LITHIUM-ION BATTERIES[1]

In 1996, the United States Advanced Battery Consortium awarded seven major research contracts to help develop solutions for electric vehicles. Lithium was identified as the front-runner material because of its light weight (living between hydrogen and helium in the Periodic Table of Elements) with the first batteries for sale 26 years ago in Sony's CCD-TR1 camcorder. Now lithium-ion batteries have become an ever-present role in every aspect of our lives, from phones, laptops, toothbrushes, power tools, scooters, vaping devices, and bikes to larger scale uses seen in electric vehicles and deployed to improve the resilience of our electric grid. With increased use comes greater quantities of batteries being manufactured and stored to keep up with demand. According to OSHA, more than 25,000 overheating or fire incidents involving more than 400 types of lithium battery-powered products occurred between January 2012 and July 2017. Imagine how that number has increased with new technologies that have come forth since that time.

Historical Events

- June 29, 2021, Morris, IL: 100 tons of lithium batteries ranging in size from phone batteries to car batteries were involved in a large warehouse fire. It took a week to extinguish the fire. The Morris Fire Protection District ended up using a Portland cement mix to smother the burning batteries.
- July 2022, Connecticut: An electric transit bus burst into flames while parked at a depot.
- August 5, 2022, New York City: Two people died in an apartment fire that was started by a charging e-scooter blocking their escape from the apartment.
- December 2022, New York City: A JetBlue flight heading to JFK from Barbados made an emergency landing at JFK and the plane evacuated due to a smoking laptop. Seven people were treated for injuries.
- December 2022, Chicago: A Lufthansa flight made an emergency landing at O'Hare after a passenger's laptop overheated in the cabin, causing a small fire. Two flight attendants were treated for smoke inhalation.
- January 2023, Boston: Failed batteries for an e-scooter started a fire that ended up engulfing a multifamily home.
- May 2023, New York City: Two people died in an apartment fire that was started by a charging e-scooter that was blocking the only way out of the apartment.

[1] This discussion does not include Battery Energy Storage Systems.

- June 20, 2023, New York City: Four people died when a fire started on the ground floor bike repair shop with 5 stories of apartments above. The fire was started by five e-bikes.
- October 18, 2023, New York City: Five people injured (3 critically) in a Brooklyn apartment started by a charging e-bike. The fire blocked the only exit from this apartment building.
- February 8, 2023, California: A passenger's laptop battery caught fire after a United flight left San Diego forcing the plane to return to San Diego. Four people were taken to the hospital for treatment. Airline crews are trained in these situations and contained the fire until the flight was able to safely land.
- February 19, 2024, France: A recycling plant in southern France became engulfed in flames when a fire started in an area recycling approximately 900 tons of lithium-ion batteries. A similar fire occurred in January 2023 in Normandy, France at a car manufacturing plant.
- October 30, 2024, Fredericktown, MO: A 225,000 ft^2 lithium-ion battery processing and recycling plant damaged their facility, including a partially collapsed roof after a fire broke out.
- And many more…

How This Technology Works

A lithium-ion cell is composed of four primary components: the anode, cathode, separator, and electrolyte. The components work together in the cells to provide an electrical current that we use. When the battery is charging an electrical potential pulls lithium ions into the recesses of a graphite-based electrode; when it is in use these ions migrate back through a liquid electrolyte to a much more complex electrode made of compounds containing lithium and other metals—the cathode. The separator allows the lithium ions to move from the anode to the cathode while preventing a short circuit.

Thermal Runaway

While lithium-ion technology has very desirable performance characteristics, such as high energy density, long life, and longer run times, lithium-ion technology also has the potential for thermal runaway hazards that need to be mitigated. Thermal runaway is the occurrence where a lithium-ion cell enters a state of uncontrolled self-heating. Thermal runaway often begins when the heat generated within a cell exceeds the heat dissipated to its surroundings. If this event is not mitigated the condition only worsens eventually leading to distortion and melting of the separator between the anode and cathode causing an internal short circuit. This internal short circuit causes the internal cell temperatures to rise, increasing the rate of the chemical reaction and creating a feedback loop. Heat is transferred to neighboring cells until propagation continues throughout the entire battery pack and eventually the lithium-ion battery catches fire releasing gases such as hydrogen, methane, carbon monoxide, and carbon dioxide.

