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Lithium-ion Batteries: Fire Investigation Health and Safety Issues

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Contents

This is an updated compilation of the material from two 2025 issues of my Health and Safety Newsletter for Fire Investigators. It addresses lithium-ion battery fires and their health hazards, and the special issues regarding data centers because of the large number of lithium-ion batteries used in them. Recommendations are at the end, along with the references.

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Introduction

Lithium-ion batteries (LiBs) come in a wide variety of shapes and sizes, ranging from one or a few cells used in flashlights or remote-controlled vehicles to large packs used in electric vehicles[1] and residential and commercial battery energy storage systems (BESS). When used, handled, and charged properly, there are rarely any issues. When they are not, bad things can happen. As the use of LiBs expands across all areas — consumer, industrial, and commercial — so will the hazards for fire investigators. (TEEX, 2024) Because they are in so many of today's devices, they could cause a fire or be damaged by one. And this damage alone can result in thermal runaway (TR).

Specifically regarding vehicles, data from the U.S. National Transportation Safety Board show that there are approximately 25 fires per 100,000 EVs sold. In comparison, there are approximately 1,530 fires for every 100,000 gas-powered vehicles sold. Similar rates have been found in Norway, Sweden, and Australia. During an electric vehicle fire, more than 100 chemicals are released, including heavy metals, carbon monoxide, and hydrogen cyanide.[2]

Also specific to vehicles, a 2025 study by NIOSH suggests that "exposure to EV fire smoke emissions (associated with metals, fluoride particulate, PAHs, and other organic compounds) may pose a wide range of short- and long-term health risks, but these health consequences could vary depending on vehicle models and battery design." (Kim, et al., 2025) These health risks include exposure to substances that could alter human genetic material (DNA), increasing the frequency of mutations.

We should all be aware that LiB assemblies can undergo TR under various adverse conditions, leading to open combustion. When they do, they release harmful gases and

[1] A 2023 examination in Australia of a Tesla Model 3 found that there were over 4,300 type 4416 battery cells in the battery pack. https://www.evfiresafe.com/post/ev-battery-fire-investigation-considerations

[2] https://news.med.miami.edu/electric-vehicle-fire-staged-to-study-environmental-health-ramifications/

nanoparticulates, both of which are health hazards. These batteries can also pose hazards of electrical shock and explosion to investigators.

The fire hazard of LiBs, in terms of the severity of the fire and the products emitted, is dependent on the internal chemical composition of the LiB, the type of abuse that the LiB was subjected to, and the amount of energy stored inside the battery, referred to as the state of charge (SoC). Many variables influence the temperatures and the products emitted during these events, such as the internal composition and the type of abuse, which can be electrical, mechanical, or thermal. (Ubaldi, 2023)

LiB safety is under investigation through practical and academic research worldwide; however, research takes time, and exposures by fire service personnel are occurring more frequently. The fire and explosion risks associated with this type of high-energy battery technology have become a significant safety concern. While considerable advances have been made in understanding the reactive chemistry and fire safety issues related to thermal runaway and fire hazards associated with LiBs (Snyder & Theis, 2022), the health and safety risks associated with these systems have not been significantly reduced.

