

LFP Batteries Are Dangerous, Say Research Scientists

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There are basically two types of lithium-ion batteries used in large-scale BESS installations, LFP (lithium iron phosphate) and NMC (nickel/manganese/cobalt). Both types have been used for a good many years around the world.

Numerous BESS installations using LFP batteries have had cataclysmic disasters, when the LFP batteries spontaneously went into thermal runaway and exploded, resulting in a fire that could not be extinguished. Probably the best known LFP BESS fire is the one that occurred in Beijing in 2021.

Likewise, there have been numerous BESS installations using NMC batteries that have also had cataclysmic disasters, when the NMC batteries likewise went into thermal runaway and exploded, resulting in a fire that, likewise, could not be extinguished. The best-known illustration being the Moss Landing CA explosion and fire last month at the world's largest BESS installation. (Incidentally, BESS stands for Battery Energy Storage Systems, which consist of large metal containers, often resembling shipping containers, each of which house hundreds of either NMC or LFP lithium-ion batteries.)

The five research articles, below, all of them written by research scientists and all of them published in peer-reviewed science journals, discuss in detail why both LFP and NMC lithium-ion batteries are highly dangerous. As I said, both go into thermal runaway (for reasons explained below) and both continue to spontaneously reignite after apparently

being quenched (because of stranded electricity in the batteries combined with the chemical cocktail used in the electrolyte, as explained below). Both types of battery produce extremely toxic HF (hydrogen fluoride) gas which, in moist air or when doused with water, turns into hydrochloric acid — the most insidious acid known to science. As it happens, thermal runaway LFP batteries produce far more toxic HF gas than do NMC batteries (when the electrical “capacity” for each is equalized). In addition, LFP batteries burn for a longer period of time than NMC batteries.

One must understand that neither LFP nor NMC batteries can be extinguished with water or chemical flame retardants; in both cases, they must burn themselves out — all the while ejecting various toxins into the air — with episodes of reigniting (like “trick” candles on a birthday cake, although for different reasons). The inability to extinguish these fires is especially apparent in BESS installations, where there are hundreds of these batteries in proximity to one another within each BESS container. (Again, the thermodynamics of this phenomenon are discussed in detail in the articles below.)

The chief difference between LFP and NMC batteries is that NMC batteries have a somewhat higher electrical capacity than LFP batteries (i.e., they hold more electricity) and that NMC batteries, on testing under laboratory conditions, seem to be slightly more thermally unstable than LFP batteries — meaning that NMC batteries may go into thermal runaway slightly more readily than LFP batteries, although this phenomenon cannot be reliably predicted when scaled up from laboratory conditions to actual, real life BESS conditions. The triggers for thermal runaway are both external and internal to both types of battery, and cannot in any way be reliably predicted.

Another significant difference between LFP and NMC batteries is that the latter eject micro and nano particulates of nickel, manganese, and cobalt oxides, as has been demonstrated at the ongoing Moss Landing BESS fire. These heavy metal oxides are carcinogenic to humans and animals, and are toxic to the soil. Prof. Ivano Aiello’s research team, Department of Marine Biology, San Jose State University, “detected unusually high concentrations of heavy-metal nanoparticles in marsh soils at Elkhorn

Slough Reserve.” I continue to quote from Prof. Aiello’s report:

The field surveys, conducted within a radius of approximately 2 miles from the [Vistra] powerplant, measured a dramatic increase in marsh soil surface concentration (hundreds to thousand-fold) of the three heavy metals Nickel, Manganese, and Cobalt. Samples of the heavy-metal layer were examined at high magnification and reveal that these metals are contained in nanoparticles that range in diameter between about 1 and 20 μm [microns].

Prof. Aiello notes that the nickel, manganese, and cobalt are from the cathode of the BESS NMC batteries. Since LFP batteries use a lithium/iron cathode, they would not eject these toxic heavy metal oxides in a thermal runaway event. Nonetheless, LFP batteries, like NMC batteries in thermal runaway, eject much more than simply toxic HF (hydrogen fluoride gas and acid); both types of batteries eject a bizarre cocktail of toxic and carcinogenic organic compounds from the combustion of the various battery components and organic solvents added to the electrolyte to enhance electron transfer between cathode and anode — as I say, during an intensely hot combustion event.