Existing Challenges and Trends

No reliable national statistics on battery fires are currently available. But FDNY reports 900 fires attributed to lithium-ion batteries since 2020 causing 500 injuries and 34 deaths. But because this technology is so engrained into our everyday lives, the bad habits also engrained into our daily lives will continue to lead to fires and thermal runaway events.

Latest News

NFPA 800, *The Battery Safety Code* (Provisional Standard) is still in development and will hopefully be published in early 2027. In the meantime, NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems,* may have helpful information and requirements as well as the more recent editions of NFPA 1, *Fire Code* and the International Fire Code. NFPA 401*, Recommended Practice for the Prevention of Fires and Uncontrolled Chemical Reactions in Hazardous Waste Handling* also contains information on battery disposal.

Illinois P.A. 103-1033(SB 3686) created the Illinois Portable and Medium-Format Battery Stewardship Act. Beginning January 1, 2026, producers selling batteries in Illinois are now required to participate in an approved Battery Stewardship Plan. This effort will offer expanded battery disposal options for all Illinois residents ensuring the proper management, handling, and recycling. Additionally, proper end of life management of used portable and medium-format batteries will prevent the release of toxic materials into the environment and will aid in removing materials from the waste stream that, if mishandled, may present safety concerns to workers, such as fires at solid waste handling facilities.

The Illinois EPA is working on rules to administer this Act still under development found at Title 35 Ill. Adm. Code 1220. OSFM has been involved in making recommendations for these rules.

Fire Protection

UL Solutions Takes Aim at Lithium-Ion Battery Fire Risks with Innovative New Certification Programs for Battery Containment Enclosures and Micromobility Charging Equipment | UL Solutions

Sprinkler design: No design criteria has been included in NFPA 13. NFPA 13 does have requirements for alternative designs. Owners of buildings that are used to manufacture, store (new and returned), rebuild, and/or recycle lithium-ion technology should consider hiring a professional engineer with expertise in fire protection/sprinkler design to develop design criteria for protection of battery storage, manufacture, or recycling of lithium-ion batteries.

Factory Mutual Data Sheet 7-112, *Lithium-Ion Battery Manufacture and Storage* is a well-researched source that provides requirements for Factory Mutual insured facilities that are manufacturing/storing as well as storing returned/defective/off-specification/damaged cells/modules/batteries. Following is a link to this document: FMDS07112.pdf

Fire Extinguishers: Normally used fire extinguisher agents are not useful with this technology. Technology specific to lithium-ion fires or thermal runaway events that are tested, listed, and approved are not currently found on the market.

Firefighting Operations: Things to Think About[2]

When firefighters respond to fires involving lithium-ion batteries, they discover that it takes much longer to be able to control the fire because it requires substantially more water.

- ***Preplanning:*** Fire departments should work with owners of lithium-ion manufacturing and storage operations to preplan and prepare for the various types of emergency incidents that might occur at the specific facility. If the fire department is unsure of operational tactics for this type of hazard, consider bringing in experts in the field to assist with determining fire suppression approaches and specialized equipment that might be needed. Generally using a licensed professional engineer with experience in this area or somebody with similar credentials would be the best choice. It is possible that the facility might have firefighting and suppression equipment unique to lithium-ion hazard that fire department may be able to use, but the problem with depending upon equipment owned by somebody else is making sure the equipment is maintained and will be operational when needed. The owner of the company might consider purchasing the equipment needed for their local fire department. OSFM offers equipment loans and information related to this can be found at Grants and Loans.
- ***Gas Production:*** Gas production, regardless of the type of lithium-ion battery, can be released when they fail. The gas is both flammable, explosive, and toxic. This can add a tremendous fuel load to a fire situation, especially when ventilation is restricted. Trapping these gases within an enclosure can easily create both toxic and flammable concentrations. In extreme cases, this can result in deflagration within the enclosure, even if flaming fire is not apparent. Make sure appropriate gas detection is being used.
- ***PPE:*** Always wear full PPE and SCBA when dealing with these technologies, even during overhaul and investigation operations unless it is confirmed that toxic gases no longer remain. Make sure appropriate gas detection is being used. PFAS chemicals are the current buzzwords related to firefighter PPE (turnout gear) and research is continuing in that area. But on the topic of lithium-ion technology, there has been no research or testing related to the compatibility of current firefighter PPE to emerging lithium-ion technologies nor do current standard protocols for PPE manufacture explicitly address lithium-ion hazards and PPE exposure. Research is being called for.
- ***Extinguishing Agents:*** Water is still the first choice for extinguishing these fires, not fire extinguishers or even foam. There are specially designed “fire blankets” available but they are single use, very expensive, but having one available as a last resort might be helpful.
- ***TIC:*** Do not depend upon thermal imaging cameras.