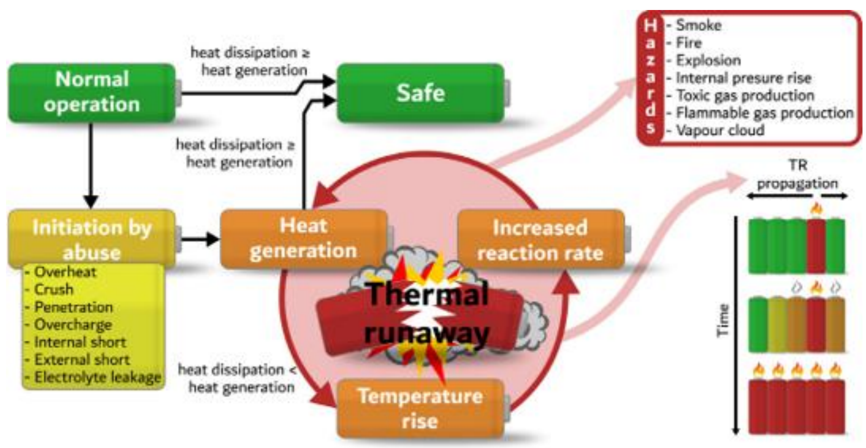
As fire investigators, this information raises some important questions. What are the LiB health hazards? How long do these health hazards persist? How do we best protect ourselves? We know that most, but not all, structure fire gases dissipate at a post-fire scene after about two hours. Is this also true for LiB fires? To help shed light on this important topic, specifically as it relates to fire investigations, I reviewed relevant scholarly articles from the past three years, as well as other information sources, and present their findings in a concise and easy-to-read format. It should come as no surprise that the majority of today's literature focuses on suppression activities rather than on investigations, but much of it remains relevant.

Lithium-ion-Battery Background Information

LiBs are electrochemical energy sources that, during TR or significant fire impingement, emit a complex mixture of gases influenced by factors such as the type of LiB, the battery's SoC, air temperature, wind speed, and location (outdoors vs. a closed room). They also release nanoparticulates in the form of various heavy metals. This aerosolized particulate is composed of carbon, silicon, and fluorine, primarily originating from the anode, with silicon used to increase battery capacity. (Meister et al., 2025)

There are multiple types of LiBs made from different materials, which affect the output of these substances during TR or failure. The presence of heavy metals in LiB-TRs may pose significant health hazards to first responders and bystanders, particularly those with repeated exposure. The aerosol composition and the presence of heavy metals determine the toxicity of aerosolized particulates, which can lead to significant health issues and DNA damage. (Meister et al., 2025)

In a multi-cell arrangement, as with most LiBs, once one cell starts TR, it will propagate to all the others. The larger the battery assembly, the greater the off-gassing; however, there is no correlation between LiB capacity and the specific volume of off-gassing materials. (Bugryniec, et al., 2024) This is a complex issue that requires a thorough risk assessment to protect the investigators and others in the area. The graphic below (Bugryniec et al., 2024) illustrates this process.



LiBs come in multiple configurations. They can comprise many different cell chemistries that emit different gases at varying levels, which means that in the post-fire environment, you will likely not know what you are dealing with. The toxic components of primary concern are carbon monoxide, hydrogen fluoride, hydrogen chloride, hydrogen cyanide, nitrogen dioxide, and sulfur dioxide (Bugryniec et al., 2024); however, others may also be present, depending on the specific battery composition. These gases are all hazardous on their own, but it is worth noting that when mixed with water, hydrogen fluoride gas[3] forms hydrofluoric acid. So you have TR, which creates an inhalation hazard from the gases, and then the water from suppression creates a dermal hazard. In the TEEX study (2024), high concentrations of lithium, nickel, cobalt, manganese, and copper were detected during each test event, with lithium being the most dominant. Typically, solvents and hydrocarbons are also present. All of these require appropriate PPE, including respiratory protection, throughout all phases of the investigation.

A higher SoC enhances combustion, leading to a higher heat release rate and increased concentrations of carbon dioxide, carbon monoxide, and methane, as well as

[3] A highly toxic and corrosive gas. In confined environments (e.g., vehicles, rooms, aircraft), these emissions can reach dangerous concentrations, posing serious inhalation hazards.

higher critical and maximum TR temperatures. (Bugryniec et al., 2024; Zhao, Xing, Jiang, Shu, & Sun, 2025). The risks of these emissions, however, depend on the incident scenario; this also means that gas meters will not detect all the health hazards that may be present, some of which can be fatal.