First responders are entirely unequipped to deal with these catastrophic events. This is amply confirmed in the testimony of HAZMAT Capt. Hunter Clare, who was literally blown (as I recall) 75 feet into the air, with his HAZMAT suit engulfed in fire, at the infamous Surprise AZ fire several years ago. Watch this recent presentation by Capt. Clare before a convention of firefighters in Washington DC:

<https://youtu.be/USnTf1JPgts?si=IKMWKa07DCPEnmDY>

Capt. Clare notes in his presentation that he spent at least a month in a hospital being treated for burns. As I recall, at least one of the other HAZMAT first responders suffered brain damage from the event, when he, too, was hurled into the air when the single BESS container exploded — literally in their faces.

I close with this chilling piece of evidence. A year ago (March 2024) Vistra (which owns the Moss Landing BESS project) commissioned a 79-page report on the likelihood of a catastrophic event at their Moss Landing BESS installation. The report was written by 5 PhD scientists and was subsequently reviewed by sixth PhD scientist who supposedly checked for accuracy and non-bias. These people titled their report, “Offsite Consequence Analysis: Vistra Morro Bay Battery Energy Storage System Project.” After 72 pages of fine-grained scientific analysis, the report concludes with the following, now haunting and tragic sentence:

In sum, the proposed BESS project poses no significant risk to the health or safety of the community during a maximum credible event under worst-case conditions

On January 16, 2025, those words exploded and went up in flames. Click here to download a copy of the report: <https://app.box.com/s/1a7x0tiovi1ygp22ihkrr1e6h3cyc34t>

I urge readers to visit the Facebook page set up by victims of the toxins ejected from the explosions and fires: <https://www.facebook.com/groups/652815133743333>. It’s heartbreaking to read the accounts of:

- skin burns and rashes
- burning airways, eyes, nose, and mouth
- intractable metallic taste in the mouth
- nausea
- brain-fog
- difficulty breathing
- congested lungs.

I am in daily contact with victims of the Moss Landing catastrophe. Each time there is a reignition of the lithium-ion batteries, their symptoms seem to reemerge, suggesting that the explosions and fires created a kind of umbrella of toxins over the region, not unlike a volcanic explosion, although certainly on a much smaller scale.

To my knowledge, there has never been a toxicological catastrophe on this scale, except for the Chernobyl event in Russia years ago and perhaps the Fukushima nuclear plant meltdown in Japan, both of which involved radiation. You will discover from reading the Moss Landing Facebook site that people are reporting the above-mentioned symptoms as far as 20 and 30 miles away in a huge arc that was blanketed by these toxins.

Read, carefully, the passages from these 5 scientific research articles. Pay close attention to the “bolded” and underlined passages which I highlighted. You don’t need training in chemistry to grasp what these researchers are saying; any layman will get the point — that neither LFP nor NMC lithium ion batteries are at a sufficiently mature and reliably safe level of development to be deployed in BESS installations anywhere near humans and animals.

All 5 articles can be downloaded by clicking here:

<https://app.box.com/s/u2byp59221ivurmmqrsls57ixp98x6dvw>

(1) Q.I. Peiyan, Zhang Ming Jie, Jiang Da, Yang Kai, Liu Jianling, Lai Yilin, Gao Fei, “Combustion characteristics of lithium-iron-phosphate batteries with different combustion states,” **eTransportation** 11 (2022) 100148.

The lithium-ion battery [using **LFP: lithium iron phosphate batteries**] combustion experiment platform was used to perform the combustion and smouldering experiments on a 60-Ah [ampere hour] steel-shell battery.¹

Temperature, voltage, gases, and heat release rates (HRRs) were analysed during

¹ Q.I. Peiyan, Zhang Ming Jie, Jiang Da, Yang Kai, Liu Jianling, Lai Yilin, Gao Fei, “Combustion characteristics of lithium-iron-phosphate batteries with different combustion states,” **eTransportation** 11 (2022) 100148, p. 1.

the experiment, and the material calorific value was calculated. The results showed that the highest surface temperatures are 323 and 331.4 °C, respectively. The combustion states did not affect the severity of thermal runaway inside the battery.²

