



FIRE EXTINGUISHING OF LITHIUM-ION BATTERIES

Omar TRABELSI,¹ Tünde Anna KOVÁCS²

¹ Obuda University, Doctoral School on Safety and Security Sciences, Budapest, Hungary,
am.rouch93@live.com

² Obuda University, Banki Donat Faculty of Mechanical Engineering, Budapest, Hungary
kovacs.tunde@bgk.uni-obuda.hu

Abstract

The spread of electric cars means the ever-wider spread of batteries. The use of lithium-ion batteries carries many dangers. The biggest danger is the possible explosion of the battery. Firefighting is not easy due to the properties of lithium. In recent years, there have been many fires caused by lithium-ion batteries. Firefighters use different methods, but their development is of utmost importance to ensure the safe use of electric vehicles. In this study, the authors try to draw attention to the dangers and present practical firefighting options.

Keywords: *electric car, batteries, fire, risk, Fire Extinguishing.*

1. Introduction

The EU has a firm goal of banning the use of fossil fuel vehicles in the coming years. It intends to implement this plan by increasing the use of electric cars. In order to reduce the harmful carbon dioxide emissions associated with fossil fuels, electric cars are used in increasing numbers [1]. Electric cars currently use lithium-ion batteries as an energy source.

2. Introduction of the Lithium-ion Batteries

Lithium is a metallic chemical element of the alkali metal family, characterized by its low density and high reactivity. It is widely used in the manufacturing of lithium batteries due to its ability to store and release energy efficiently [2]. Lithium is also used in other applications such as medicines, lubricants and metal alloys. Due to its highly reactive nature [3], lithium must be handled with care to avoid the risk of fire or explosion. Despite its advantages as a battery material, lithium presents safety and waste management challenges, requiring special attention when using and recycling it.

Lithium batteries are widely used in many electronic devices due to their high energy density and long cycle life [4]. However, it is important to recognize the potential risks associated with these batteries, such as overheating, overcharging and short circuits, which can lead to serious incidents such as fires. By understanding the inner workings of lithium batteries and adopting proper handling and storage practices, it is possible to minimize risks and ensure the safe use of these advanced technologies. The main types of lithium batteries include lithium-ion (Li-ion) batteries, lithium-polymer (LiPo) batteries [5] and lithium-iron-phosphate (LiFePO₄) batteries [6]. Li-ion batteries are widely used in consumer electronic devices and electric vehicles due to their high energy density and long cycle life [7]. LiPo batteries are often used in drones, model cars and portable devices due to their flexible and lightweight form. LiFePO₄ batteries are known for their thermal stability and durability [8], making them ideal for applications requiring high performance and increased safety [9]. Each type of lithium battery has its advantages and disadvantages, and the choice of battery type will depend on the specific needs of the application [10].

3. Risks of the Lithium-ion Batteries

Lithium batteries present ignition hazards that must be taken seriously due to their potential to cause serious incidents. One of the main risks is overheating batteries, which can be caused by overcharging, short-circuiting or exposure to high temperatures. This overheating can cause an uncontrolled chemical reaction inside the battery, leading to a fire or explosion. Additionally, lithium batteries can also ignite in the event of physical damage, such as puncture or crushing (eg car crash) [11] which can compromise the integrity of the battery and start a fire. It is, therefore, crucial to handle and store lithium batteries appropriately to reduce the risk of ignition and ensure the safe use of these advanced energy sources [12].

A lithium battery ignition or explosion scenario can occur due to various factors, such as overcharging, overheating, short circuits, or physical damage [13]. When a lithium battery is overcharged, lithium ions can deposit non-uniformly on the electrodes, creating hot spots that can result in an uncontrolled thermal reaction. Likewise [25], an internal short circuit in the battery can cause excessive heating and an increase in internal pressure, possibly leading to an explosion. Physical damage, such as battery puncture, may also leak flammable electrolyte liquid and cause fire [14].

