EPA On-Scene Coordinator Lithium-Ion Battery Response Guide

Written by the Lithium-Ion Battery Task Force

October 2025

Legal Disclaimer

The information provided herein is intended for informational purposes only and should not be construed as legal advice, nor as establishing a professional or contractual relationship with any participants. The actions carried out by the U.S. Environmental Protection Agency (EPA), its contractors, and support staff during lithium-ion battery incidents are based solely on the knowledge, data, and information available at the time. It is important to note that, during any response period, the behavior of lithium-ion batteries in various scenarios may not be fully understood, and any interpretations or conclusions drawn from subsequent analysis may differ from those applied at the time.

The EPA, its contractors, and support staff acknowledge that lessons learned from past responses, emergent data, and evolving regulatory frameworks may inform future actions and decisions related to lithium-ion battery incidents. As such, individuals and entities are advised to consult other relevant sources and subject matter experts for current information and guidance regarding environmental safety and emergency response protocols. The EPA disclaims any liability for actions taken or decisions made based on the information provided herein.

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Introduction and Scope

The United States Environmental Protection Agency's (EPA) Lithium-Ion Battery Taskforce (LIBTF) was formed in 2024 with representation from the Office of Emergency Management (OEM), all ten regions, the Environmental Response Team (ERT), Office of Resource Conservation and Recovery (ORCR), and Office of Research and Development (ORD). The mission of the LIBTF is to enhance emergency response planning, preparedness, and technical capabilities of On-Scene Coordinators (OSCs) to respond to lithium-ion battery incidents. The LIBTF also aims to increase the awareness of hazards and response preparedness for lithium-ion battery incidents throughout partner response agencies at the local, state, tribal, and federal level. In addition, the LIBTF coordinates internal and external research opportunities with regard to lithium-ion battery response.

The EPA OSC Lithium-Ion Battery Response Guide is intended to be a nationally consistent, user-friendly guide that primarily addresses technical, administrative, and organizational practices, specifically for EPA OSCs involved with lithium-ion battery responses. The scope of this document includes, but is not limited, to:

- Lithium-ion battery background information
- Health and safety considerations
- Air monitoring
- Firefighting awareness
- EPA removal operations
- Transportation
- Disposal

The guide is created with the best understanding of available information as of October 2025 and is intended to be updated/reviewed at least every 3 years and/or as new information becomes available.

If you have questions, comments, or identify something in the document that is not true, or doesn't work based on an experience at a site, please let us know here.

For additional outside resources concerning LIB responses, please see the Helpful Links section at the end of this document.

Please note this guide does not address EPA's response to other types of batteries such as Alkaline, Lead Acid, Nickel Cadmium (NiCad), Nickel Metal Hydride (NiMH), Lithium Metal, or other battery technologies not listed or not yet released to market.

Lithium-ion Batteries are an evolving technology that have captured the majority of the global energy storage market. At this point lithium-ion batteries are ubiquitous throughout our daily lives. Lithium-ion batteries are the preferred choice due to their superior performance characteristics. Their high energy density allows them to store substantial energy relative to their size and weight, enabling extended use in portable electronics. Furthermore, they offer rapid charging, a long lifespan with numerous charge cycles, minimal self-discharge, and require relatively little maintenance. These advantages make them ideally suited for a wide range of applications, from smartphones to electric vehicles to grid scale energy storage.

Due to the large number of lithium-ion batteries within the consumer marketplace and global economy, the rate of battery failures and consequential incidents are on the rise. These incidents may occur at any point of the battery life cycle from manufacturing, transportation, consumer use, handling, repair/alteration, and during final disposal/recycling.

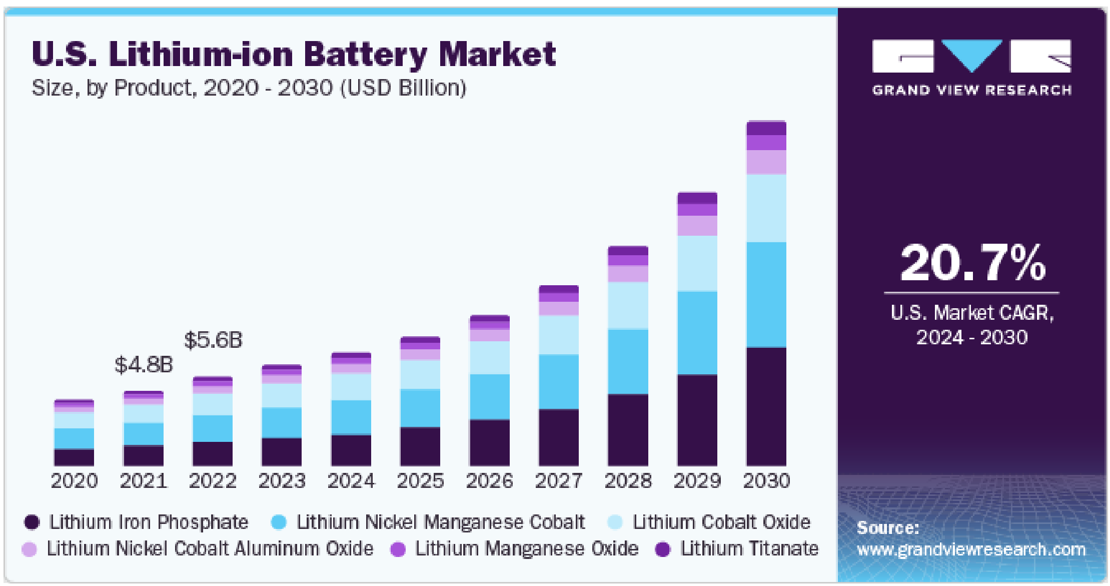

Figure 1. A graph depicting the market share of Lithium-ion Batteries, broken down by chemistry type.

Definitions and Acronyms

Anode – The negatively charged electrode of a battery. In lithium-ion batteries, the anode is where the lithium ions are moved to during charging. Graphite is the most commonly used coating material over the current collector that is typically made of copper.

Battery Cell – Refers to a single anode and cathode separated by electrolyte used to produce a voltage and current. A battery can be made up of one or more cells.

Battery Pack/Module/Casing – A module groups together individual lithium-ion battery cells to form a larger, functional unit, while a battery pack is the complete assembly that contains these modules (or sometimes is only one module), along with a protective outer casing (the pack/module casing) and a Battery Management System (BMS). The terms pack and module may be used interchangeably, and sometimes incorrectly when describing different configurations.

Battery Energy Storage System/Energy Storage System (BESS/ESS) – A BESS/ESS is a type of energy storage system that uses batteries to store and distribute energy in the form of electricity. BESS/ESSs can come in multiple sizes, ranging in storage capacity from kilowatt-hour (kWh) to gigawatt-hour (GWh) depending on the application, and ranging in size from a carryon suitcase to a warehouse filled with battery racks. They can be found in use in residential, recreational, and commercial/industrial areas.

Battery Management System (BMS) – A BMS is technology that is dedicated to the upkeep of a battery. The BMS manages the charging, discharging, and electrical storage of the battery pack, preventing electrical abuse to the batteries from over or undercharging. The BMS may also provide thermal protection of the battery pack, maintaining the temperature of the pack in optimal ranges (mostly found in electric vehicles and BESS/ESS). A BMS may shut down a battery to prevent overheating conditions.

Brine – A water-based solution containing a salt. Various salts may be used at various concentrations depending on availability. The intended purpose of a brine solution is to reduce the voltage of damaged, or potentially damaged, batteries to near 0 volts, to reduce the risk of fire or explosion.

Best Management Practices (BMPs) – BMPs are strategies, techniques, and procedures designed to effectively and practically prevent or reduce environmental issues.

Burst Disc/ Rupture Disc – This is a disc at the top of the cylindrical cell that acts as a pressure relief valve. As a battery undergoes thermal runaway the burst disc will allow for the release of toxic and flammable gases. Burst discs are not required, but are generally included in cylindrical cells.

Cathode – The positively charged electrode of a battery. In lithium-ion batteries, the cathode is where the lithium ions are moved to during discharge. There are multiple chemistries, normally a lithium salt, for the coating material on the aluminum current collector. Lithium-ion batteries are often “named” based on their cathode chemistry. For example, LFP refers to Lithium Iron Phosphate ($LiFePO_4$) and NMC refers to Lithium Nickel Manganese Cobalt ($LiNiMnCoO_2$). For more information see the Chemistry of Lithium-Ion Batteries section.

Cell Failure (of the battery) – A general term for when damage to or defect of a battery is sufficient to cause the battery to undergo thermal runaway. The most common mechanisms of damage are mechanical abuse (puncture or dent), incorrect charging (either over or undercharging the battery, typically due to a damaged or incorrect battery management system), and thermal damage (exposure to temperatures above 149-170^{o}F).