Battery combustion exhibited a high thermal hazard, and its total heat release was approximately 17 times that of the smouldering process. The smouldering process showed a high gas hazard. The toxic gas concentration in this experimental platform (6.48 m3) can reach 5.38 times the lethal concentration. The HRR [heat release rate] and remaining energy [called “stranded electricity”] of the battery were greatly affected by the combustion states. The proportion of energy remaining under the smouldering states was as high as 75.8% after the test.³

The batteries employed are a **60-Ah large-format LIB [lithium-ion battery] with a LiFePO₄ (LFP: lithium iron phosphate) cathode and a carbon-based anode. The electrolyte used is the solution of a lithium salt (LiPF₆) and a mixture of organic solvents, containing ethylene carbonate, dimethyl carbonate, and methyl carbonate. The separator is PP/PE/PP material. The nominal voltage is 3.2 V. The length, width, and height (without considering the tab height) of the battery are 209, 28, and 138 mm, respectively.**⁴

Conclusions:

3) In terms of hazard, **LFP [lithium iron phosphate]-1** has a higher thermal hazard than LFP-2, and its THR [total heat release] is approximately 17 times that of LFP-2; LFP-2 has a higher gas hazard than LFP-1, and **the concentration of the toxic gas [hydrogen fluoride] in this experimental platform can reach 5.38 times the lethal**

² Peiyan et al., p. 1

³ Peiyan et al., p. 1.

⁴ Peiyan et al., p. 2.

concentration. In practical applications, LFP-2 can accumulate a large amount of premixed combustible gas in a small space, which presents a deflagration hazard. In poor-ventilation states, LFP-2 can be more dangerous and destructive than LFP-1.⁵

4) During the experiment, the HRR [heat release rate] and remaining energy [stranded electricity] of the battery were considerably affected by the combustion state. **After the test, most energy was not released, and the proportion of energy remaining under the smouldering states was as high as 75.8%. The internal materials of the battery could still burn in the oxygen environment.** Therefore, fire sources should be avoided and fire prevention measures should be taken when storing these batteries.⁶

(2) David Sturk, Lars Hoffmann, Annika Ahlberg Tidblad, "Fire Tests on E-Vehicle Battery Cells and Packs," **Traffic Injury Prevention** (2015) 16, S159-S164.

Objective: The purpose of this study was to investigate the effects of abuse conditions, including realistic crash scenarios, on Li-ion battery systems in E-vehicles [electric vehicles] in order to develop safe practices and priorities when responding to accidents involving E-vehicles.⁷

Method: The 2 most common battery cell technologies were tested: **Lithium iron phosphate (LFP) and mixed transition metal oxide (lithium nickel manganese cobalt oxide, NMC) cathodes against graphite anodes**, respectively.⁸

⁵ Peiyan et al., pp. 6-7.

⁶ Peiyan et al., pp. 6-7.

⁷ David Sturk, Lars Hoffmann, Annika Ahlberg Tidblad, "Fire Tests on E-Vehicle Battery Cells and Packs," *Traffic Injury Prevention* (2015) 16, S159.

⁸ Sturk et al., p. 159.

Results: The test results indicate that the state of charge (SOC) affects the HRR [heat release rate] as well as the amount of toxic hydrogen fluoride (HF) gas formed during combustion. A larger number of cells increases the amount of HF formed per cell. There are significant differences in response to the fire exposure between the NMC and LFP cells in this study. The LFP cells generate a lot more HF per cell, but the overall reactivity of the NMC cells is higher. However, the total energy released by both batteries during combustion was independent of SOC, which indicates that **the electric energy content of the test object contributes to the activation energy of the thermal and heat release process, whereas the chemical energy stored in the materials is the main source of thermal energy in the batteries.⁹**

Li-ion batteries contain high electric energy and possess high power density and contain combustible materials and fluorine-based salts. **Risk analysis identifies thermal abuse as a key pathway to critical failure of Li-ion batteries** as illustrated in Fig. A1 (see online supplement). A critical failure event is here defined as an incident involving emission of combustible gases and the subsequent risk for ignition of these gases leading to fire. **The main cause for ventilation of gases from an Li-ion cell is the exothermal breakdown of its internal components, mainly the electrolyte, initiated by an increase in the internal temperature of the cell.**¹⁰

Gases emitted during a thermal event in Li-ion batteries contain a variety of organic and inorganic species, including flammable constituents like hydrogen and hydrocarbons (e.g., methane and ethane) as well as vaporized electrolyte (alkyl carbonate). **The organic solvents in the Li-ion battery electrolyte and the conductive salt LiPF₆ are the major source of the gaseous species.**¹¹

⁹ Sturk et al., p. 159.

