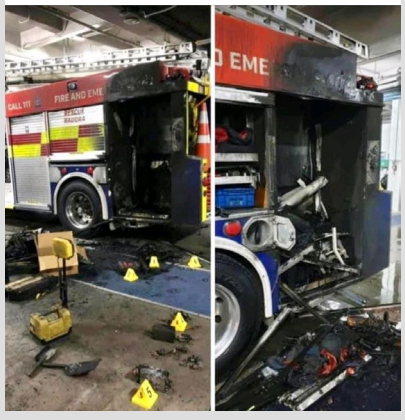
Addressing Safety Requirements in Lithium Battery Packaging and Logistics



Lithium Ion Battery Fire on a fire apparatus in the station. The suspected point of origin is an electric battery operated fan.

NAATBatt Meeting 2023

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Facts:

- Internal Combustion Engine (ICE) vehicle fires occur once every 3 minutes in the US - NFPA
- ~7000-9000 garage fires in the US/year
- Beijing Inst. Of Technology: ~7-8 EV TR events/day in China (30% while charging, 40% while parked)
- 100 years of experience guide safety, tools, and SOP for ICE vehicles
- xEV's have ~***90% LOWER probability*** of experiencing a fire incident than ICE vehicles
- Many incidents in the headlines are from extreme (high speed) crashes
    - xEV's can put much more torque to the wheels than ICE vehicles

Challenges with xEV's / Lithium-ion Battery fires:

- Pack location is difficult to access
- Thermal Runaway temps >600 – 1000 C
- Hazardous and flammable gas release; explosive risk
- High Voltage (400 to 1.2kV) systems external shorts if relays fail
- Gases, particulates and water vapor increase risk of arc discharge
- Lithium-ion batteries provide their own oxygen to support combustion
- Damaged cells/stranded energy can cause re-ignition
- Difficult to assess state of cell, pack and determine "end of event"
    - Events require hours of engagement and 1,000's of liters of water to extinguish

New technology requires training, new processes, new tools

2022 Hurricane Ian flood vehicle

Why are lithium ion battery fires so pernicious?

While rare, Lithium ion battery fire pose unique challenges to suppression

1. **Lithium ion cells undergoing thermal runaway can provide their own oxygen as a reactant**

   SEI Decomposition: $(CH_2OCO_2Li)_2 \xrightarrow{\Delta H} Li_2CO_3 + C_2H_4 + CO_2 + \frac{1}{2}O_2$

   Carbonate combustion & Lithium rx with binder and electrolyte :

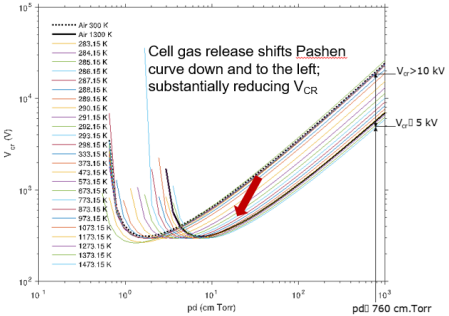
   $$\frac{5}{2}O_2 + C_3H_4O_3(EC) \xrightarrow{\Delta H} 3CO_2 + 2H_2O$$

   $$\text{-}CH_2\text{-}CF_2\text{-} + Li \xrightarrow{\Delta H} LiF + \text{-}CH{=}CF\text{-} + \frac{1}{2}H_2 \qquad CMC\text{-}OH + Li \xrightarrow{\Delta H} CMC\text{-}OLi + \frac{1}{2}H_2$$

2. **Battery TR releases hazardous and flammable gases and electrolyte**
   - Cells can achieve temperatures of >600C, transferring heat to adjacent cells
   - Electrolyte can cause external fires on other cells
   - ***Gas /particulate release increases potential for HV discharge***
   - Once external oxygen is consumed, flammable gases can reignite with reintroduction of O2
   - H_2O hydrolysis inside/outside cell

3. **Battery packs in EV's and ESS applications can be difficult to access**
   - It is often difficult to remotely assess the state of a battery cell
   - No clear path to identify "End of Event"
   - Stranded energy /damaged cells can generate reignition events