- 1. Lithium battery overload due to defective or unsuitable charger.
- 2. Increased internal temperature of the battery, causing an unstable chemical reaction.
- 3. Accumulation of flammable gases inside the battery.
- 4. Failure of the separator membrane, resulting in an internal short circuit.
- 5. Triggering a rapid chain reaction, causing a sudden increase in temperature.
- 6. Rapid expansion of the battery and rupture of the outer casing.
- 7. Release of intense heat and flames, resulting in a potentially dangerous fire.
- 8. Risk of lithium battery explosion due to increased internal pressure and release of flammable gases.

4. Case Studies of Lithium Battery Fires and Consequences

4.1. Case Study 1: A cell phone caught fire due to an internal short circuit in the lithium-ion battery

In 2016, the Samsung Galaxy Note 7 incident was widely publicized due to faulty batteries that caused fires and explosions. Lithium-ion batteries used in cell phones were identified as the cause of the incidents, leading to massive recalls and flight

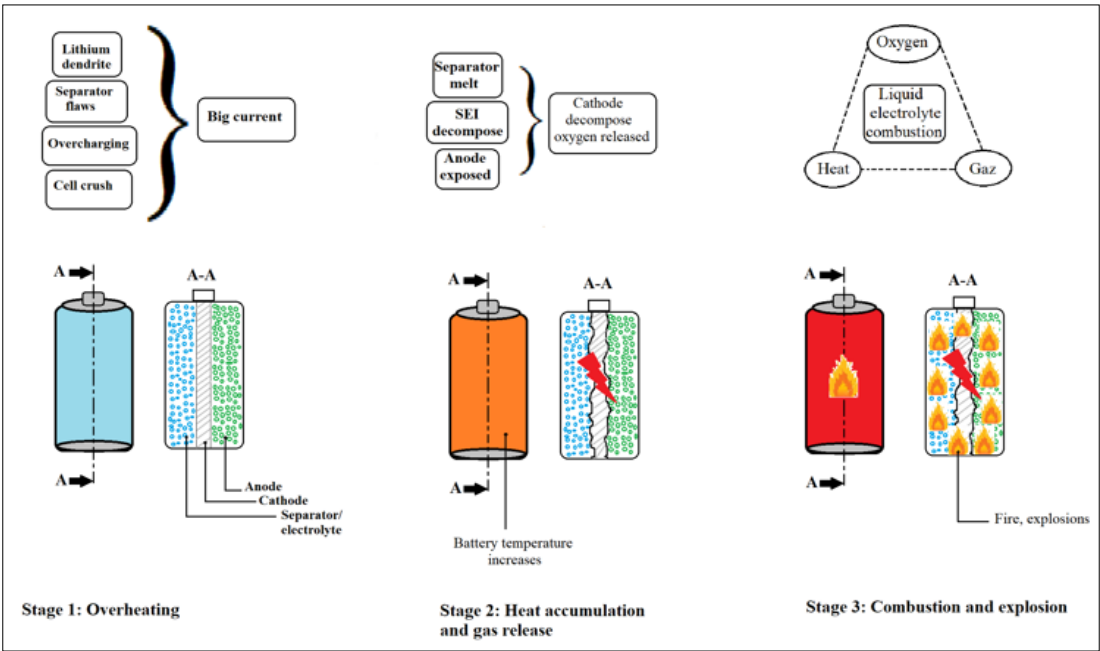


Fig. 1. Battery fire initiation

bans for the device. Flaws in battery design and manufacturing have led to overheating, short circuits and thermal failures, putting user safety at risk. This incident highlighted the importance of the quality and safety of electronic components, prompting manufacturers to strengthen their quality control processes to avoid such issues in the future. Many airlines around the world have banned passengers from using or charging Samsung Galaxy Note7 smartphones on their planes over concerns about their flammable batteries [15].

4.2. Case Study 2: Felicity Ace Cargo Ship Fire

In February 2022, the Felicity Ace cargo ship caught fire and ultimately sank to the bottom of the Atlantic Ocean. Some 4,000 cars were lost in the fiery incident, most of which were new vehicles from various Volkswagen Group brands. VW Group has been sued twice over allegations the fire started from a lithium-ion battery pack inside a Porsche car that was on its way to a customer. Felicity Ace was carrying an estimated \$155 million worth of high-end cars. All 22 crew members were safely evacuated from the ship.