[2] This is not meant indicate final tactical decision making. Information gathered from various sources and experts should be considered on an incident by incident basis. Preplanning with local facilities to obtain information is very important.

- ***Overhaul Operations:*** Collecting and removing these batteries and devices from a structure should be a fundamental part of overhaul operations. One method of safely removing damaged batteries during overhaul, as discussed in the fire department arena, is to completely submerge batteries in 5-7 gallon open buckets of water. The same concept for safety is also to remove a lithium-ion battery-supported vehicles impacted by fire from any enclosures.
- ***Overhaul Operations:*** Electrical shocks to firefighters caused by these battery devices continue to occur. There is a potential for serious injury from these devices. During overhaul operations lithium-ion devices should be removed. However, overzealous physical deconstruction of battery packs by firefighting crews is very dangerous. What the fire service considers to be "less conductive tools" will not always safeguard firefighters when overhauling lithium-ion batteries.
- ***Overhaul Operations:*** Batteries can go from stable to incinerate in seconds. This has forced a reevaluation of our existing understanding of fire progression, especially as it applies to private dwellings. Lithium-ion batteries, which heavily influence gas production, are now a common part of fire debris for a private residence.
- ***Overhaul Operations:*** Do not ride in elevators with damaged devices. If there is no other option, use the firefighter recall option and have the device travel alone in the elevator. Remember batteries can go from stable to very unstable in seconds.

Understanding Lithium-ion Battery Fire Hazards to Improve Firefighter Safety

How Can Firefighters Stay Safe in Lithium-ion Battery Fires?

Parking Garages and EVs

The Science of Lithium-Ion Batteries Guide by FSRI_1.pdf

Public Education

Safety message from the National Fire Protection Association, the UL Fire Safety Research Institute, and OSFM:

EVACUATE QUICKLY if there is a fire. Follow your home fire escape plan and call 911.

EDUCATE OTHERS on safe practices.

PURCHASE only listed products:

- When buying a product that uses a lithium-ion battery, take time to research it. Look for a stamp from a nationally recognized testing lab on the packaging and product, which means that it meets established safety standards.
- Many products sold online and in stores may not meet safety standards and could increase the risk of fire.

CHARGE devices safely:

- Always use the cables that come with the product to charge it.

- Charge the device in accordance with the manufacturer's instructions.
- If you need a new charger, buy one from the manufacturer or one that the manufacturer has approved.
- Charge your device on a hard surface. Do not charge it under a pillow, on a bed, or on a couch. This could cause a fire.
- Do not overcharge your device. Unplug it or remove the battery when it is fully charged.
- Do not charge micromobility devices inside homes or in common areas of multi-unit buildings (business or residential).
- Do not charge things overnight and do not leave them charging for days at a time. This includes all chargeable items, including your cordless vacuum cleaner to your electric toothbrush.
- Store batteries at room temperature and do not leave in direct sunlight or leave in a hot vehicle.

WHILE TRAVELING follow the instructions for packing lithium-ion products and using them in the various forms of transportation. Keep lithium-ion powered products with you in the plane cabin and do not pack in checked luggage. Imagine being 30,000 feet above the earth in a plane that is experiencing a cargo fire because somebody packed their lithium-ion powered electronic device. Additionally, follow instructions by transportation officials for use of and retrieval of electronic devices (if they fall between seats). Transportation officials are trained in safe retrieval and storage of possibly damaged electronics.

DISPOSE OF/RECYCLE batteries responsibly:

- Do not throw lithium-ion batteries in the trash or regular recycling bins because they may ignite a fire in an unwanted location.
- Recycling your device or battery at a safe battery recycling location is the best way to dispose of them. Visit www.call2recycle.org, https://batterysafetynow.org/ or check with municipal public works department to find a recycling spot near you.

