risk?

- Provide and enforce designated charging stations
  - This can help remove auxiliary power packs, generators, solar panels, and other ad-hoc charging methods in the field
  - It also helps contain risk location, and the charging area can be made fire resistant
- Specify certain features that e-bikes must have in order to access the mountain
  - non-removable battery
  - UL or CE or other regulatory approval marks
  - E-bike registration and licensing