Collector Plate/Tab – The collector plate, or collector tab, is a connection to multiple cathodes and anodes and brings all the battery anodes and cathodes to a single point acting as the terminal of the battery. When the collector plate/tab is damaged it can be difficult to get full discharge of a battery and there is a higher likelihood of stranded energy.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – CERCLA is an environmental statute that is informally called Superfund. It allows EPA to clean up contaminated sites. It also forces the parties responsible for the contamination to either perform cleanups or reimburse the government for EPA-led cleanup work.

Damaged, Defective, or Recalled (DDR) Lithium-Ion Batteries – A DOT definition indicating misused, abused or insulted lithium-ion batteries with the full definition located in 49 CFR § 173.185(f). EPA responders use this term to describe damaged batteries, colloquially. https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf

De-energize – Used synonymously as "discharge". The reduction of energy stored in a battery to measurements as close to 0 Volts (V) as possible. It may be impossible to achieve discharge to 0 V, but batteries with a charge below 1 V are considered less likely to go into thermal runaway conditions.

Dendrite – Lithium dendrites are a metallic projection, a branch-like structure, that can form on the negative electrode of a lithium-ion battery during charging. If dendrites grow too large they may damage the separator leading to an internal short circuit and thermal runaway. Dendrites tend to grow if a battery management system allows the battery to be overcharged or when batteries are charged in low temperatures.

U.S. Department of Transportation (DOT) – is a federal agency responsible for developing and regulating national transportation policy across all modes, including highways, air travel, rail, and public transit. Its mission is to ensure safe, efficient, accessible, and sustainable transportation systems. DOT also administers funding for infrastructure projects and sets safety standards nationwide.

Electrode – The electrical conductors in the battery through which electrons flow to create a current. Lithium-ion batteries contain two electrodes, an anode, and a cathode. The anode and cathode are normally coated onto copper or aluminum foils that act as current collectors (i.e. collector plates).

Electrolyte – The solution that the lithium ions pass through, from the anode to the cathode. This solution is often an organic liquid and typically flammable. As such, electrolyte compositions all have similar risks due to their flammable nature. A common example of an electrolyte used in lithium-ion batteries is lithium hexafluorophosphate and organic solvents. Specific chemical makeup of the electrolyte solutions may vary from different manufactures and Safety Data Sheets (SDS) may not be available as some solutions may be considered proprietary or trade secrets.

End of Life (EOL) – "End of life" is a term used by some shippers of batteries to refer to batteries that have been used and are being shipped under the normal, non-DDR, DOT lithium-ion battery regulations.

Lithium-Ion Battery – Composed of cells in which lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge and the reverse pathway when charging. Commonly referenced in this document simply as "battery."

Micro-mobility Devices – small, lightweight vehicles for traveling short distances (i.e. e-bikes, e-scooters, hoverboards, skateboards, and electric wheelchairs) powered by lithium-ion batteries. Typically, the battery packs are removable from the device and contain 50-150 cylindrical cells.

Module or Battery Pack – An assembly of battery cells connected together in either series and/or parallel that may or may not have a battery management system.

Off-Site Rule – The Off-Site Rule was promulgated on September 22, 1993 (58 FR 49200). The regulatory citation is 40 CFR 300.440. It requires that CERCLA wastes may only be placed in a facility operating in compliance with the Resource Conservation and Recovery Act (RCRA) or other applicable Federal or State requirements

Pipeline and Hazardous Materials Safety Administration (PHMSA) – is a federal agency within the U.S. Department of Transportation responsible for ensuring the safe transportation of energy and hazardous materials. PHMSA regulates and enforces safety standards for pipelines and the shipment of hazardous goods by land, sea, and air. Its mission is to protect people and the environment from risks associated with these materials.

Primary Battery – Batteries that cannot be recharged and are single use products. They are not lithium-ion batteries, but may be lithium metal batteries. Alkaline batteries are another common primary battery.

Propagation – When thermal runaway in one battery cell causes sufficient damage to neighboring battery cells forcing them to enter thermal runaway. Propagation may occur from battery cell to battery cell within a module/battery pack.

Resource Conservation and Recovery Act (RCRA) – Is a federal law that governs the management of solid and hazardous waste in the United States. It gives EPA authority to control waste from its creation to disposal, including treatment, storage, and cleanup.

Secondary Battery – Batteries that can be recharged (i.e. multi use batteries). Lithium-ion batteries are secondary batteries.

Separator – Used to isolate the two electrodes from one another and is usually made up of a microporous polymer membrane. The separator prevents the two electrodes from contacting one another but allows the lithium ions to pass through.

Short Circuit – A short circuit in a lithium-ion battery can occur when a connection forms between the two electrodes inside the battery cell, typically because the separator has been damaged. A short circuit can lead to overheating of the battery cell and eventually thermal runaway.

State of Charge – The State of Charge (SOC) of a lithium-ion battery is the measure of the remaining charge of the battery compared to its full capacity, often expressed as a percentage. SOC does not refer to the amount of volts remaining in a lithium-ion battery. When a lithium-ion battery has a 0% SOC it does not have 0 volts. Often an individual cell may have greater than 3 volts remaining when the SOC is 0%.

Thermal Runaway – Occurs when a damaged or defective battery cell fails and generates heat that reaches a stage where it becomes self-sustaining. This creates an exponential rise in cell temperatures that typically results in any combination of explosion, fire, and release of toxic and flammable vapors. Thermal runaway in a damaged or defective cell may occur instantaneously in several seconds or may be delayed unpredictably. Thermal runaway is likely to propagate to neighboring cells or nearby batteries as shown in Figure 2 Below.

Figure 2. Thermal Runaway

Voltage/volts(V) – voltage is the measure of electrical potential difference between two electrodes. For individual lithium-ion battery cells a fully charged battery (100% SOC) will normally measure between 4.0 to 4.2 volts, depending on the battery chemistry. A lithium-ion battery at 0% SOC will still have greater than 2.0 volts, often 2.7-3.2 volts, depending on the battery chemistry. Battery pack voltages will be dependent on wiring of cells internal to the pack, but will show a similar relationship of voltages to state of charge. For example, a 24-volt battery pack may still have 12 to 18 volts of energy at 0% state of charge.

Watt-Hour (Wh) – A lithium-ion battery's watt-hour rating describes the energy capacity of the battery. Watt-hours are a unit of energy that measures the amount of power used over time. Typically, larger batteries have a higher watt-hour rating and therefore have more energy capacity. Batteries with larger watt-hour ratings may be referenced in other units to indicate scale (e.g. a kilowatt-hour (kWh) is 1000-watt hours, a megawatt-hour (MWh) is 1000 kWh, etc). Battery size does not always indicate the designed voltage or amperage of a battery.

Anatomy of Lithium-Ion Batteries

What is a Lithium-Ion Battery?

A LIB is a rechargeable battery where lithium ions move from the anode to the cathode. The anode is typically coated in graphite and the cathode chemistry can vary but is typically a lithium salt. An organic electrolyte solution allows the lithium ions to move between the anode and the cathode. A separator, typically a polymer/plastic membrane keeps the anode and cathode from touching.

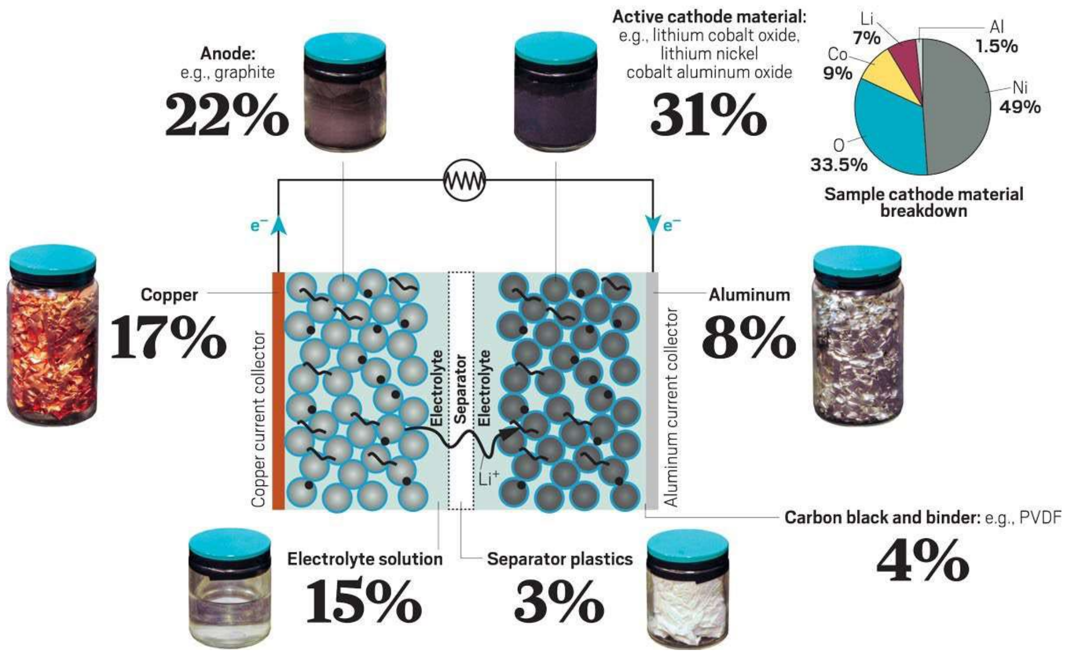

Figure 3. A diagram showing the typical makeup of a Lithium Ion Battery with examples of materials used and their percentage makeup in the battery.[1]

Structures of Lithium-Ion Batteries

Lithium-ion batteries can come in different sizes and structures. Technology is constantly evolving in the shape, chemistry, and power density of batteries.