¹⁰ Sturk et al., p. 159.

¹¹ Sturk et al., p. 159.

Figure 7 indicates that HF [hydrogen fluoride] emissions from NMC [nickel/manganese/cobalt lithium-ion batteries] cells are significantly lower than those for LFP [lithium iron phosphate] cells. Figure 8 shows that the number of cells affect the amount of HF released on an average from each cell. Cell assemblies with a larger number of cells appear to generate more HF per cell than single cells or assemblies with fewer cells.¹²

The dependence on SOC [state of charge] implies that the electric energy content contributes to the onset of the thermal event by providing activation energy needed to initiate thermal runaway or combustion of electrolyte. ... However, the difference between the total energy released per cell is small, with regards to both cell type and SOC.¹³

The energy released per Ah [ampere hour] [during thermal runaway] is almost double for the LFP [lithium iron phosphate] cells compared to the NMC [nickel/manganese/cobalt] cells. A possible conclusion is that the LFP cells and the NMC cells contain similar amounts of electrolyte, which is the main contributor of heat energy released during combustion.¹⁴

It is common to refer to the cathode material when discussing parameters of safety and thermal runaway. However, the cathode material may not be the weakest link in all cell types. Instead, **focus is currently set on the composition of electrolytes. The manufacturers' use of flame retardants and additives further adds to the diversity in results when it comes to fire propagation, heat evolution, and amounts of toxic species generated under thermal abusive conditions.**¹⁵

Our test results, and especially the similarity between the total energy

¹² Sturk et al., pp. 161-162.

¹³ Sturk et al., p. 162.

¹⁴ Sturk et al., p. 163.

¹⁵ Sturk et al., p. 163.

released by the LFP [lithium iron phosphate] and NMC [nickel/manganese/cobalt] cells ... support the importance of the electrolyte contributing to the fire and the amount of combustion energy formed. The tested NMC [nickel/manganese/cobalt] cells have twice the electric capacity of the tested LFP cells. Additionally, LFP is generally portrayed as a “safe” cathode material. Nonetheless, despite the somewhat slower propagation of the fire in the LFP cells, the combustion energy released in the event of the Li-ion battery catching fire appears to be more closely related to cell volume, and hence content of chemical constituents, rather than specific electric energy density of the cathode material.¹⁶

This investigation shows that the amount of toxic emissions per LFP [lithium iron phosphate] cell increases with the number of burning cells (Table A3, see online supplement). A possible explanation is that the **highly reactive HF [hydrogen fluoride]** and its intermediary PFs [phospho-fluorides] are able to accumulate before being vented from the cells not directly exposed to the flame while the bottom cell acts as a thermal shield. According to Yang et al. (2006), accumulation of intermediary PF [phospho-fluorides] inside the upper cells prior to venting, made possible by the shielding effect of the cell closest to the flame, results in higher HF [hydrogen fluoride] concentrations as the PF [phospho-fluoride] reacts with humidity in the air after ventilation.¹⁷

A higher SOC [state of charge] also results in more HF [hydrogen fluoride] released per cell, indicating that the higher SOC [state of charge] increases the overall reactivity inside the cells.¹⁸

There is a significant difference in the behavior, and particularly the rate of HF [hydrogen fluoride] released, from the LFP [lithium iron phosphate] cells

¹⁶ Sturk et al., p. 163.

¹⁷ Sturk et al., p. 163.

¹⁸ Sturk et al., p. 163.

compared to the NMC [nickel/manganese/cobalt] cells, especially at high SOC [state of charge]. LFP [lithium iron phosphate] cells appear to release more HF [hydrogen fluoride] than NMC [nickel/manganese/cobalt] cells in total but over a longer time period. This is consistent with the observation of the shielding effect on HF [hydrogen fluoride] generation; that is, when the onset of HF [hydrogen fluoride] gas emission is very fast, there is less time to form intermediary PFs [phospho-fluorides] inside the cell before venting and, consequently, the total HF [hydrogen fluoride] amount emitted is less than when venting occurs later on in the thermal process. This can be seen in Fig. 8, where it is apparent that **the 10-cell battery assemblies generated more HF [hydrogen fluoride] per cell than the 5-cell assemblies and the single cells.** This implies that it is difficult to draw conclusions about higher order system behavior with respect to HF [hydrogen fluoride] emissions based on data from tests on single cells or small assemblies of cells. This applies to energy release rates as well; **the present data show that mass and shielding effects between cells in multicell assemblies affect the propagation of a thermal event.**¹⁹