18650-style LiB

After conducting experiments with 18650-style cylindrical LiBs (the most common rechargeable lithium-ion batteries in the world), Zhao (2025) found that "the SoC influences the intensity of energy release, gas toxicity, and fire dynamics by regulating the distribution and reaction pathways of active materials." (p. 19) Additionally, Yan's (2022) extensive research around SoC and LiB fires found that "as the SoC increased, the onset temperatures of thermal runaway generally decreased, while the peak temperatures of thermal runaway generally increased." (p. 229) It is important to note that suppression can take hours or days, depending on the LiB size and configuration, and that the battery units often reignite several times. (Snyder & Theis, 2022)

The vapor cloud or plume that can appear during TR is yet another complex phenomenon, with numerous variables influencing its formation, composition, and rate of dispersion. These clouds also contain vaporized organic electrolytes, which, under normal operating conditions, help the battery's functionality. LiB TR off-gassing is known to be flammable and toxic, making it a serious safety concern. This all leads to health hazards as long as TR is occurring, and for an indeterminate time thereafter. This vapor cloud may or may not be visible, depending on various conditions. LiB TR fires are extreme-emission events that release highly toxic gases and particles that exceed the US Occupational Safety and Health Administration's permissible exposure limits. (TEEX, 2024)

"The longer TR continues without suppression actions, the more severe the health hazards become and the harder it is to control" (emphasis added). (Snyder & Theis, 2022) Although this vapor is typically visible, I have not found any research on its full extent. There may be harmful aerosols and nanoparticulates in the air outside of the visible cloud or plume. Is there a minimum safe distance from this? Totally unknown. Suffice it to say, upwind and the further away the better, is a good plan.

In circumstances when damage to LiBs has occurred, additional potential safety risks may be introduced in the form of stranded energy.[4] The damage to the LiBs may also increase certain safety risks related to thermal stability. Since the electrical energy at the time of an event is unlikely to be in a safety-optimized state, **safety risks increase as the battery pack's SoC decreases**. This combination of a damaged LiB and SoC poses elevated safety risks to individuals handling EVs and battery packs, including emergency responders. (Snyder & Theis, 2022) The only way to determine the SoC of a LiB in the post-

[4] Stranded energy refers to the residual electrical energy that remains trapped inside a lithium-ion battery even after it has been damaged, especially following a thermal runaway event or fire. This leftover energy poses serious safety risks because it can cause the battery to reignite unexpectedly.

fire environment is to use a meter, but doing so can be dangerous for several reasons. Do not do that!

Lithium-ion Battery Issues During an Investigation

Attending a fire investigation that involves LiBs after the fire has been extinguished is one thing. What about when TR starts during an investigation? I paraphrase here information from a cautionary story shared in a March 2023 Facebook post by Wisconsin public fire investigator Chris Schlecta, who experienced this firsthand.

(Written on a Thursday) This past Monday, our department implemented a 100% on-air policy for investigators until two hrs. post-fire,[5] then P100s with OV/AG/FM cartridges afterward. We had discarded the notion that air monitoring was sufficient to protect ourselves.

Previously, if the O^2 and CO readings were satisfactory, we began work immediately. Dust masks were available, but optional. That policy change on Monday likely saved me and at least one other investigator a trip to the hospital yesterday afternoon.

Suppression had wrapped up; everything was cool, and the air was "clear". We started our work in the area of fire origin in the basement. The area was heavily cluttered with debris and entanglements.[6] As we narrowed in, we found several lithium-ion battery packs used for RC cars. After taking photos in situ, the plan was to pick up each battery and photograph the underside. One had clearly melted down already.

As the first battery was moved, something bounced off my leg, hit the water, and began to sizzle and smoke. My partner commented, "another spray can," hinting at other cans we had encountered, including one that had earlier come through a window like a missile. We stood there as he checked with the thermal camera and commented that the water temperature was over 200 degrees. The basement also filled quickly with dense white smoke. This all happened in about 10 seconds. We started weaving our way outside.