While the presentations of battery cells vary, the science and raw metals used in developing the structures are relatively the same. Cylindrical cells have sheets of materials tightly rolled together; prismatic cells are folded at the ends and encased in plastic or metal. Pouch cells are configured in a similar layered format, but are only encased by foil to create a thin, flexible structure. Some button structure cells are also lithium-ion, but they are less common.

The most common lithium-ion battery structures that may be encountered include:

1. **Cylindrical cells:** The most common battery in micromobility devices (scooters, e-bikes, etc.) are cylindrical battery cells. Electric vehicles (EVs) commonly use batteries made up of thousands (5,000+) of cylindrical cells in a series, depending on the make, model, year, and option. Vehicle manufacturers use different battery formats: some prefer cylindrical cells, while others opt for the flat, rectangular design of prismatic cell or the flexible, soft casing of pouch cells. Cylindrical cells are also found in residential scale BESS/ESS systems. Cylindrical cells are typically referred to by their size in millimeters (mm), diameter first then length. For example, 2170 is a battery with a 21 mm diameter that is 70 mm long. 18650s

[1] Source: Argonne National Lab, published in Jacoby, M., 2019. "It's time to get serious about recycling lithium-ion batteries." Chemical & Engineering News, Volume 97, Issue 28. July 14, 2019. Available online at https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28.

are batteries with an 18 mm diameter and 65 mms long, the extra 0 historically meant it was a cylindrical cell made by Sony but is not used by all battery manufacturers. 18650s are most typically found in micromobility devices while larger cells are found in EVs or BESS/ESS units.

Figure 4. A typical example of a cylindrical LIB cell

Figure 5. Examples of damaged cylindrical LIB cells

2. **Prismatic cells:** Rectangular in shape and larger than the cylindrical cell. These can be found in electric and some hybrid vehicles and hold more charge than a cylindrical cell. Vehicle manufactures tend to place prismatic cells in sequence, held in a sturdy case typically on the bottom of the vehicle chassis. Depending on the vehicle and amount of damage received, the outer cases may be largely intact, or appear unharmed, but may not properly indicate damage to the prismatic battery cells within them. Commercial grid scale systems and newer residential BESS/ESS systems may also use this type of cell.

Figure 6. A typical example of a prismatic LIB cell (left), a prismatic cell on fire (center) and a damaged prismatic cell structure EV battery from the 2025 Southern California Wildfire response.

3. **Pouch cells:** Commonly used in computers and cell phones. However, some vehicle manufactures utilize pouch cells to complement existing power or to fully power the vehicle. Pouch cells can be small enough for handheld devices or large enough to power vehicles.

Electrodes are stacked on top of each other with a separator between, several times over before being sealed in a foil-like pouch. Cathodes and anodes can be on the same side or opposite, depending on the housing module.

Figure 7. Typical examples of pouch LIB cells

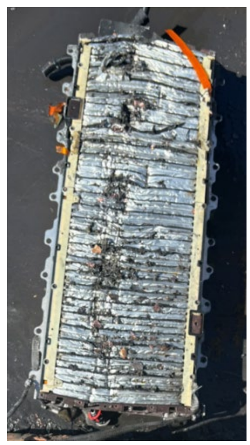

Figure 8. Damaged pouch cells from an electric vehicle.

Chemistry of Lithium-Ion Batteries

Not only is there a wide variation in structure of lithium-ion batteries, but also in their chemistry. Battery chemistry affects the energy density of a battery, which can impact how dramatically a battery cell fails, and determines the desirability/value in the recycling industry. Different battery chemistries will also have different metal particulate emissions during fire. The most common chemical makeups of lithium-ion batteries as of September 2025 are:

1. Lithium Nickel Manganese Cobalt Oxide - NMC –LiNiMnCoO2 – broad applications, primarily found in micromobility devices, electric vehicles, and BESS/ESS
2. Lithium Ferrous Phosphate – LFP –$LiFePO_4$ – broad applications, primarily found in BESS/ESS and some electric vehicles
3. Lithium Cobalt Oxide – LCO – $LiCoO_2$ – primarily found in small portable electronics like smartphones, laptops, and power tool batteries
4. Lithium Manganese Oxide – LMO – LiMn2O4 – primarily found in power tool batteries and medical devices often as cylindrical cells
5. Lithium Manganese Rich – LMR – touted as next generation batteries for some American car manufacturers but is another form of LMO
6. Lithium Nickel Cobalt Aluminum Oxide – NCA – LiNiCoAlO2 – Primarily found in electric vehicles. Most notably Tesla Model S (2012-present) Model X (2015-present) Model 3 Long Range (2017-present) and Model Y Long Range (2020-present) and the Lucid Air (2021-present).
7. Lithium Titanate – LTO – Li4Ti5O12 – primarily found in power supplies, electric power trains, and solar streetlights

Lithium-Ion Battery Failures and Fires

Lithium-ion batteries can fail for a multitude of reasons. The 3 most common reasons for failure (which will be the focus of this document) are electrical, physical, or thermal (overheating) abuse, generally related to damage to the separator. Cell failure can also result from defects in the manufacturing process, battery chemistry, or the battery management system (BMS) engineered by the original equipment manufacturer (OEM). Regardless of the reason for the failure, all failures have the potential for the release of toxic gas, smoke, fire, and explosion. However, it is also possible for a battery to fail with none of those obvious signs. The failure mechanisms and potential exposures are described in more depth below.

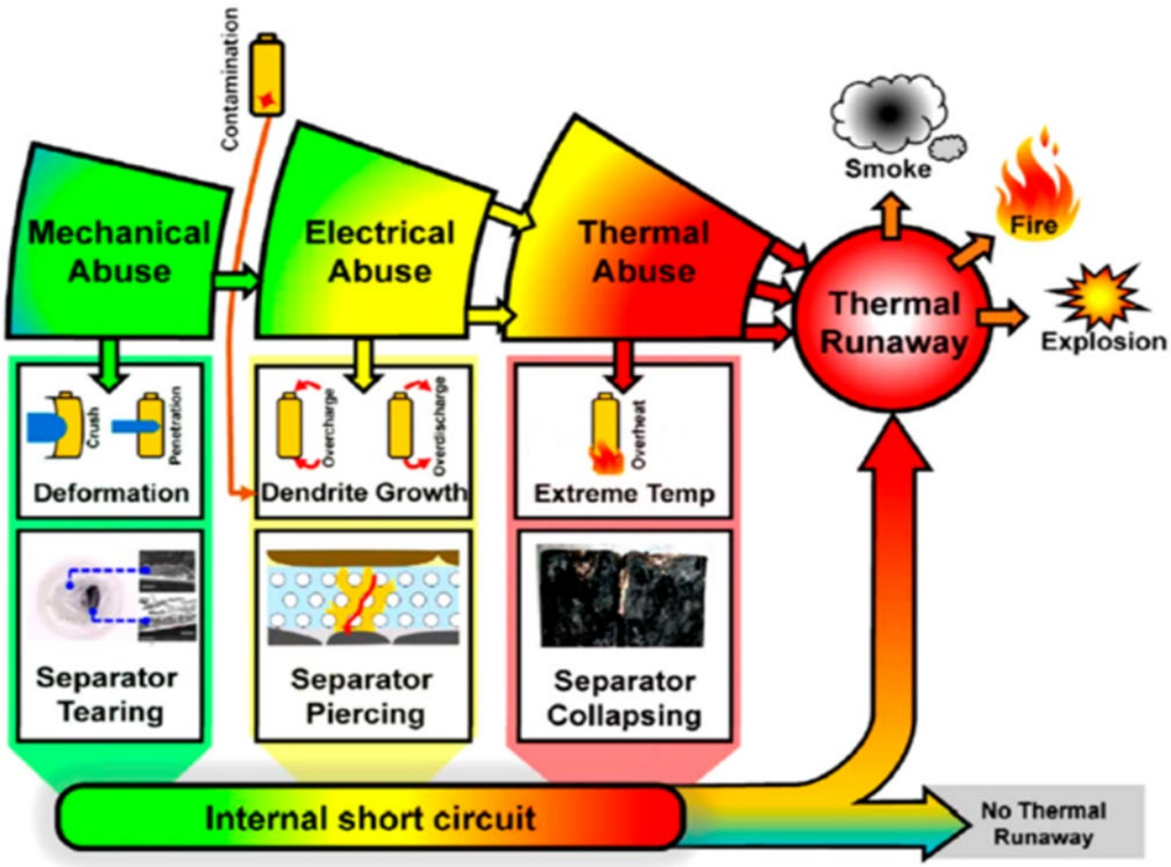

Figure 9. A roadmap of how LIB failures lead to thermal runaway conditions.