The NMC [nickel/manganese/cobalt] cells tested generate significantly less total amount of HF gas than the LFP [lithium iron phosphate] cells tested. The possibility of HF [hydrogen fluoride] emissions in critical thermal events involving Li-ion traction batteries in E-vehicles is causing a lot of concern and uncertainties among policy makers and first responders.²⁰

(3) Shilin Wang, Chenyu Zhang, Dapeng Chen, Yiming Qin, Lejun Xu, Yitong Li, Qinzhen Wang, Xuning Feng, Huaibin Wang, "Explosion characteristics of two-phase ejecta from large-capacity lithium iron phosphate batteries," **eTransportation** 22 (2024) 100377.

¹⁹ Sturk et al., p. 163.

²⁰ Sturk et al., p. 164.

Large-scale lithium iron phosphate batteries: Studies have shown that in a two-phase system explosion, EMC [ethyl methyl carbonate] can make the two-phase system more explosive and more powerful, and the thermal runaway gas expands its explosion concentration range. The coupling explosion of the two enhanced the sensitivity and explosive power of the two-phase ejecta. Increasing the concentration of any combustible in a two-phase system will cause the explosion intensity parameters of the system to increase. Both explosion intensity parameters and sensitivity parameters are more sensitive to EMC concentration, and the higher the EMC [ethyl methyl carbonate] concentration, the stronger its dominant role in the explosion of the two-phase system. This work can lay the foundation for revealing the disaster-causing mechanism of explosion accidents in lithium-ion battery energy storage power stations, guide the safe design of energy storage systems and the prevention and control of explosion accidents.²¹

Fires and explosions in energy storage power facilities [BESS: Battery Energy Storage Systems] occur frequently around the world. This is because lithium-ion batteries (LIBS) [consisting of LFP (lithium iron phosphate) and NMC (nickel/manganese/cobalt) batteries] can undergo thermal runaway (TR) and rapidly propagate in the battery module under conditions such as thermal abuse, mechanical abuse, electrical abuse, and electrochemical abuse.²²

Based on a comprehensive study of gas generation and combustion characteristics of LIBs [lithium-ion batteries], Wang [26] et al. conducted qualitative and quantitative analysis of TR [thermal runaway] gas generation in LIBS [lithium-ion batteries] with different cathode materials. **Through experiments, they compared the explosion intensity and sensitivity parameters of TR [thermal**

²¹ Shilin Wang, Chenyu Zhang, Dapeng Chen, Yiming Qin, Lejun Xu, Yitong Li, Qinzhen Wang, Xuning Feng, Huaibin Wang, "Explosion characteristics of two-phase ejecta from large-capacity lithium iron phosphate batteries," eTransportation 22 (2024) 100377, p. 1.

²² Wang et al. (2024), p. 2.

runaway] gas, and found that LFP [lithium iron phosphate] batteries are more hazardous in terms of combustion and explosion compared to NCM [nickel/cobalt/manganese] batteries. Wang [27] et al. studied the combustion characteristics of vent gas from 18650 LFP [lithium iron phosphate] batteries at different states of charge (SOC), and found that **the TR [thermal runaway] gas from LFP [lithium iron phosphate] batteries at 100% SOC [state of charge] are the most easily ignitable and have the highest laminar flame speed. In addition to combustible gases, electrolyte vapor can also explode under certain conditions.** Henriksen [28] et al. used a 20L [liter] spherical explosion container to measure the explosion characteristics of three common electrolyte solvents: dimethyl carbonate (DMC), ethyl methyl carbonate (EMC) and diethyl carbonate (DEC). They found that their explosion intensity parameters were similar and slightly higher than those of H₂, CH₄, and C₃H₈.²³

In 2021, a serious fire and explosion accident [involving LFP: lithium iron phosphate batteries] occurred at the Beijing Dahongmen Energy Storage Station, resulting in multiple casualties and significant property losses. The investigation results of the accident showed that a large amount of TR [thermal runaway] gas and electrolyte vapor was generated after the TR [thermal runaway] of the LFP [lithium iron phosphate] batteries, and the ejecta spread to another building, where it was ignited and exploded.²⁴

Conclusion:

(3) In coupled explosions of the two-phase system, EMC [ethyl methyl carbonate] makes the system more prone to explosion with greater explosive power, while TR [thermal runaway] gas expands the range of their explosion concentrations. Together, they compensate for each other's deficiencies in single-phase medium explosion parameters, thereby enhancing the explosiveness and explosive power of the two-phase

²³ Wang et al. (2024), p. 2.