Peugot 208 EV fire 10/2022
50 kW-h pack

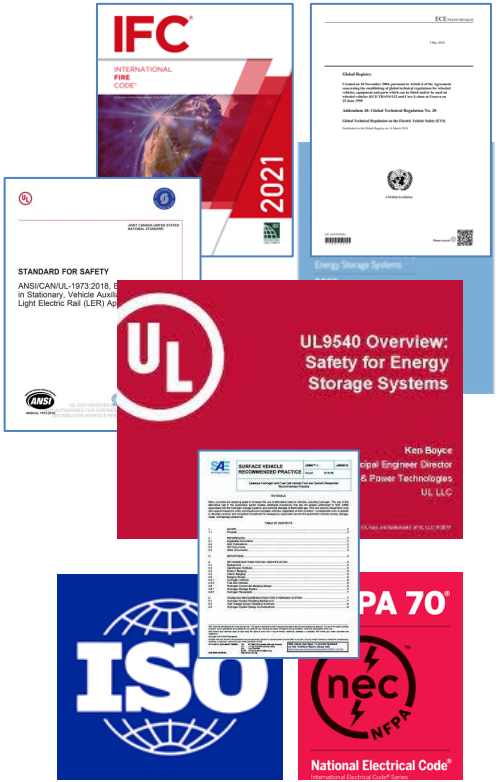


Courtesy Jeremy Riousset, FIT

Hazards proximate to pack include: fire/explosion, hazardous gas/asphyxiation, HV discharge

Evolving Battery Safety Regulations & Standards:

- UN 3090, Lithium metal batteries (shipped by themselves)
- UN 3480, Lithium ion batteries (shipped by themselves)
- UN 3091, Lithium metal batteries contained in equipment or packed with equipment
- UN 3481, Lithium ion batteries contained in equipment or packed with equipment Code of Federal Regulations 40: Protection of the Environment Part 273
- UN38.3: Certification for Lithium-ion batteries
- NFPA 855: Standard for the Installation of Stationary Energy Storage Systems
- IFC: 2024; Chapter 3: Section 321 Rechargeable Battery Storage
- GTR-20: Electric Vehicle Safety
- UL 1973: Batteries for use in Stationary, Vehicle Aux Power and light rail apps
- UL9540: Safety for Energy Storage Systems
- NFPA 70: Electrical Safety
- ISO-17840: Road vehicles — Information for first and second responders
- SAE J2990: Hybrid and Electric Vehicle Safety Systems Information Report
- SAE J3235 (Draft) BEST- PRACTICES FOR THE STORAGE OF LITHIUM-ION BATTERIES
- 23 SAE Battery Standards Committees authoring >50 documents



Regs & Standards challenged to keep up with technology changes in the field

Regulations & Standards:

Transport by Air: http://www.imo.org/ & http://www.faa.gov/hazmat

Lithium batteries and battery-powered equipment may be transported within the United States by aircraft and by motor vehicle or rail either before or after being transported by aircraft in accordance with the ICAO TI.

- The Federal Aviation Administration (FAA) maintains a website devoted to lithium battery safety, with a focus on transportation by air: https://www.faa.gov/hazmat/resources/lithium_batteries
- SAE AIR6840: Recommendations and Background for Battery Package Testing
- SAE AS6413/2: Performance based package standard for lithium batteries as cargo on aircraft – Direct flame test
- SAE AS6413/1: Performance based package standard for lithium batteries as cargo on aircraft - Oven Test

Transport by vehicle, rail, or vessel: http://www.icao.int/

- May be transported within the United States by vessel and by motor vehicle or rail either before or after being transported by vessel in accordance with the IMDG Code

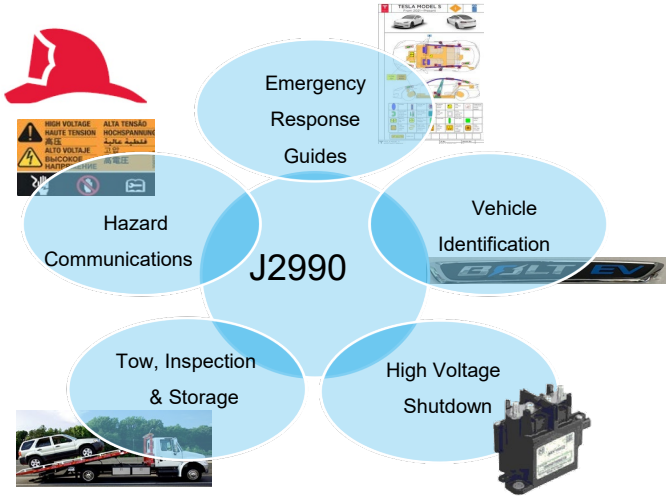
https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-273?toc=1

https://www.federalregister.gov/documents/2018/11/27/2018-24620/hazardous-materials-harmonization-with-international-standards
https://www.imo.org/en