Stages and Characteristics of Lithium-Ion Battery Failures

1. **Initial damage to battery**

   Battery failure typically entails damage to the separator causing an internal short circuit of the battery. When the short circuit occurs, the battery gets hot and begins to boil the electrolyte inside of the closed cell, building up pressure. Eventually the pressure causes the cell to fail releasing a mixture of gases to the atmosphere. The separator is typically damaged through one of three types of abuse/insult.

   - Mechanical abuse – the crushing or penetrating of a battery cell causing the separator to deform or tear through physical force exerted on the battery.
   - Electrical abuse – repeated over/undercharging can lead to dendrite growth. Dendrites are a branch-like structure that forms on the anode or cathode and can grow to pierce the separator.
   - Thermal abuse – when batteries are exposed to high temperatures, around 150^{o}F or greater depending on the cell type and battery chemistry, the separator can become damaged or may collapse.

*Water exposure can result in corrosion to the battery electrodes and may lead to failures similar to mechanical or thermal abuse.

After the battery experiences one of these types of abuse, it is considered DDR per DOT.

2. Internal Short Circuit

In any of the abuse cases, the battery cell may have an internal short circuit. The timing and intensity of the short circuit can vary widely. Some cells may have a small short circuit and experience little to no heating and never enter thermal runaway. Other cells may experience a larger short circuit and immediately go into thermal runaway and quickly fail, releasing a mixture of toxic gases likely leading to a fire or explosion. Other batteries may be damaged but experience a delayed short circuit and not go into thermal runaway for a considerable time after the damage occurs (hours, days, weeks, months).

3. Thermal Runaway

Thermal runaway is best understood as rapid heating of the internal components of the battery through a combination of internal electrical short circuit and a chemical reaction resulting from the heating. The voltage of the battery and the battery chemistry drives the intensity of thermal runaway. A self-sustaining reaction in a particular cell is impossible to interrupt and generally leads to off-gassing and fire. A cell undergoing thermal runaway will typically be over 550^{o}F and that heat may transfer to surrounding battery cells, thermally damaging them and causing them to enter thermal runaway as well. This heat transfer from battery cell to battery cell is called propagation. It is important to note that once a battery goes into thermal runaway there is no way to stop the reaction. The full reaction will continue until it has run its course. However, cooling efforts (water application) may interrupt any propagation that occurs. Thermal runaway in a damaged or defective cell may occur immediately following abuse or may be delayed unpredictably.

4. Off-gassing

A popping sound may be audible during the off-gassing stage of battery failure. It is mostly associated with cylindrical cells but may also occur with other battery types. For cylindrical cells, the "pop" is generated as the top cap separates or splits from the cell body due to increased internal pressure buildup.

5. Fire/explosion of released gases

Often, following the initial off-gassing the batteries are hot enough to cause the gases to ignite. Sometimes the ignition happens at the very beginning of off-gassing and the fire appears like a jet of fire from a flare. Other times the ignition can happen after large amounts of gas have been emitted, this fire would have an explosive start as all of the gases in the vicinity are rapidly ignited. In either scenario, the self-sustained exothermic, chemical reaction within the internal battery cell cannot be extinguished by any traditional firefighting methods such as application of water, CO_2, foam blanket, sand or other covering materials. There is currently no known technology, or method, to extinguish a lithium-ion battery fire at the internal cell level of origin when the batteries are undergoing self-sustained thermal runaway. Additionally, there is no scientific evidence to prove that there is an extinguishing or cooling agent to limit heat propagation to cells that is more effective than water. During thermal runaway or heating of the cell, the gases contain fuel and oxygen and typically enough heat to cause/maintain ignition. Submersion of burning batteries into water, or aggressive water application does not extinguish the battery fire, but it may inhibit propagation to cells that are not currently on fire. Water application may also be necessary to prevent other combustible materials from becoming involved in the fire. When cylindrical cells catch fire, depending on the damage to the surrounding casing, they may become projectiles that can shoot 50 feet or more[2]. These projectiles may hit other objects and could cause other fires or injure a nearby person. See the Fire Fighting Tactics section for more information on LIB firefighting.

6. **Fire of ancillary plastics/non-batteries**

   Batteries are rarely shipped as just battery cells. There is often surrounding packaging, and that packaging is generally flammable. Battery fires are hot enough to catch the surrounding packaging, typically plastics, on fire. The fires of the plastics can be extinguished by usual means with water or other inert agents.

7. **Reignition**

   Reignition of battery fires is common. Individual cells do not reignite, once they have undergone thermal runaway and have been fully consumed by fire. However, it is common that not all of the battery cells in a group of batteries/battery pack/module will burn. In those instances, the non-consumed batteries are likely damaged by the surrounding batteries on fire. Once damaged, a battery can enter thermal runaway at any time, unpredictably. The potential for reignition is one of the primary health and safety concerns for EPA and response personnel at a battery site.

Responding to Lithium-ion Battery Incidents

Responding to incidents involving lithium-ion batteries presents a complex and multifaceted challenge that necessitates an alteration of traditional emergency response protocols. The inherent characteristics of lithium-ion batteries, including their potential for thermal runaway, the release of toxic and flammable gases, and unpredictable behaviors like reignition, demand unique considerations and tactical decision-making to ensure the safety of responders and the public. Unlike conventional fires or hazardous materials incidents, lithium-ion battery incidents require a tailored approach that takes into account the specific conditions of each event. These considerations encompass a wide range of factors and critical decision-making points including health and safety considerations, air monitoring options, fire-fighting tactics, and curated removal activities.

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[2] Observations at several responses have indicated battery casings laying 75ft or more away from the battery location. Those responses are: San Diego battery testing of shipping container on February 23, 2024 where battery cells traveled over the head of observers that were 50 feet from the bag being tested; San Diego Airport Bus on February 2024 where cells travelled up to 75 feet from the bus; FedEx Truck Fire in Monahan Texas Feb 2023 where batteries scattered at least 50 feet in all directions

Health and Safety for Responders Considerations

The health and safety of responders and the public are primary objectives to any response. Below are concepts to consider, however each incident or site will present its own unique challenges and objectives may vary. Job Hazard Analysis (JHA) can be included in any health and safety plan associated with lithium-ion battery responses. Some recent Wildfire Response JHAs are attached (attachment 1) as examples that can be modified and expanded based on site specific conditions.

Hazards

The hazards encountered on a battery site include physical, health, and chemical hazards. Physical hazards can be divided into the concerns associated with the work environment and the hazards associated with the batteries. The physical site hazards will be the standard hazards experienced at most emergency response and removal sites. These include hazards presented by heavy equipment such as crushing and struck-by injuries and lacerations and punctures from sharp objects. Other hazards include repetitive motion injuries related to manual handling and lifting of heavy objects and the ubiquitous slips, trips and falls. Personal protective equipment will be required so heat stress will be present along with cold stress based on the geographical location. Review the Agency's Emergency Response Health and Safety Manual (EPA Network access required) for detailed guidance hazard recognition and risk reduction. Lithium-ion batteries present additional hazards; some unique to batteries.

Larger battery systems, e.g., EV and BESS/ESS, can hold a significant electrical charge that can cause an electrocution or an arc flash fatality. Assessing a damaged lithium-ion battery for stranded energy or live wires may be necessary prior to handling. A lithium-ion battery supplies direct current (DC) power, and a multimeter must be set to the DC mode to measure its voltage or current accurately. It is common with lithium-ion battery components and systems to invert DC and AC current, and for safety reasons based upon battery presentation type, must be assessed by approved and certified/trained personnel (e.g., specialized electrician).

Damaged Lithium-ion batteries may experience instantaneous or delayed thermal runaway. Damage, along with defects, may not be identifiable. As such, OSCs should address fire preparedness in the site health and safety plan when handling batteries during activities on-site. The Site Considerations and Stabilization section below provides some key considerations for site fire emergency planning. During a thermal runaway, thermal burns, flash fires, and the explosive release of contained gasses are possible. The explosive release of contained gasses can cause splash hazards from the battery electrolytic fluid as well as puncture and lacerations from the fragmenting battery case and the equipment the battery is contained in. Cylindrical cells may become projectiles and could cause burns or lacerations if they impact personnel.

