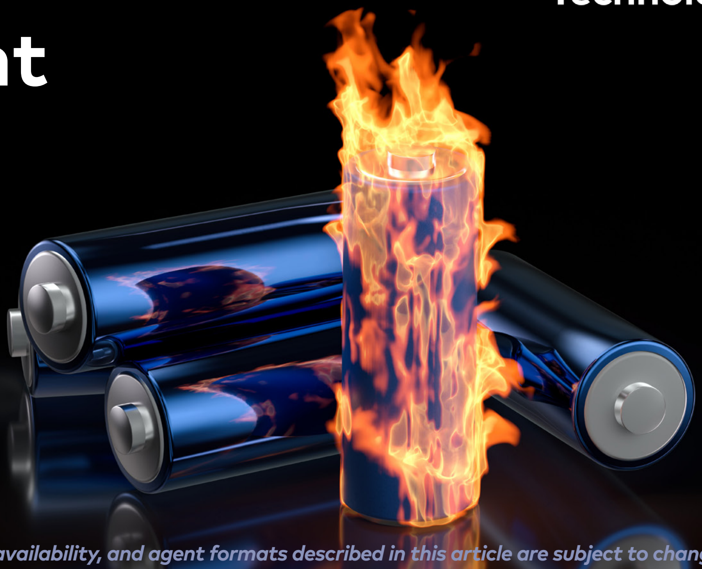
How to Prevent Lithium-Ion Battery Fires

A SYSTEM ENGINEER'S GUIDE



TLX agents are in active development. Product specifications, availability, and agent formats described in this article are subject to change. All performance claims are based on testing conducted to date; contact us directly for the most current data.

IN APRIL OF 2025, a Tesla collided with a tree in Sacramento, California, damaging the lithium-ion battery pack. As the car was being towed from the scene, the battery pack went into thermal runaway. The ensuing toxic vapor cloud engulfed firefighters who were as far away as 300 feet. Some of them suffered lasting, career-altering injuries from the exposure.

In September of 2025, a Nissan LEAF went into thermal runaway while charging in Littleton, Colorado. Firefighters cleared a nearby strip mall to protect the public from the toxic vapor cloud. They also let the fire burn itself out rather than try to extinguish it, spraying the surrounding area with water to keep the fire from spreading to adjacent trees. Some fire departments are adopting this strategy when dealing with battery fires because it's almost impossible to extinguish a battery with water, and spraying water on a battery fire creates a highly toxic runoff.

These stories highlight a fundamental reality that must be faced to develop solutions for fighting or even preventing lithium-ion battery fires. These fires aren't like any other kind of fire. Legacy fire suppression approaches simply don't work well enough. They're effective at controlling and extinguishing secondary fires, but they aren't effective at extinguishing the battery fire itself.

Because these batteries power so much of our modern life—smartphones, electric vehicles, e-bikes, e-scooters, cordless power tools, portable power stations, home energy storage systems—a new approach has to be developed. Integrating the extinguishing agent inside the battery enclosure is the best strategy.

Why Are Lithium-Ion Battery Fires Different?

The International Organization for Standardization (ISO) recently established an entirely new classification just for lithium-ion battery fires: Class L. This is because the fire hazard is the result of an electrochemical system with high energy density and differs substantially from other electrical fires.

The root cause of a lithium-ion battery fire is a phenomenon known as thermal runaway, a condition which produces heat, flammable gases, and oxygen within the battery. The resulting fire burns furiously, often with jets of flame as hot as 1000˚C. Even after the fire is extinguished, thermal runaway can continue.

What is Thermal Runaway?

Thermal runaway is a cycle of self-reinforcing exothermic reactions inside the battery cell where increasing temperatures cause the internal components to decompose. The cycle repeats as rising temperatures accelerate the destructive reactions, creating even more heat. Eventually, the cell reaches the point of no return. Heat is generated faster than it can be dissipated, and the exothermic reactions become self-sustaining and uncontrollable.

In a multicell battery pack, the heat can damage adjacent cells, causing thermal runaway to spread throughout the battery pack. This is why electric vehicles will commonly catch fire again hours, days, or even weeks after the initial fire is extinguished.