After things had settled and the smoke had cleared, we found that a portion of the lithium-ion battery had fallen into the water and had immediately started thermal runaway.

Lithium-ion Batteries and Data Centers

Lithium-ion batteries are increasingly used in data centers as high-performance backup power sources (uninterruptible power supplies (UPS)), replacing traditional lead-acid systems due to their compact size, longer lifespan, and advanced safety features. Lithium-ion batteries are integrated into UPS systems to provide backup power during outages or grid instability, supporting the continuous operation of servers, cooling systems, and networking equipment. Rack-mounted lithium-ion systems are common, especially in modular data centers.

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[5] This is now required per NFPA 1550, 2024 ed., Section 9.11.9

[6] This description meets the OSHA definition of a non-permit-required confined space!

Data centers are specialized facilities designed to house computing infrastructure that stores, processes, and distributes digital data. They serve as the backbone of modern IT operations, cloud services, and internet connectivity.

According to the datacentermap.com website, as of July 4, 2026, there are 4,450 data centers in the US, including 633 in Virginia, most of which are in Northern Virginia. By comparison, Australia has 285, the UK has 560, and Canada has 288. Virginia is widely considered the data center capital of the world, with the largest concentration of data centers. Virginia is home to 35% of the world's known hyperscale[7] data centers.[8] There are additional, smaller centers.

A hyperscale data center may contain tens of thousands to millions of lithium-ion battery cells, organized into thousands of battery backup units, or rack-mounted assemblies. For example, Google has deployed over 100 million lithium-ion cells across its global data center fleet.[9]

Even if you do not have any large data centers, there are plenty of smaller ones all over, and the data rooms businesses, especially larger ones, have will present many of the issues and hazards mentioned here.

The image below shows a Google data center in Dublin, Ireland (Source: https://datacenters.google/discover-more/photo-gallery/). The interior image appearing further below is from the same source.

[7] Hyperscale is an IT architecture that uses a vast number of standard servers in a distributed system to provide massive, flexible computing power and storage that can be scaled up or down quickly to meet demand. Large cloud service providers use this approach to deliver services like big data analytics and cloud computing to users worldwide. Hyperscale data centers range from 100,000 to over 1 million square feet. Source: Google and Copilot.
[8] Source: https://www.vedp.org/industry/data-centers
[9] Source: https://cloud.google.com/blog/topics/systems/100-million-li-ion-cells-in-google-data-centers

In the fall of 2025, I had an extensive conversation with Loudoun County (VA) Fire–Rescue Battalion Chief Jasen Dodson, an expert on data center fire issues.[10] In his Northern Virginia county alone, there are 260 data centers, with another 150 in the pipeline. While Virginia considers itself the data center capital of the world, Loudoun County is by far the premier player, with many more than any other area of the state. Several factors play into Loudoun County being the data center king. First, its proximity to the Washington, DC area's government complex. Second, the region inherited a robust fiber-optic infrastructure from the days when AOL was headquartered nearby, making it ideal for internet-based industries. Third, at the outset of data center development, undeveloped parcels of land near Dulles International Airport were inexpensive and well-positioned for growth. There was also a robust pro-business local government that offered tax incentives, and Dominion Energy and other utilities supported the high-capacity power needs critical to data centers.[11]

Data Center-specific Issues

Here are the major issues affecting data center fire investigation activities.

- The technology is moving faster than the building codes.
    - This means that an investigator could be presented with unexpected structures and contents.
- These facilities can be VERY large! Loudoun has one that could fit seven Home Depot stores inside. Powhatan County, Virginia, in the Richmond area, recently approved a 2-million-square-foot data center with a maximum height of 90 feet (meaning it will likely be multi-story).[12]
    - These buildings typically have tilt slab exterior wall construction, which presents its own unique set of issues.
    - We are seeing more multi-story data centers because it is often cheaper to go up than out.
    - While some data centers have large interior open spaces, others are designed like self-storage units, with lots of smaller rooms.
        - These smaller rooms are typically leased to individual customers. This can present issues with access and owner identification. Airflow can also be an issue.
    - There is typically a building engineer on-site or nearby handling a complex of several buildings 24/7.