SAE J2990 Hybrid and First and Second Responder Recommended Practice
SAE J3235 Best-Practice for Storage of Lithium-Ion Batteries

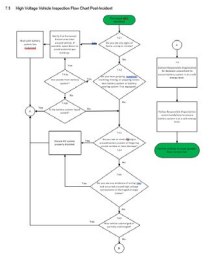
SAE J2990 / ISO 17840 Critical Elements:

- Hazard Communications
- Emergency Response Guides
- Vehicle Identification
- High Voltage Shutdown
- Towing, Storage, and Inspection
  - Decision tree for “end of event” to turn over to second responders



SAE J3235 Storage of Lithium ion Batteries :

- Mitigating risk for storage of lithium-ion cells, batteries and battery systems
- Intended for use in automotive-type and similar large format systems



Field experience provides feedback for next steps

FDNY: Onerous Regulations due to poor outcomes

- Intro. 656: which requires the fire department to develop an informational campaign to educate the public on fire risks posed by powered mobility devices
- Intro. 663: which prohibits the sale of batteries for mobility devices are not listed by a nationally recognized testing laboratory or approved organization, such as Underwriters Laboratory
- Intro. 749: which require the Department of Consumer and Worker Protection and the FDNY to provide information on safety measures and also require food service establishments to provide delivery workers with information
- Intro. 752: ***prohibit the sale and assembly of second-use lithium ion batteries***
- ***City of New York now requiring e-bike batteries to be removable***

How will old/damaged batteries be handled in NYC and other cities?

E-bike battery fire in NYC leaves 3 kids injured, including 2 critically: FDNY

By Tina Moore

February 5, 2023 | 1:30pm | Updated

Lithium ion batteries used for e-bikes and scooters were the cause of a Sunset Park fire Monday, the FDNY said. (FDNY)

FDNY: Hazmat Guidance after 190 fires in 2022

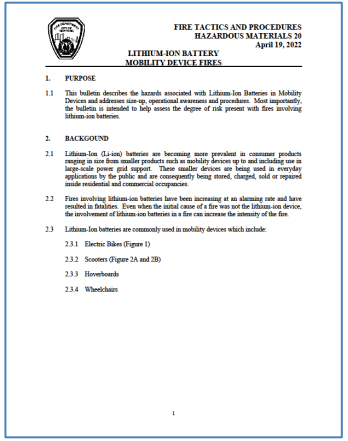
In less than two years, 11 people perished and 251 were injured in NYC fires sparked by lithium-ion batteries used to power e-bikes and e-scooters, the FDNY said.

- 5.5 The batteries or mobility device should be moved to the following location in order of preference until it can be appropriately over packed/mitigated by Haz Mat Company 1 or a Haz Mat Tech Unit:
- 5.5.1 Bathroom tub in fire apartment, with all cells fully submerged in water.
- 5.5.2 Sink large enough that all cells can be fully submerged in water.
- 5.5.3 Garbage pail or bucket large enough that all cells are capable of being fully submerged in water

- 5.6 When the above options are not practical, the Incident Commander may remove the batteries or mobility device via a fire apartment window.

- 5.7 When the battery or mobility device is in a location that makes removal via fire apartment window not practical, such as in an upper story apartment in a high-rise building, the Incident Commander may move the batteries or mobility device to a different location on the fire floor and ensure the batteries are protected by a charged hoseline. The charged hoseline will remain in place until overpacking/mitigation procedures have been completed by a Haz Tech Unit.

- 5.8 A lithium-ion battery or mobility device shall NOT be moved in an elevator or via stairs unless overpacked (mitigated) by Haz Mat Technicians and approved by the IC.



FIRE TACTICS AND PROCEDURES
HAZARDOUS MATERIALS 20
April 19, 2022

LITHIUM ION BATTERY
MOBILITY DEVICE FIRES

1. PURPOSE

1.1 This bulletin describes the hazards associated with Lithium-Ion Batteries in Mobility Devices and addresses size-up, operational awareness and procedures. Most importantly, the bulletin is intended to help assess the degree of risk present with fires involving lithium-ion batteries.

2. BACKGOUND

2.1 Lithium-Ion (Li-ion) batteries are becoming more prevalent in consumer products ranging in size from smaller products such as mobility devices up to and including use in large-scale power grid support. These smaller devices are being used in everyday applications by the public and are consequently being stored, charged, sold or repaired inside residential and commercial occupancies.