5. Importance of Proper Fire Extinguishing Techniques

Fire suppression techniques are essential to ensure the safety of people and property in the event of a fire emergency [10]. Various methods are used to fight fires, including the use of water, foam, carbon dioxide, and dry chemical agents. Each technique is tailored to the type of fire and its specific characteristics, such as fuel source and intensity [16]. Fire suppression has a classification used to categorize different types of fires based on their fuel source. There are five main classes of fire:

- Class A: Fires of solid materials such as wood, paper and fabrics.
- Class B: Fires involving flammable liquids such as gasoline, oil and grease.
- Class C: Fires involving live electrical equipment.
- Class D: Fires involving combustible metals such as magnesium and sodium.
- Class K: Cooking fat and vegetable oil fires in commercial kitchens.

Each class of fire requires specific extinguishing methods and appropriate extinguishing agents to be controlled safely.

Lithium batteries, as well as batteries found in cars in general, are typically classified under Class B fires. Class B fires involve flammable liquids or gases, which can include the electrolytes and other components found in batteries [17]. It is important to note that fires involving lithium batteries can also exhibit characteristics of Class C fires if they involve electrical components. Therefore, it is essential to consider the specific nature of the fire and the materials involved when determining the appropriate extinguishing techniques for lithium battery fires [18].

6. Common Fire Extinguishing Methods for Lithium Batteries

Lithium batteries pose specific risks in the event of a fire due to their chemical composition and their potential for overheating. To extinguish a fire involving lithium batteries, several common extinguishing methods are used.

- Use of sand or earth: Sand or earth can be used to smother the fire by depriving the batteries of the oxygen necessary for combustion.
- Using a Dry Powder Fire Extinguisher: Dry powder extinguishers are effective in extinguishing lithium battery fires by smothering the flames and cooling the heat source.
- Submersion in water: If possible, immerse lithium batteries in water to quickly cool the heat and prevent the spread of fire. Using a Foam Fire Extinguisher: Foam extinguishers can be effective in smothering flames and preventing the re-burning of lithium batteries [9].
- Using a Carbon Dioxide Fire Extinguisher: Carbon dioxide fire extinguishers can be used to smother flames by depriving batteries of the oxygen needed for combustion.

Proper training and knowledge of extinguishing techniques are crucial for effective fire suppression and prevention of further damage.

7. Best Practices for Extinguishing Lithium Battery Fires

Lithium battery fires pose unique suppression challenges due to their chemical composition and violent reaction potential [19]. To effectively extinguish these fires, it is essential to follow best practices recommended by fire safety experts [20]. It is crucial to maintain a safe distance from the burning battery, as lithium battery fires can release toxic gases and flammable substances [21]. It is recommended to wear appropriate personal protective equipment, such as a respi-

rator mask and heat-resistant gloves, to protect against potential hazards. It is important to use specific extinguishing agents for lithium battery fires, such as carbon dioxide, lithium carbonate or extinguishing agents specially designed for battery fires [22]. These agents are effective in smothering fire without the risk of a dangerous chemical reaction [23]. It is recommended to cool the battery after extinguishing the fire to avoid any resumption of combustion. Using water in a controlled amount to cool the battery can help prevent the risk of overheating and thermal reaction [24] [25].

8. Conclusions

Knowledge of proper fire-fighting techniques in the event of a lithium battery fire is essential to ensure the safety of both individuals and the environment. Vehicles powered by lithium batteries should be equipped with fire extinguishers so that extinguishing can be started at the first sign of fire. Research should be continued to find a solution to make these vehicles safer to use. To this end, it is necessary to build up a system of safety rules, e.g. parking areas with surveillance systems and automatic fire extinguishers, and to develop a detection and extinguishing system for the vehicle batteries.

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