During thermal runaway, internal temperatures can exceed 600˚C, and the resulting fire can exceed 1000˚C.

The Thermal Runaway Cycle

Thermal runaway is triggered by damage to the battery, such as manufacturing defects, puncture, crushing, overcharging, short circuit, or exposure to too much heat.

The temperatures below are typical, but will vary based on specific battery chemistry:

+ **Between 90˚C and 120˚C,** the solid electrolyte interphase (SEI) layer breaks down. This exposes the anode to the electrolyte and initiates an exothermic reaction.
+ **Between 110˚C and 150˚C,** the anode reacts with the electrolyte. Because of this reaction, heat in the battery continues to rise.
+ **Between 130˚C and 180˚C,** the battery separator, a polymer membrane between the anode and cathode, fails. This creates an internal short circuit, generating more heat.
+ **Between 150˚C and 250˚C,** the cathode decomposes, releasing oxygen and intensifying the exothermic reactions. The electrolyte solvents decompose producing large volumes of toxic, flammable gases containing CO, CO_2, HF, H_2 and hydrocarbons. Pressure inside the battery case rises.
+ **Between 200˚C and 300˚C,** the rapid production of gases causes internal pressure to rise sharply. The cell either vents the gases, or it ruptures. This is the popping noise that is often heard as thermal runaway unfolds.
+ **Above 250˚C** the gases can ignite resulting in fire or even jets of flame with temperatures between 600˚C and 1200˚C.
+ **Above 300˚C** thermal runaway is now fully self-sustaining. Battery cell temperatures can reach 600˚C, and the risk of propagation to adjacent cells is at its greatest. The exothermic reactions will continue until all the fuel in the cell is consumed.

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Why Are Li-Ion Fires So Hard to Extinguish?

There are at least three factors that make dealing with a battery in thermal runaway so difficult.

First: A battery in thermal runaway has plenty of fuel and produces its own oxygen. Extinguishing agents (foams) or techniques (like fire blankets) that are intended to smother the fire and starve it of oxygen are often ineffective, but they can control or extinguish secondary fires.

Paradoxically, fire blankets can actually create new dangers. The Fire Safety Research Institute issued an advisory about using fire blankets to fight electric vehicle fires. Flammable gases produced by thermal runaway can accumulate under the blanket even after the fire is out, creating an explosion hazard.

Second: The battery cells are usually housed in a protective case, making it extremely difficult to get water or any other extinguishing agent to the source of the fire, the cells that are in thermal runaway.

Professor Paul Christensen, speaking at the Green Fire Safety Conference in 2023, likens spraying water on an electric vehicle fire to pouring water on the roof of a house to put out a kitchen fire. He states that the battery case and the car's chassis act like an umbrella.

Third: The vapor cloud that is released when a cell in thermal runaway vents or ruptures contains a toxic cocktail that includes heavy metal nanoparticles, CO (carbon monoxide), and HF (hydrogen fluoride), which is highly corrosive and dissolves in water, including moisture in the air and moisture in skin, eyes, and lung tissue, to form hydrofluoric acid.

It's dangerous to even be near a battery when it's in thermal runaway. A person in San Jose, California, died after trying to extinguish an e-bike fire inside an apartment. The person made it outside and collapsed after exposure to the vapor cloud, which would have contained lethal levels of carbon monoxide.

A Different Philosophy: Integrating the Extinguishing Agent into the Battery Case

TLX Technologies has found that integrating a specialized extinguishing agent directly into the battery case is the best strategy for fighting lithium-ion battery fires. This reliably delivers the agent directly to the cells, where intervention is the most effective.

Target Applications

TLX's agents are being developed for use across a broad range of applications:

+ **Micromobility:** E-bikes, e-scooters, and other battery-powered personal mobility devices are gaining wider adoption and are responsible for an increasing number of battery fires. As just one example, New York City saw a 53 percent increase in structural fires from lithium-ion batteries in 2025.
+ **On- and Off-Highway Vehicles:** Electric powertrains are proliferating among mobility platforms, including passenger vehicles, buses, commercial fleet vehicles, farming vehicles, and mining vehicles. In March of 2026, in Williston, Vermont, four electric buses caught fire, resulting in more than $2 million in damages. While not widespread, there are bans on parking EV's in

underground parking structures due to fire risk.