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[10] Interestingly, while many US fire departments average 30% fire calls and 70% medical calls, on average, theirs is the opposite due in large part to the large number of data centers.
[11] Source: https://www.loudoun.gov/6188/Data-Centers-in-Loudoun-County
[12] Source: https://www.wric.com/news/local-news/powhatan-county/data-center-campus-eastern-powhatan/

- Depending on who is leasing or owns the building, there may be private security present 24/7. This can present access issues.
- Blueprints are great if they are available, but they may not be for some secure government-related facilities.

- Data centers are huge users of energy, and from an investigation perspective, this can be a big issue. While most buildings get electricity from the local grid, some are looking at or experimenting with hydrogen-powered systems and small nuclear reactors. LiBs and BESS may be throughout the building. This makes the pre-scene work, information-gathering, and site safety assessment processes even more important.

Data Center Fire Investigations

Fire investigators working at data center fires can face unique health hazards and safety issues, including electrical risks, toxic exposures, and structural challenges. Adequate and appropriate PPE and protocols are essential. Here is a breakdown of the key health hazards and operational concerns, in no particular order:

- Investigators need access to preplan information, inspection reports, and building plans. These buildings, especially when very large or multi-story, present unique challenges to the fire investigation process.
  - It is important to know, before you go, what type of fire occurred and what suppression systems were activated or used.
  - Coordinate with the building engineer(s) to identify power zones, battery locations, and suppression system information.
- Most data center fires are small, but most are also energy-related, which requires extra caution by investigators.
- Data centers often have maze-like designs with raised floors, tight server aisles, and limited egress, increasing trip, fall, and entrapment risks.
  - Suspended cable trays and HVAC systems may collapse, presenting access issues or concealing fire spread.

    - Post-fire, the area of interest for the investigator may meet the US-OSHA definition of a non-permit-required confined space. This requires special safety considerations.
- Data centers contain high-voltage systems and energized components that may remain active after a fire. Investigators risk electrocution if proper lockout/tagout procedures are not followed.
- Uninterruptible power supplies (UPS) and battery banks can undergo thermal runaway, releasing heat, toxic gases, and even causing explosions.
- Burning plastics, circuit boards, and insulation releases hazardous compounds like hydrogen cyanide, carbon monoxide, and heavy metals. Lithium-ion batteries can emit hazardous compounds and aerosols during failure or fire.
    - **Adequate and appropriate respiratory protection is a must the entire time in the hot and warm zones!**
- For larger fires, there are unique issues with these large and complex buildings.
- The primary hazard/issue is energy. Lots of LiB use in UPS and BESS systems, as well as in the primary energy generation system.
- Ventilation takes a LONG time due to building size and configuration. This does not eliminate the health hazards, just reduces them.
    - Clean agents (e.g., FM-200, Novec 1230) or inert gases used by some suppression systems may displace oxygen or cause respiratory irritation if not properly ventilated.
        - Document the suppression agent type and discharge time as part of your scene assessment.
- A site safety assessment is critical and must include the building engineer and security.
    - Residual heat, toxic residues, and an unstable structure may be issues that need to be remediated or delay the investigation.
    - Hazard remediation may take an extended period of time.
- Dense electronics and shielding can disrupt public safety communication equipment, complicating coordination.
- A thorough field decontamination/preliminary exposure reduction will likely be necessary.
- High-value environments and pressure to preserve digital evidence can increase cognitive load and stress.