²⁴ Wang et al. (2024), p. 2.

system.²⁵

This work demonstrates that the ejecta from the two stages of TR [thermal runaway] in large-capacity LFP [lithium iron phosphate] batteries pose significant combustion and explosion hazards. Particularly, the coupling explosion resulting from the mixture of two-phase substances can lead to even greater explosion hazards.²⁶

(4) Shuang Wang, ZhiMing Du, ZhiYue Han, ZeLin Zhang, Ling Liu, Jin Yuan Hao, "Study of the Temperature and Flame Characteristics of Two Capacity LiFePO₄ Batteries in Thermal Runaway," **Journal of the Electrochemical Society**, 165 (16) A3828-A3836 (2018).

The thermal runaway of 20 Ah [ampere hour] and 24 Ah LiFePO₄ [LFP: lithium iron phosphate] batteries under different stage of charge conditions is tested using the combustion chamber. The temperature at the center of the battery surface and the negative electrode is relatively high. Thermal runaway can be divided into two phases when the battery is heated continuously. The temperature increases sharply in the second phase of thermal runaway, which presents a high risk. The rising rate of temperature and the maximum surface temperature increase with increasing state of charge and battery capacity.²⁷

The temperature characteristics of the battery in thermal runaway are related to the composition of the electrolyte and the electrode material closely. The internal chemical reaction of the battery is very complicated

²⁵ Wang et al. (2024), p. 8.

²⁶ Wang et al. (2024), p. 8.

²⁷ Shuang Wang, ZhiMing Du, ZhiYue Han, ZeLin Zhang, Ling Liu, Jin Yuan Hao, "Study of the Temperature and Flame Characteristics of Two Capacity LiFePO₄ Batteries in Thermal Runaway," *Journal of The Electrochemical Society*, 165 (16) A3828-A3836 (2018), p. 3828.

during the thermal runaway.²⁸

This paper shows that the safety is not optimistic [i.e., not good] of [for] the commercialized [for commercial] batteries with large capacity [i.e., LFP (lithium iron phosphate) and NMC (nickel/manganese/cobalt)] and high SOC [state of charge] state.²⁹

(5) Zhuangzhuang Jia, Kaiqiang Jin, Wenxin Mei, Peng Qin, Jinhua Sun, Qingsong Wang, “Advances and perspectives in fire safety of lithium-ion battery energy storage systems,” **eTransportation** 24 (2025) 100390.

With the advantages of high energy density, short response time and low economic cost, utility-scale lithium-ion battery energy storage systems are built and installed around the world. However, due to the thermal runaway characteristics of lithium-ion batteries, much more attention is attracted to the fire safety of battery energy storage systems [BESS: Battery Energy Storage Systems]. **In this review, we comprehensively summarize recent advances in lithium iron phosphate (LFP) battery fire behavior and safety protection to solve the critical issues and develop safer LFP [lithium iron phosphate] battery energy storage systems.**³⁰

TR [thermal runaway] is an inherent property of LFP [lithium iron phosphate] batteries. A number of major battery fire accidents have occurred frequently around the world, resulting in catastrophic loss of life and property. Fig. 2 shows the installed capacity and accident data of global

²⁸ Wang et al. (2018), p. A3828

²⁹ Wang et al. (2018), p. A3835.