- **Powersports:** Electric dirt bikes, jet skis, ATVs, and side-by-sides are growing in popularity. Because they are used in such challenging environments, fire safety is particularly important. A punctured battery case or short circuit caused by water intrusion could be catastrophic.
- **Marine:** The combination of confined spaces, intense heat, and toxic smoke make battery fires particularly dangerous on marine vessels. In 2022, the Felicity Ace **caught fire** and sank while transporting nearly 4,000 automobiles across the North Atlantic. The cargo included Audi and VW electric vehicles.
- **Home Use:** Cell phones, laptops, cordless power tools, and home energy storage systems use lithium-ion batteries. Many consumers are unaware of the associated fire risks. A family in Australia **lost their home** when a brand new power tool charging in their garage caught fire. In a less tragic case, a dog began chewing on a battery-powered device, causing the battery to go into **thermal runaway** and catch fire. Thankfully, the dog was unharmed and only the rug was destroyed.

A PFAS-Free Solution: Keeping Up with Evolving Regulations

Since the 1960's, firefighting foams have relied on per- and polyfluoroalkyl (PFAS) substances for their effectiveness. These synthetic chemicals have been prized for their ability to lower surface tension, allowing firefighting foams to spread rapidly and evenly across burning liquids like gasoline or jet fuel. They're also chemically and thermally stable and withstand intense heat.

But PFAS have been recognized as **dangerous to human health** and are known as forever chemicals. They do not break down naturally, are bioaccumulative, and are linked to numerous health risks, including some forms of cancer.

Consequently, there has been a global effort to eliminate PFAS from extinguishing agents. In Europe, the **EU REACH regulations** eliminate the use of PFAS foams by October, 2030. In the US, **the FAA,** in conjunction with the DOD, has developed a plan to move away from the use of PFAS firefighting foams, and **state-level bans** are increasing. The **SOLAS Convention**, an international treaty that establishes maritime safety standards for merchant ships, banned PFOS, a specific PFAS compound, as of January 2026.

TLX Agents: Clean Chemistry by Design

In light of the known health and environmental risks and the evolving regulatory landscape, every agent in TLX's portfolio is PFAS-free and uses ingredients listed on the **EPA's Safer Chemical Ingredients List (SCIL).** These chemicals are evaluated across a broad range of toxicological categories, such as carcinogenicity, mutagenicity, reproductive toxicology, and endocrine disruption.

The agents are also designed with the following additional safety characteristics:

- **Temperature Stability:** The agent must be functional at the environmental temperatures the battery is likely to experience in service. Indoor consumer electronics and electric vehicles often operate in very different temperature ranges. TLX's portfolio includes formulations for the full range of environmental temperatures.
- **Non-Corrosive:** This protects the battery and other components within the battery case from secondary damage.
- **Non-Harmful to Humans and the Environment:** The agents are suitable for enclosed spaces occupied by humans and safe for the environment.
- **Biodegradable:** Each agent has varying biodegradability depending on the specific formulation.
- **Near-Neutral pH:** All agents have a pH between 6.9 to 8.5, depending on the formulation, minimizing their reactivity with surrounding materials.
- **No Odor or Mild, Pleasant Odor:** This is an important feature for consumer-facing applications.
- **Patented or Patent Pending:** These agents have unique properties that set them apart from competing solutions.
- **Undergoing or Have Completed UL Testing:** This ensures independent evaluation of each agent's effectiveness.

Looking Ahead

TLX's extinguishing agents are currently in development and have either completed or are undergoing third-party testing. As milestones are reached, specific product configurations and availability will be announced.

The applications listed above—micromobility, on- and off-highway, recreational, marine, and home use—represent the initial focus. However, the fundamental agent chemistry may be applicable to scenarios beyond lithium-ion battery fires (Class L). TLX is open to expanding these offerings for other markets as testing continues.

EXPLORE THE RESULTS: If you're an engineer, product designer, or systems integrator working on applications that involve lithium-ion batteries, we'd welcome the opportunity to share more detail on agent specifications, compatibility data, and testing results as they become available. ***Contact us to request technical information or to schedule a conversation about your application: sales@tlxtech.com***

TLX Technologies