The chemical hazards that may be encountered are flammable and combustible gases, corrosive gases, toxic gases, toxic liquids (electrolyte and coolant). The specific gaseous hazardous substances associated with lithium-ion batteries are further discussed in the air monitoring section of this document.

During an off-gassing or fire event involving a lithium-ion battery, hydrogen is the primary flammable gas released. As hydrogen has a wide explosive range, it poses a significant hazard. This risk is especially high in enclosed or confined spaces, including small rooms and shipping containers. In these areas, the gas can accumulate, leading to the potential for energetic ignitions or explosions. For this reason, response personnel must exercise special caution when operating in such environments.

Carbon monoxide (CO) is a serious hazard in a lithium-ion battery fire or off-gassing incident. As the second most prevalent gas, it is both toxic and flammable. During such an event, CO concentrations can rise to levels far above the Immediately Dangerous to Life and Health (IDLH) and can exceed the sensor operational range. Responders should recognize the risk of significant gas accumulation in confined spaces, similar to the danger posed by hydrogen.

Hydrogen fluoride (HF) gas is one of the most toxic gases generated during a LIB off-gassing/fire event. However, it is generated at much lower amounts, measured in the ppm range, than hydrogen and carbon monoxide (both are generated in double digit percent concentration ranges). The battery electrolytic solution is typically a toxic and combustible liquid. Common toxic substances contained in the electrolytic solution are lithium hexafluorophosphate ($LiPF_6$) and organic solvents. Exposures to solutions containing $LiPF_6$ should be handled similarly to exposures to hydrofluoric acid solutions. Emissions from thermal runaways and fires involving $LiPF_6$may produce hydrogen fluoride gas. In addition, electrolyte solutions may vary per manufacturer with specific formulations assigned as proprietary. Additional hazards which may not be fully understood, may exist based on the chemical makeup of the electrolyte

Like all response actions, implement engineering controls to the extent practical to reduce or eliminate the need for certain types of personal protective equipment.

PPE Recommendations

Standard PPE ensemble:

The below suggested standard PPE ensembles are suggested for LIB incidents. OSCs should make modifications to the standard ensembles to address site-specific risks that may not have been described here-in.

Level	Respiratory	Eye	Suit	Gloves	Feet	Typical activity
D	Not applicable	Safety Glasses	Not applicable	Work Gloves	Safety Boots	Non-handling activities outside of exclusion zone; Mobilization/demobilization; Site setup
C	APR (half-face or full face) with multipurpose cartridge	Safety Glasses	Tyvek	Work Gloves	Safety Boots	Work in the exclusion zone after all batteries are removed but other exposure risks remain
C with FR	APR (half-face or full face) with multipurpose cartridge	Safety Glasses when wearing half face or FF APR	FR Coverall and SFR Tyveks	Thermal Work Gloves	Safety Boots	Applicable when no active thermal runaway or fire exists: Non-handling activities inside the exclusion zone with batteries present; All battery handling activities (collection, packaging, battery deconstruction, etc)
B with FR	SCBA or Supplied Air	SCBA Face Mask	FR Coverall and SFR Tyveks	Thermal Work Gloves	Safety Boots	Any fire; Active thermal runaway; Sustained air concentrations exceeding PPE upgrade levels

Table 1: Standard PPE Ensemble Recommendations

Below are more detailed discussions highlighting LIB-specific hazards and conditions that were considered when developing the recommended standard PPE ensemble.

Hydrofluoric Acid Dermal Protection Discussion

Normally, responders associate an HF release with a Personal Protective Equipment (PPE) standard of Level A ensemble due to the risk of dermal exposure. HF gas generation and exposure risk during a battery fire is highly variable based on the location, e.g., indoor vs. outdoor, battery watt-hours, heat of the fire, etc. Standard conditions encountered during a typical battery response action do not require fully encapsulating, vapor tight chemical protective clothing (Level A) or a chemical protective suit. In general, Level A is not required for a lithium-ion battery response because the HF gas/vapor source is dilute (<30 ppm). Level A PPE requirements are usually associated with sites involving a source of the HF in free liquid form or direct contact with an anhydrous/concentrated source. The table below is based on NIOSH recommendations using EPA's 8-hr Acute Exposure Guideline Levels (AEGL) and IDLH values as their point of reference.[3]

HF Concentrations in Air with low risk of splash hazard	Appropriate PPE
≥30 ppm	**Level A**
>25 ppm and <30 ppm	**SCBA with HF chemical protective clothing**
>12 ppm and <25 ppm	**Full face APR with HF chemical protective clothing**
>1 ppm and <12 ppm	**Full face APR and FR clothing**
<1 ppm	**FR clothing**

Table 2. PPE Recommendations in relation to HF concentrations in air.

Flame-Resistant Clothing (FRC) Discussion and Disposable FR Clothing Recommendation

Thermal protection is a unique hazard control not often encountered at EPA emergency response and removal sites. Special planning and preparedness for both EPA responders and contractors is required. The lithium-ion battery response PPE ensemble needs to include considerations for flame and arc flash protection. This is accomplished by adding FR coveralls to the standard PPE ensemble. FR clothing is designed to limit burn injuries, provide additional escape time, and increase a worker's overall chance of survival in flame hazard situations. FR material does not ignite, melt, drip, or continue burning once the initial flame has subsided. The following are the main standards FR clothing must meet or exceed:

- NFPA 2112 - Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire
- ASTM F1930 - Standard Test Method for Evaluation of Flame-Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin

[3] American Chemistry Council, Hydrogen Fluoride Panel. (2018). Emergency Preparedness and Response Guidelines for Anhydrous Hydrogen Fluoride (AHF) and Hydrofluoric Acid (HF). Retrieved from https://www.americanchemistry.com/content/download/5432/file/Emergency-Preparedness-and-Response-Guidelines-for-Anhydrous-Hydrogen-Fluoride-AHF-and-Hydrofluoric-Acid-HF.pdf
NIOSH Guidance for HF
https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750030.html

- NFPA 70E - Standard for Electrical Safety in the Workplace
- ASTM F1506 - Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs
- When purchasing FR clothing also consider third party testing certifications such as the Underwriters Laboratory First Responder and Emergency PPE Testing and Certification.

Emissions data suggests that high levels of metals may be emitted during lithium-ion battery fires and may pose a risk to personnel during the fire as well as following the fire through deposition of the metals on batteries/debris.[4]

Given the potential for hazardous dust exposure, FR coveralls used in the work zone should not be worn in the support zone or leave the job site without first being laundered or protected by a disposable secondary fire-resistant (SFR) coverall. There are commercially available options for disposable SFR coveralls. Carefully review the technical data; disposable SFR coveralls are typically designed to be worn over and protect primary FR clothing from hazardous dusts, oils, dirt, and grime. Disposable SFR coveralls may not meet the standards listed above and should not be the sole flame/arc flash protective part of the PPE ensemble. Below are examples of disposable SFR coveralls commercially available.

1. DuPont™ Tyvek® 400 SFR
2. DuPont™ ProShield® 6 SFR
3. Lakeland™ Pyrolon® Series
4. Kapler™ Zytron® 300 FR

Appropriateness of Air Purifying Respirators in a Potential Nano Particulate environment

Inhalation of toxic materials is nothing new when responding to toxic emergencies, however lithium-ion battery emissions are not usually considered when selecting respiratory PPE. Preliminary data from the National Renewable Energy Lab, shared in November 2024, suggests metals emitted during a lithium-ion battery fire will have a size range between 100 nanometers (nms) to greater than 10 microns in diameter. In the filter certification test used to certify air purifying respirator cartridges the size of particulate used is approximately 300 nanometers. NIOSH has conducted further testing demonstrating that respirators equipped with P100 cartridges or N95 cartridges provided better or similar performance levels for 10-100 nms as compared to larger particulates (100-400 nms). Further all respirators were found to provide the expected protection against all particulate ranges.[5]

Decontamination

A dry decontamination approach is best for most of the tasks associated with lithium-ion battery response. Equipment, resources, and most components of PPE can be dry decontaminated, however porous materials, such as SCBA fabric straps and FRC outerwear may need to be laundered or wet decontaminated.