As data centers continue to grow in size, complexity, and energy intensity, fire investigators must adapt their strategies to address the evolving challenges these environments pose. From navigating maze-like layouts and high-voltage systems to managing toxic exposures and preserving digital evidence, the stakes are high, and the margin for error is slim. Pre-incident planning, interdisciplinary coordination, and rigorous site safety assessments are not optional—they are essential. Whether you are responding to a small UPS fire or a multi-story facility incident, understanding the unique risks and operational dynamics of data centers is critical to protecting both personnel and investigative integrity.

The Future

From a research perspective, teams at the University of Miami conducted detailed air and ground sampling during an EV fire in the summer of 2025. Once the data analysis is complete and published, there should be insight into some of the issues discussed here.

The Ormond Research Group at North Carolina State University has a FEMA grant to "comprehensively identify battery fire contaminants, assess cleaning methods for PPE, and establish validated sampling protocols, with findings shared through journals, conferences, and training for actionable safety guidelines." [13] This is likely the same research project referenced on the NFPA website,[14] which is expected to be completed in late 2027. Hopefully, the results of these projects will expand our knowledge of this issue from an investigative perspective.

There is also work underway to develop alternative battery systems that do not have the issues associated with LiBs. However, all of this takes time.

University of Miami test burn

Recommendations

Based on this information, what safety protocols should be implemented to ensure the safety of the individuals involved? The IAAI's Fire Investigator Health and Safety Best Practices, Third Edition (2022), states that LiB fires can create an IDLH situation that requires SCBA use (Section 3.1.13.1), which is true; however, we know that gas meters cannot measure all the gases that may be present, and there is no correlation between the

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[13] https://ormondresearch.textiles.ncsu.edu/lithium-ion-battery-fires/
[14] https://www.nfpa.org/about-nfpa/press-room/news-releases/2024/new-research-project-investigates-lithium-ion-battery-fires-impact-on-firefighters-ppe

reading of one gas and the levels of any other, so a default assumption of IDLH may well be necessary.

Section 2.0.6.3 of that document says, "Proper PPE and battery-handling precautions are necessary." This is also true, but what exactly are these? While some literature addresses PPE in relation to LiBs, it primarily focuses on specific industries, such as utilities that utilize BESS and automotive companies that collect EV batteries for recycling, with an emphasis on suppression events. For suppression, full structural PPE and SCBA are always warranted. The US Fire Administration has a website[15] that discusses LiB hazards and addresses response strategies, but it does not mention investigators or post-fire actions. Aside from the referenced ATF document, I found no information that specifically addresses post-fire activities, which is not surprising.

Given the above information and our current understanding of gas and particulate health hazards in the post-fire environment, the following recommendations are made.

- Follow safety precautions
    - Understand that there is no such thing as a completely safe post-fire scene; anything can happen at any time.
    - Conduct a thorough site safety assessment.
    - Have an escape plan.
    - Ensure that the area is well ventilated and that there is sufficient light to work and see to escape, if necessary.
    - Use a thermal imaging camera to assess battery heat levels. It should be at or near the ambient temperature. Then, it is necessary to continue monitoring for any temperature rise.
    - Do not touch any LiB or LiB-containing device that has been damaged or subjected to fire until you can determine, through non-contact means, such as a TIC, that it is safe to do so. (IAAI, 2021)
    - Damaged LiBs can reignite hours or days after the last event. This means that significant safety precautions need to be taken. Generally speaking, the longer the fire has been extinguished without reignition, the better.
        - Unless absolutely necessary, do not conduct any investigation less than two hours after the most recent extinguishment.
    - LiBs may have been involved in the fire, even if not the ignition source. The presence of damaged LiB devices should serve as a warning flag for potential health and safety hazards.
    - There is an increased level of safety by having more than one investigator at the scene.

[15] https://www.usfa.fema.gov/a-z/lithium-ion-batteries/risks-and-response-strategies/ Last updated November 7, 2024.