SIGNS OF PROBLEMS. Stop using the battery if you notice these problems:

- Odor
- Change in color
- Too much heat
- Change in shape
- Leaking
- Odd noises

Snake Oil Products: Widespread demand of lithium-ion cells and batteries has attracted illicit copying to profit through counterfeiting. Counterfeit cells are manufactured by copying high-quality lithium-ion products and deceive unsuspecting customers. These counterfeit lithium-ion products often contain an unauthorized trademark or logo that is the same as the trademark of another product and may make it impossible to differentiate. These lithium-ion products have low quality components and are not certified to any standards. Counterfeit lithium-ion products pose many safety risks as they may be prone to failure and cause fires and explosions. Certifications are falsified along with misleading performance claims on the label or on the website selling them. This directly results in compromised safety of the lithium-ion products and eventually the devices that use them. The proposed bargain may not be worth the purchased higher risk in safety.

Counterfeit lithium-ion products make false claims of certifications and test results that are exhibited by authentic lithium-ion products. Certifications to standards and regulations confirm that the minimum requirements for performance, quality and safety have been met. Lithium-ion products receiving the certification establish confidence in customers that they are genuine lithium-ion products. In many cases, it is challenging to distinguish an authentic certification or certification mark on a counterfeit lithium-ion product. Hence, caution is warranted when purchasing cells when verifiable performance, safety and quality are of utmost importance. Purchases from third-party sellers on online marketplaces and unauthorized resellers may involve the risks of counterfeits and must proceed with caution.

Considerations for avoiding counterfeit products: Precautions must be taken during purchase to avoid counterfeit lithium-ion products. Some easy-to-follow considerations may be helpful in avoiding these:

- Purchase only from the original equipment manufacturer (OEM) or from reputable retailers and suppliers recommended by the OEM.
- Check every detail of the product as described in previous section to detect and avoid counterfeit products.
- Whenever possible, ask the vendor for pictures of the actual products.
- Buy only listed products.
- Compare the trademark and the logo with the authentic one.
- Verify that the certification label is authentic.

Bibliography and References

Barowy, Adam, *The Science of Fire and Explosion from Lithium-Ion Batteries,* Fire Safety Research Institute, (Northbrook, IL: Underwriters Laboratories, Inc., 2023)

Counterfeit Lithium-ion Cells and Batteries (Underwriters Laboratories, 2024)

Ditch, Ben and Stephanie Thomas, *Is It a Battery Fire or Just a Fire? Fire Protection of Lithium-Ion Batteries in Manufacturing and Storage,* Fire Protection Engineering, (Gaithersburg, MD: Society of Fire Protection Engineers Q3, 2024 Issue #103)

Electrifying Everything, (The Economist: August 12, 2017)

Greene, Chris, *Lithium-Ion-Influenced Fires: Back to Basics,* Fire Engineering, (December 2025)

Lithium Ion Battery Safety for Consumers (NFPA)

Nakano, Andrea, CBS San Francisco, (June 15, 2023)

New York Daily News, firehouse.com, (Firehouse Magazine: June 2023)

New York Daily News, firehouse.com, (Firehouse Magazine: October 2023)

NFPA Fire Protection Handbook-21st edition, (Quincy, MA: National Fire Protection Association, 2023)

OSHA Issues Safety Bulletin on Hazards of Lithium Batteries, Lithium-Powered Devices, Safety+Health Magazine, (National Safety Council: April 2019)

Progress with Li-Ion Battery Fire Safety: Engineering Solutions to Mobility and Storage Hazards, SFPE Engineering Solutions Symposiums, (Society of Fire Protection Engineers: June 4–6, 2024 Phoenix, AZ)

Roman, Jesse, *Spotlighting Lithium-Ion*, NFPA Journal, (Quincy, MA: National Fire Protection Association, Winter 2025)

Sankranti, Shashwat, www.wionews.com, (WION: February 19, 2024)

Stull, Jeffrey, *PPE Supplement 2026: PPE Reimagined,* Fire Engineering, (January 2026)

Verzoni, Angelo, *Missouri Fire Highlights Unique Dangers of Battery Recycling,* NFPA Blog, (National Fire Protection Association: November 1, 2024)

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