Due to the high concentrations of metals produced during a lithium-ion battery fire, PPE should be treated as contaminated following work. Reusable PPE like FR coveralls and thermal work gloves may be

[4] **https://teex.org/wp-content/uploads/LITHIUM-ION-BATTERY-FIRES-AND-EMISSIONS-CHARACTERIZATION.pdf**
[5] https://pubmed.ncbi.nlm.nih.gov/26180261/

difficult to decontaminate between shifts/entries. If available, disposable SFR coveralls can be worn to protect primary FRC outerwear. If disposable PPE is not available and PPE decontamination is not feasible, the PPE should be stored in the contamination reduction zone for donning immediately prior to reentry to the exclusion zone. Ensure crew members understand the importance of treating the reusable PPE in a way that reduces cross contamination during the daily safety meetings. Personnel should not wear clothing that has not been decontaminated in vehicles, Incident Command Post, or other areas outside the exclusion zone.

Air Monitoring and Sampling During Lithium-Ion Battery Response

Conceptual Site Model for Battery Fires

A significant portion of Lithium-ion battery response is planning for and/or reacting to the release of vapors and/or smoke from damaged batteries that undergo thermal runaway. For modeling purposes it may be useful to understand the estimated gas generation volumes and make-up for different size batteries. Research to define gas production rates/amounts have been published from multiple researchers, but there are many variables (e.g. battery chemistry, electrolyte solution, type of cell, size of battery, voltage etc.) that confound the creation of specific vapor production rates and amounts. Other materials involved in a battery fire, such as plastics surrounding a battery pack or foams in an EV, may also contribute to gas/vapor generation volumes. A good rule of thumb, for estimating gas production during failure of a single 18650 of a lithium-ion battery is estimated to be 6 liters per watt-hour[6] (L/Wh). Hydrogen is typically found to be approximately 30-50% of the total gases emitted. Hydrogen fluoride production is estimated to be between 20 and 200 milligrams per watt-hour (mg/Wh) across all batteries tested. These estimates are for gas production from batteries undergoing thermal runaway, and do not account for burning of surrounding material (e.g. plastics surrounding a battery pack or plastics and foams in an EV).

Battery Type/Size	18650 battery cell (10Wh)	Laptop battery (30-100 Wh)	Scooter/Ebike battery (100 – 750 Wh)	EV battery (50 to 100 kWh)	BESS/ESS (13.5 - 3,000 kWh)
Estimated Gas Production	60 L	180 to 600 L	600 – 4500 L	30,000 to 600,000 L	81,000 to 18,000,000 L

Table 3. Estimated gas production by battery type/size.

Additional constituents of the vapor cloud can vary based on the type of electrolyte used within the battery, the state of charge, and the structure of the battery (cylindrical, prismatic, pouch). The toxic gases given off in smaller percentages include carbon monoxide, hydrogen cyanide, hydrogen chloride, , phosphoryl fluoride, phosphorous pentafluoride, and phosphorous trifluoride. A mixture of additional hydrocarbons (e.g. methane, ethane, propylene, etc) are also contained in the vapor mixture. If the vapor ignites, metals will also be released. Metals such as aluminum, cobalt, copper, lithium, manganese, and nickel and others have been found in at least one study where lithium-ion batteries have been burned[7]**.** Other, unpublished studies, such as a burn EPA participated in with San Diego Fire in 2024 indicated similar results.

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[6] There are a multitude of studies evaluating the makeup and volume of gas produced during lithium-ion battery failure events. Results vary widely depending on the cell type and state of charge of the batteries tested. 6 L/Wh is the rule of thumb EPA typically uses for inputs to modeling based on experiences gained at various lithium-ion battery sites.

[7] **https://teex.org/wp-content/uploads/LITHIUM-ION-BATTERY-FIRES-AND-EMISSIONS-CHARACTERIZATION.pdf**

Firefighting tactics will determine how to address the environmental impacts from a battery fire. If fire suppression activities, such as water application, are chosen then a more localized air monitoring plan may be appropriate. If fire suppression activities, such as water application, are chosen then an effort to collect firefighter runoff should be made for further evaluation of contaminants, particularly metals, to determine disposal options. A decision to let a battery fire burn may impact a surrounding community necessitating the need for a wider array of air monitoring and potential recommendations for shelter-in-place or evacuation of public or responders.

Soil sampling and runoff pathway sampling has not been well studied and is generally not implemented at lithium-ion battery incidents. It is up to the OSC to determine this need.

Air Monitoring

Air monitoring is a tool for surveying environments to determine personnel health and safety measures, establishing hot zones, and evaluating the potential for exposures to the community. This section will discuss instruments found in the "Emergency Response Technical Group's (ERTG) National Equipment List (NEL). However, there are a variety of handheld and perimeter air monitoring units available that are not on the NEL that are similar to the instruments discussed in this section. An Air Monitoring Table (attachment 2) has been developed that is broken out by specific analyte, appropriate instruments and their detection levels, action levels (AEGL, PAC, and ERPG), and air sampling references.

Air Monitoring Table

A variety of chemicals are released during off-gassing and active fires from lithium-ion batteries. Many of the chemicals have been identified in laboratory settings but may not have been definitively proven to be released from all battery chemistries in real-world scenarios. The Air Monitoring Table (attachment 2) is sorted to display the chemicals most likely to be emitted or most likely to drive decision making at a response first (Primary) and to highlight other potentially released compounds that are unlikely to drive decision making second (Secondary). A summary table of the primary and secondary chemicals of concern is below.

Primary Chemicals/Metals of Concern	Secondary Chemicals/Metals of Concern
Hydrogen	Sulfur Dioxide
Hydrogen Fluoride	Hydrogen cyanide
Carbon Monoxide	Hydrogen chloride
Nickel	Hydrogen sulfide
Lithium	Ammonia
Manganese	Formaldehyde
Cobalt	Phosphorus pentafluoride
Copper	Phosphoryl fluoride
Carbon Black	Phosphorus trifluoride
Aluminum	Zinc oxide
	Cadmium

	Lead
	Silver
	Antimony
	Tin
	Barium
	Iron
	Thallium

Table 4. Primary and Secondary Chemical of Concern During Lithium-Ion Battery Fires.

Initial Suggested Air Monitoring Approach

The initial approach for air monitoring during an active lithium-ion battery fire is similar to typical industrial fires. An initial deployment should include the following:

- **5-gas meters**, with a
  - LEL sensor (capable of hydrogen detection),
  - Oxygen (0_2) sensor,
  - carbon monoxide (CO) sensor,
  - photo ionization detector PID/sensor, and
  - hydrogen cyanide (HCN) sensor
- **SPM flex** with mineral acid tapes setup to display HF,
- **Particulate monitors**,
- **Air sampling equipment for metals analysis** (37 mm mixed cellulose ester [MCE] cassette, 225-3-01)

Air monitoring tactics during the removal phase of a lithium-ion battery site, when no active fire is present, but batteries are being handled and a fire could occur, is not necessarily different than an active fire. However, the extent of the monitoring may be limited to on-site/perimeter monitoring. Similar instruments and action levels are appropriate.

Air Monitoring Considerations

As described above, a significant air monitoring array will likely be needed during lithium-ion battery incidents. Below are more detailed air monitoring considerations for lithium-ion battery air monitoring tactics.

Photo Ionizing Detectors Combustible Gas Indicators and CO sensors

MultiRAEs and AreaRAEs should contain a photo ionization detector (PID) sensor that measures volatile organic compounds (VOCs) and a combustible gas indicator/sensor that measures the lower explosive limit (LEL). Neither sensor can differentiate the chemical it responds to. Furthermore, PIDs are typically installed with a 10.6 electron volts (eV) lamp and will only provide a response to compounds with an ionization potential less than or equal to 10.6 eV.

LEL sensors indicate the risk of fire or explosion in the atmosphere. This sensor measures in the percent range and could indicate the presence of high concentrations. Due to the amount of hydrogen produced by battery off-gassing, the LEL sensor becomes key for establishing a hot zone, recognizing a potential explosive atmosphere, and initiating engineering controls. Depending on the monitoring instrument used and the sensor technology accompanying it, the LEL sensor may not be able to detect hydrogen.

Infrared (IR) LEL sensors, which will not detect hydrogen, are known to be prevalent in some equipment that EPA regions stock. RAE Systems instruments typically use an LEL sensor with catalytic bead technology that will detect hydrogen. Verify your sensors will detect hydrogen prior to use. Always use LEL sensors in conjunction with 0_2 sensors. Oxygen deficient environments can cause LEL sensor readings to be inaccurate.

Hydrogen Cross-Sensitivity

The standard electrochemical sensor configuration in EPA's MultiRAEs and AreaRAEs is 0_2, PID measuring VOCs, combustible gas indicator for LEL, CO, and hydrogen sulfide (H_2S). Hydrogen (H_2) has cross sensitivities with CO electrochemical sensors and the combined CO/H_2S electrochemical sensor. This is due to hydrogen reacting similarly within the sensor's electrode triggering a response. We know that during battery off-gassing there is production of CO and $H_{2,}$ which means that some of the CO sensor reading will be true CO and some of it will be a cross-sensitive reaction to the H_2. Therefore, it can be difficult to quantitate the concentrations of either CO or H_2. The CO sensor remains a good general indicator of low level off-gassing below the measurement range of an LEL sensor.