    - If it is necessary to transport a damaged LiB or a device that contains a possibly damaged LiB, it should be placed in a sturdy container filled with sand or other inert material to stabilize it and prevent further damage.
        - Understand that the LiB may still retain energy and could enter TR while in this container, resulting in gas production that may increase the pressure inside the container and present significant health hazards when the container is opened.
    - If you are dealing with a BESS soon after suppression:
        - These large systems necessitate a utility representative or qualified expert on scene before any investigation starts.
        - Do NOT open the battery container doors during a potential TR event. This could result in an explosion.
        - Do NOT disconnect the auxiliary power supply to the affected battery container(s). This could cause TR in other containers. (Mylenbusch, Claffey, & Chu, 2023)
- Wear adequate and appropriate PPE as dictated by the incident and the site safety assessment.
    - Follow the Hot and Warm Scene PPE recommendations in the IAAI's Fire Investigator Health and Safety Best Practices, Third Edition (2022), depending on the time since extinguishment.
    - Use SCBA instead of an APR/PAPR.
    - If you wear an APR, use a full-facepiece respirator; if not available, wear gas-proof goggles with a half-facepiece APR.
    - Do not handle LiBs without wearing gloves.
    - Depending on the voltage of the LiB assembly being examined, electrical protective PPE may be necessary. Refer to the current edition of NFPA 70E Standard for Electrical Safety in the Workplace for detailed information on required electrical PPE.
- Cleaning
    - Follow the recommended preliminary exposure reduction/field decontamination and cleaning procedures found in the IAAI's Fire Investigator Health and Safety Best Practices, Third Edition (2022).
    - Properly package and dispose of all items that are to be thrown away.
    - Clean all PPE and tools/equipment as soon as possible after exposure.
        - The TEEX (2024) study found that cleaning bunker gear by NFPA 1851 traditional washing or by carbon dioxide methods produced virtually the same results for metals, and that the outer bunker gear layer "proved effective in stopping most metals." However, the carbon dioxide method removed a much higher amount of the gases. It also found that some metals remained after the cleaning process.

Here are some additional recommendations from the ATF:

- Extreme care should be used when handling cells and batteries on a scene. The investigator should avoid work practices that would further damage a cell or battery or cause a short circuit.
- To prevent additional damage that can result in re-ignition and to preserve the items for future examination, disassembly of cells and battery packs on scene should be avoided.
- If the investigative team has determined that there is no need to collect any cells or batteries as evidence, consideration should be given to the handling and storage of the items to be left at the scene.
    - Consider bagging any individual cells or batteries to prevent accidental shorting.
    - Isolate the artifacts in a safe area within the scene.
    - Individual bags should be labeled as to where the artifacts originated.
    - It is important to communicate the locations and condition of these items to subsequent investigators. (ATFFRL-TB-240001, 2024)

Conclusion

As LiB technology continues to proliferate across consumer, industrial, and commercial domains, fire investigators face increasingly complex and hazardous post-fire environments. The risks posed by TR events—including toxic gases, nanoparticulates, stranded energy, and unpredictable reignition—demand a heightened level of awareness, preparation, and protection. This paper underscores the urgent need for fire investigators to adopt rigorous safety protocols, leverage emerging research, and advocate for clear post-fire guidelines and policies specific to LiB incidents.

While suppression strategies have evolved, post-incident health and safety remains under-addressed in the current literature and in many policies. Investigators should assume that LiB-related scenes present an IDLH environment, regardless of gas meter readings or visual cues. The recommendations outlined here—grounded in peer-reviewed research and field experience—offer a practical framework for minimizing exposure and enhancing scene safety.

Ultimately, safeguarding the health of fire investigators requires a cultural shift: one that prioritizes long-term well-being over short-term convenience, embraces interdisciplinary collaboration, and insists on evidence-based practices. As research advances and new technologies emerge, continued vigilance and adaptation will be essential. Until then, the best protection is knowledge, preparation, and a commitment to safety above all.

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