³⁰ Zhuangzhuang Jia, Kaiqiang Jin, Wenxin Mei, Peng Qin, Jinhua Sun, Qingsong Wang, “Advances and perspectives in fire safety of lithium-ion battery energy storage systems,” **eTransportation** 24 (2025) 100390, p. 1.

energy storage stations in the past decade.³¹

Among the publicly available data, there are 6 LFP [lithium iron phosphate] battery fire accidents, and they mainly occurred in recent years. There have been many fire accidents of BESS [Battery Energy Storage Systems] in United States, Australia and China. For example, in 2024, three LFP [lithium iron phosphate] battery energy storage station fire accidents occurred in Germany within three months. A BESS [Battery Energy Storage System] made of LFP [lithium-ion phosphate] batteries exploded and caught fire in China, and several firefighters suffered death and mutilation in the blast in 2021.³²

Due to the **high voltage characteristics of BESS [Battery Energy Storage System] and the re-ignition phenomenon of LFP [lithium iron phosphate] batteries.**³³

Generally speaking, commercial LFP [lithium iron phosphate] batteries in BESS [Battery Energy Storage System] are hard-shell prismatic batteries with a capacity of 50-300 Ah [ampere hour]. A LFP [lithium iron phosphate] battery includes a LiFePO_4 cathode, a graphite anode, a separator, and electrolyte. The electrolyte is usually made of lithium salt (LiPF_6) dissolved in carbonate solvents. Common carbonate solvents have multiple compositions, including ethylene carbonate (EC), propylene carbonate (PC), dimethyl carbonate (DMC), diethyl carbonate (DEC), and ethyl methyl carbonate (EMC). These flammable carbonate solvents are the primary fuel in battery fire during TR [thermal runaway]. The TR [thermal runaway] of LFP [lithium iron phosphate] batteries is caused by various abuse conditions in BESS [Battery Energy Storage System], which can be mainly divided into: thermal abuse, electrical

³¹ Jia et al., pp. 2-3.

³² Jia et al., p. 3.

³³ Jia et al., p. 3.

abuse, and mechanical abuse. Overheating and overcharging are the most common triggers during charging and discharging. Some heat is generated inside the batteries during the charging and discharging process. If the heat dissipation rate is lower than the heat generation rate, the working battery may overheat to trigger TR [thermal runaway] due to accumulation of self-heating. **Similarly, when the battery management system (BMS) fails during the battery charging process, it may cause the battery to overcharge and trigger TR [thermal runaway]. Mechanical abuse may also occur during the maintenance or installation of energy storage stations.**³⁴

Based on the common reaction characteristics, **the TR [thermal runaway] process of LFP [lithium iron phosphate] battery is divided into four stages.**³⁵

After the SEI [solid electrolyte interphase] layer decomposes [in thermal runaway], the lithiated graphite anode loses the protective layer and reacts with electrolyte. However, when lithium salt and electrolyte were mixed, four exothermic peaks were detected by C80 micro calorimeter, and two distinct exothermic peaks were detected by DSC [differential scanning calorimeter]. Furthermore, the leached lithium reacted with the electrolyte at elevated temperature before the new SEI [solid electrolyte interphase] layer was formed, releasing a large amount of heat and flammable gases.³⁶

After the shrinkage and melting of the separator, cathode and anode react, releasing heat and gas.³⁷

The cathode and anode inside the battery come into contact and the battery has an internal short circuit (ISC).³⁸

³⁴ Jia et al., p. 3.

³⁵ Jia et al., p. 4.

³⁶ Jia et al., p. 4.

³⁷ Jia et al., p. 4.

³⁸ Jia et al., p. 4.

It is worth noting that large amounts of flammable gases (e.g., H₂, CO, CH₄) are released from LFP [lithium iron phosphate] batteries after safety venting, and these gases may burn when they encounter an ignition source.³⁹

The toxicity of water mist during fire extinguishing should be taken seriously. Hydrogen fluoride (HF) is a kind of irritant gas, which is mainly produced by the decomposition of LiPF₆ and electrolyte solvents at elevated temperatures and poses a great threat to personal safety.⁴⁰

When water is applied, it reacts with PF₅ [phospho-fluoride] to form HF [hydrogen fluoride] and initiates the decomposition of LiPF₆-based carbonate electrolytes, resulting in a higher HF [hydrogen fluoride] yield.⁴¹

This paper reviews the research progress on fire behavior and fire prevention strategies of LFP [lithium iron phosphate] batteries for energy storage at the battery, pack, and container levels.⁴²

³⁹ Jia et al., p. 4.

⁴⁰ Jia et al., pp. 14-15.

⁴¹ Jia et al., p. 15.

⁴² Jia et al., p. 17.