Consult with RAE Systems by Honeywell's Technical Note TN-114, *Sensor Specifications and Cross-Sensitivities*, for specific correction factors. Generally, this cross-sensitivity is observed with other electrochemical sensors across a variety of air monitoring devices from other manufacturers.

Some manufacturers, RAE Systems for example, also sell H_2-compensated CO sensors that are much less cross sensitive to hydrogen. EPA typically stocks non-compensated CO sensors but users should make sure to know the sensor in use and understand the cross sensitivities.

Acid Gases

RAE Systems have electrochemical sensors to monitor for hydrogen chloride (HCl), HF, and HCN in ambient air. However, HCl and HF can only be used in AreaRAE Pros and require unique calibration methods. Because the Rae Systems instruments include other sensors that may be damaged by acid gas exposure, it is not recommended to use them for acid gas detection, and generally to avoid placing them in environments where they will experience prolonged exposure to elevated concentrations of acid gas. HCN is available for both the MultiRAEs and AreaRAE Pros.

Honeywell SPM Flex is an instrument that can be used as a handheld or perimeter ambient air monitor. The SPM Flex utilizes a chemcassette tape treated with a chemical reagent that reacts with the target gas as it passes through the instrument. The reaction is interpreted by an optical lens, resulting in a digital reading displayed on the instruments screen. Chemcassette tapes are individually formulated for a specific gas or family of gases that can be monitored for. The SPM Flex can only utilize one chemcassette tape at a time to monitor for a specific gas or family of gases as identified by the chemcassette tape type (i.e. mineral acids, hydrides, HCN, etc.). HF and HCl are within the mineral acids family of gases and HCN is a compound specific chemcassette tape. Multiple SPM Flex units may be necessary for monitoring multiple constituents. Response personnel should be mindful of the detection limits of the SPM Flex as historical data has shown a release of gas from LIBs may maximize or exceed the detection limit, saturating the device.

SPM Flex units have different calibration settings when being used at elevation above 3000 ft and cannot be used above 6000 ft. Consideration should be given to instrument choice and use care with this risk in mind.

Metals

Currently, there is not a handheld instrument that can measure real-time metal concentrations in ambient air recognized on the NEL. The use of particulate monitors (TSI DustTrak II-handheld, TSI DuskTrak DRX-stationary, Met One E-BAM) could be used to measure the particulate matter size (PM_{10} and $PM_{2.5}$) in ambient air. DustTrak air monitors measure particulate ranging in size from 0.1 to 10 microns (which is inclusive of the currently understood particulate sizes, including metals, emitted during a battery fire). Particulate monitors do not distinguish one particulate constituent from another. General action levels for particulate concentrations have been taken from EPA AirNow *WildFire Smoke: A Guide for Public Health Officials* (Revised 2019).

AQI Category	**$PM_{2.5}$ µg/m³ 24-hour average**	**Recommended Actions**
Good (0-50)	0- 12	If smoke event in forecast, implement communication plan
Moderate (51-100)	12.1- 35.4	Issue public service announcements advising public about health effects, symptoms, and ways to reduce exposure.
Unhealthy for Sensitive Groups (101-150)	35.5- 55.4	If smoke event is projected to be prolonged, evaluate and notify about possible sites for cleaner air shelters.
Unhealthy (151-200)	55.5- 150.4	Consider canceling outdoor events based on public health and travel considerations.
Very Unhealthy (201-300)	150.5- 250.4	Cancel active outdoor events. Consider closing schools and non-active outdoor events.
Hazardous (>300)	250.4> 500	Cancel outdoor events. Consider closing schools. Consider indoor air quality for active work. Consider evacuation of at-risk populations.

Table 4. General action levels for particulate concentrations.

On other removal sites where at least some of the particulates are metals particulates, a site-specific action level can be identified for particulates based on known metals concentrations in the soils being disturbed. Because lithium-ion batteries are an emerging threat, the metals emissions are not well characterized. It is not known if metals emissions in a fire are consistent over the time of the burn or if the concentration varies as the fire burns.

Based on data available as of October 2025 the lithium-ion battery task force consulted with an EPA toxicologist to develop a recommended particulate action level, summarized in Table 5 below. The development of those action levels is detailed in the attached memo, Attachment 3.

Battery Type	Public Action Level	Level D to C Upgrade	Level C to B Upgrade
Unknown LIB	**100 μg/m^3**	**100 μg/m^3**	**1600 μg/m^3**
LFP LIB	**100 μg/m^3**	**100 μg/m^3**	**2000 μg/m^3**
NMC LIB	**160 μg/m^3**	**160 μg/m^3**	**1600 μg/m^3**

Table 5: PM-10 Proposed Action Levels

Air Sampling Considerations

Depending on the CSM for a particular site, personnel air sampling may be considered to confirm no exposure to re-aerosolization of particles deposited during the battery fire. Further, knowledge of air quality conditions can be used for critical decision points, such as shelter-in-place and/or evacuation considerations.

Metals

There are a variety of analytical methods for sampling metals in air. While batteries are in thermal runaway, the release of metal particulates to the air is a hazard. See Air Monitoring Table in attachment 2 for analytical methods, pump flow, and total volume needed for a sample for metals.

Fluoride Compounds

NIOSH Method 7906 is a method for sampling the air to quantify HF and fluoride ions. Calcium, iron and aluminum can cause negative interference.

See Air Monitoring Table in Attachment 2 for analytical methods, pump flow, and total volume needed for a sample.

Firefighting Considerations

***Disclaimer* EPA OSCs are not firefighters. The information below, which has been informed by response partners from the fire service, is intended to inform OSCs, to enhance collaboration with fire departments and/or hire private firefighting capabilities if needed. It is important for OSCs to understand firefighting strategic and tactical considerations to work effectively with the firefighting community on lithium-ion battery responses and to manage flare-ups at EPA sites. The information below is also not intended to be direction for firefighters prescribed by EPA.**

Potential response partners during a lithium-ion battery fire

- BESS/ESS Personnel/ Technicians/Potentially Responsible Party
- EPA – 1-800-424-8802
- State Environmental Agency
- Health Department
- Hazmat Teams

- Local/State/Federal Fire Departments/Agencies
- Gas/Electric Company/electricians
- Private Contractors and Outsourced Parties

Firefighter Jargon

"Boom, Left or Right of" – The phrase "right of boom" comes from military and security contexts, especially in counterterrorism, bomb disposal, and emergency response. Think of a timeline drawn left to right. The "boom" is the explosion (or major incident). "Left of boom" = everything before the explosion (prevention, intelligence, detection, deterrence). "Right of boom" = everything after the explosion (response, damage control, medical care, investigation, recovery). So, if someone says, "we need to improve our right-of-boom capabilities," they're talking about being better prepared to respond effectively after an explosion incident occurs.

General Considerations for Responding to lithium-ion Battery Fires

The approach to any lithium-ion battery fire incident should follow normal incident priorities and exposure profiles for fires (life, environment, property, commerce); and for the concern of hazmat, this type of incident should represent a common known material (no different than gasoline, natural gas, or LPG) within the normal capabilities of non-specialized traditionally resourced fire companies/units of personnel and equipment. Fire personnel who initially respond should be minimally certified at the hazmat first responder level of training. While higher trained hazmat personnel and specialized units and equipment may be useful or needed for some incident responses involving lithium-ion batteries, they should not be deemed essential to initiate routine emergent priorities of life safety, incident stabilization or property-environmental conservation efforts. The fire resulting from ignition of the gases from the lithium-ion battery cells cannot be extinguished by any traditional firefighting methods such as application of water, CO2, foam blanket, sand or other covering materials etc. There is currently no known field deployable technology or method to extinguish a lithium-ion battery fire undergoing thermal runaway. There is no scientific evidence to prove that there is any proprietary extinguishing agent more overly effective than water and a well-trained firefighter on a traditionally resourced fire company.

For the purposes of lithium-ion battery fire response by non-specialized traditionally resourced fire companies of personnel and equipment the following strategies are identified:

- **"offensive":** This strategy suggests physically invasive hands on direct or forcible contact with or into energized battery structural components, compartments, or spaces and should be considered very high risk and not recommended.
- **"defensive":** This strategy suggests non physically invasive hands on direct or forcible contact with or into energized battery structural components, compartments, or spaces and should be considered lower risk and the primary strategy considered. Tactical considerations under the defensive strategy include but are not limited to: evaluation, prevention and mitigation of explosion risk; search and rescue; fire, smoke, and gas control; exposure protection; non-invasive handling, lifting, or movement/relocation of battery material/units, etc.
- **"non-intervention":** This strategy suggests firefighters do not engage the battery fire or situation directly at all. Goal is to preserve firefighter safety: when the risk is extreme;

hazard exposure is unnecessary; the component, vehicle, or structure is already lost; or conditions are untenable for life. Often accompanied by monitoring, public warnings, or letting the fire burn or incident hazard resolve itself in controlled circumstances. This strategy should be considered the lowest risk and utilized when the defensive strategy cannot be implemented safely or defensive objectives have been met.