2.2 Fires involving lithium-ion batteries have been increasing at an alarming rate and have resulted in fatalities. Even when the initial cause of a fire was not the lithium-ion device, the involvement of lithium-ion batteries in a fire can increase the intensity of the fire.

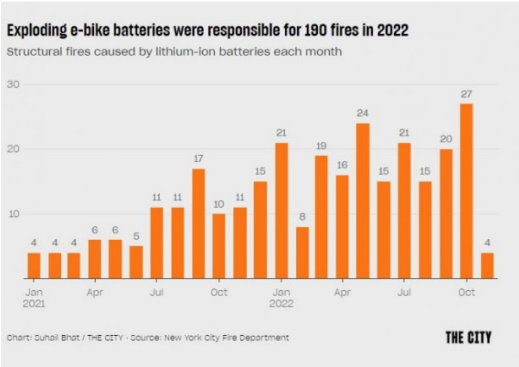
2.3 Lithium-Ion batteries are commonly used in mobility devices which include:

2.3.1 Electric Bikes (Figure 1)

2.3.2 Scooters (Figure 2A and 2B)

2.3.3 Hoverboards

2.3.4 Wheelchairs

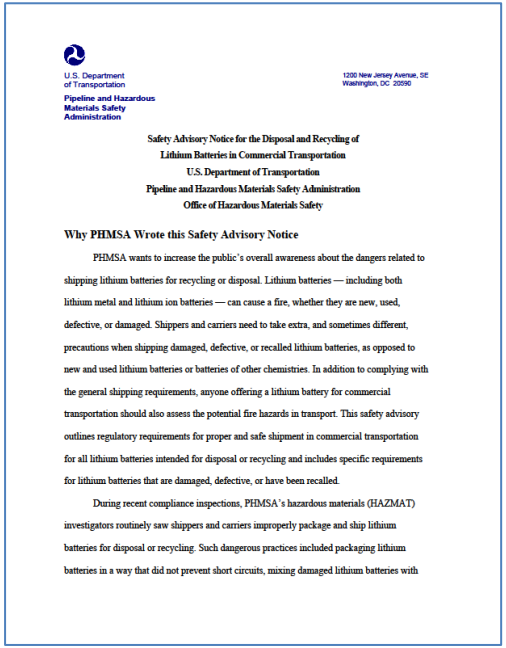


Identification, mitigation, and handling must take pragmatic approach

Safety Advisory Notice for the Transportation of Lithium Batteries for Disposal or Recycling – Response Guides May 17, 2022

To best assist emergency responders at the scene of the incident, emergency response information must include:

- The basic description and technical name of the hazardous material.
- For example, “UN3480, Lithium ion batteries, 9” or “UN3090, Lithium metal batteries, 9.”
- Immediate hazards to health.
- Risks of fire or explosion.
- Immediate precautions to be taken in the event of an accident or incident.
- Immediate methods for handling fires.
- Initial methods for handling spills or leaks in the absence of fire.
- Preliminary first aid measures.



U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

Safety Advisory Notice for the Disposal and Recycling of Lithium Batteries in Commercial Transportation
U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Hazardous Materials Safety

Why PHMSA Wrote this Safety Advisory Notice

PHMSA wants to increase the public’s overall awareness about the dangers related to shipping lithium batteries for recycling or disposal. Lithium batteries — including both lithium metal and lithium ion batteries — can cause a fire, whether they are new, used, defective, or damaged. Shippers and carriers need to take extra, and sometimes different, precautions when shipping damaged, defective, or recalled lithium batteries, as opposed to new and used lithium batteries or batteries of other chemistries. In addition to complying with the general shipping requirements, anyone offering a lithium battery for commercial transportation should also assess the potential fire hazards in transport. This safety advisory outlines regulatory requirements for proper and safe shipment in commercial transportation for all lithium batteries intended for disposal or recycling and includes specific requirements for lithium batteries that are damaged, defective, or have been recalled.

During recent compliance inspections, PHMSA’s hazardous materials (HAZMAT) investigators routinely saw shippers and carriers improperly package and ship lithium batteries for disposal or recycling. Such dangerous practices included packaging lithium batteries in a way that did not prevent short circuits, mixing damaged lithium batteries with

Keep in mind who is handling your product – drivers, transporters, & material handlers
Plan to reduce energy and risk in transporting cells & packs