Life Safety

Is priority – operations should follow normal fire response firefighting procedures:

- Don appropriate PPE, stay out of smoke when possible, and approach/enter from upwind or into well-ventilated areas
- Assess if an explosion risk exists with the material, package, or space/enclosure and if the situation is “Left of Boom” or “Right of Boom”; consider prevention and mitigation for safety
- Determine if a life safety profile exists and achieve normal fire service operational benchmarks.

Let It Burn

- Consider defensive or non-intervention strategy and let the lithium-ion battery burn complete if exposure profile(s) permit:
  - Protect exposures to life, environment, property, and commerce as safety permits
  - With the exception of a life safety priority, personnel should not approach, manipulate, handle, or move, packages nor enter or forcibly enter intermodal containers, enclosed truck trailers or spaces, residential garages, etc. that have a report or evidence of lithium-ion battery thermal runaway or off-gassing, until explosion risk has been evaluated and determined “Left of Boom” or “Right of Boom”; consider prevention and mitigation for safety
  - May take multiple operational periods and facilitate long fire watch timeframes
  - Monitoring of temperature and gas release should be performed at the cell level when practical to do so. Lack of elevated temperature is not an indicator that damaged battery cells are stable, but elevated temperatures can indicate an immediate risk of further thermal runaway.
  - Provide awareness to surrounding community and other responders based upon established levels of concern and protective action criteria

Moving Batteries

- Acting within the defensive strategy, move the involved lithium-ion battery material presentation/package/container to a safer and lowest exposure risk location as possible:
  - Assess if an explosion risk exists with the material, package, or space/enclosure and if the situation is “Left of Boom” or “Right of Boom”; consider prevention and mitigation for safety.
  - With the exception of life safety priority, personnel should not approach or move lithium-ion battery presentations that have undergone thermal runaway or off-gassing until explosion risk has been evaluated; consider prevention and mitigation for safety.

- If explosion risk has been evaluated/addressed via prevention and mitigation, is no longer a critical factor, or the material package/container is "Right of Boom", and safety is within acceptable limits; consider moving the material to a safer and lowest exposure risk location. Relocation may be to any location determined best to protect firefighters and civilians for life safety; or appropriate for exposure protection of environment, property, and commerce.

Water Application Situations

- Any water application tactics will require a large and consistent supply.
- Water application ONLY if exposure protection is required.
- Water application directly on exposed battery cells is most effective at cooling and preventing propagation to adjacent battery cells. Battery casings or other obstructions may prevent adequate cooling.
- Extinguish and protect other exposures such as infrastructural neighboring structures, superstructures, and vegetation.
- Prevent fire propagation by cooling adjacent battery cells that have not experienced thermal runaway or been destroyed by fire, with water.
- Defensive water curtains and unstaffed lines preferred for protection, use 30-degree fog for water curtains.
- Apply water from a distance and upwind if possible.
- Collect contact water, which may present among other contaminants, a low concern for pH.
- Be aware of electrical arcing consequences when using water.
- When applying water, there will be a potential increase in steam and smoke. Keep out of both.
- **Reignition** can occur at any time for battery cells that are damaged (including water).
- Never cut, crush, puncture, or open a battery pack/BESS/ESS/EV high voltage battery to extinguish it (without proper precautions described later in this document).
- Use a thermal imager to check for continued heating. However, be aware of shielding effects that may not reveal batteries at elevated temperatures.

Specific Considerations for Various Types of Lithium-Ion Battery Fires

<u>BESS/ESS Firefighting</u>

- Assess if an explosion risk exists within the BESS/ESS container, space/enclosure and if the situation is "Left of Boom" or "Right of Boom"; consider prevention and mitigation for safety
- DO NOT ENTER A BESS
- Review commercial facility pre-plans and determine if a panel breaker can be safely reached to shut down system
- Contact BESS/ESS operations personnel for remote shutdown
- Allow system safety devices to operate as designed
- Monitor alarm panel and manually activate any safety devices if appropriate
- BESS/ESS in transit (usually intermodal-sized): Consider use of heavy equipment and heavy wreckers to assist with moves and to limit personnel contact/exposure.

Electric Vehicle Firefighting

- Refer to the Emergency Response Guide (ERG) for the specific make and model of the vehicle for guidance on securing electrical power to the lithium-ion battery, rescue and recommended firefighting tactics. [NHTSA ERG Website]
- **If EV is located in an underground garage, residential garage or area of limited or confined space, understand the toxic atmosphere being created, potential for an explosive environment, and potential structural impacts due to fire.**
- Avoid unintentional contact with orange cables due to high voltage electrocution hazard
- Rescue/ Check for victims, approach from upwind location
- Chock wheels to prevent vehicle roll.
- After life safety priorities have been addressed and confirming that the EV batteries are involved, if possible, allow the batteries to burn, protect exposures, and evacuate the area 330-feet in all directions per Emergency Response Guide (ERG)
- If fire attack is necessary, fight the fire like a normal vehicle fire with water. If the battery cells are exposed to battery case damage, direct a hose stream directly on the exposure.
- Foams are not more overly effective than water and could encapsulate toxic and explosive vapors from lithium-ion batteries experiencing thermal runaway. However, the use of foam may be effective on the class A fire.
- Consider tilting the vehicle to gain access to the battery pack for cooling operations (some batteries are located in other areas of the vehicle).
- Consider directing water into side vents of battery pack if present/accessible
- Tow Company notes
    - Make sure EV towed on a flatbed. Do not allow the wheels to move.
        - Regenerative braking sends power to batteries. This may cause a fire with rotational force on wheels
    - Store vehicle away from all exposures
    - Keep the impound lot secured and under surveillance
- **For a more in-depth discussion on EV Lithium-ion battery firefighting please refer to:** https://www.usfa.fema.gov/downloads/pdf/publications/electric-vehicle-fire-rescue-response-operations.pdf

Micro-Mobility Device Firefighting

Devices like e-bicycles, e-scooters, hoverboards etc.

- **If outdoors**
    - Establish a perimeter
    - Allow micro mobility to burn to completion
    - Prevent propagation to other devices/battery packs by moving unburned devices away from the area
    - If surrounding uncompromised devices cannot be moved, consider cooling options or thermal blankets to protect
- **If indoors**
    - Attack residential fire like normal
    - **During fire attack, uninvolved, damaged micro mobility device may ignite behind you.**

- Move unburned devices away from the scene, preferably outdoors and away from combustible materials.
- Move all lithium-ion battery cells and devices to a safe location, away from firefighting operations, PRIOR to overhaul
- Use shovel with wooden handle to collect batteries. DO NOT HANDLE BATTERIES WITH BARE HANDS
- Remove the batteries from the interior space, outside location is preferred
- Consider bathroom, bathtub, sink, or metal bucket and fill with water if movement to an outdoor environment is not an option
- Wear SCBA during overhaul
- Advise investigators of possible lithium-ion battery presence
- Request Hazmat to assist with battery stabilization, mitigation, overpacking, and disposal
- Provide protection line during overpacking procedures

Battery Recycler/Accumulator/Warehouse Firefighting

- Recyclers, Accumulators and Warehouses will present similarly during a fire. Responders should review the general firefighting tactics and approach the fire similar to an industrial facility plastics fire. It will be difficult to extinguish and on-going fire over a longer period of time.

EPA Removal Operations

Lithium-ion battery sites, like all removal sites, can range in size and scope. The varying sizes and scopes will affect the cleanup approach. Tactics and considerations described further in this section can be used in different combinations to complete site cleanups safely and efficiently, while minimizing overall costs. A Lithium-Ion Battery EPA Site Management Decision Tree that summarizes various battery removal phases and options is attached for reference, see Attachment 4. Removal operations tactics for lithium-ion batteries should be considered to be modular and only apply when site conditions warrant. The modules, further discussed in the subsequent sections, are as follows:

Site Set-up Considerations and Stabilization – many of these best management practices (BMPs) would apply to all sites

Battery Pack Disassembly – battery pack disassembly is an optional, middle operation conducted when site conditions warrant.

De-energizing and Brining - these recommendations apply to energized batteries that have been damaged, rendering them as DDR. De-energizing is not necessary if the batteries are not DDR.

Battery Deconstruction – battery deconstruction is a step following de-energizing process that involves destruction of a battery such that it no longer meets the EPA or DOT definition.

Transport and Disposal – transportation and disposal will occur on nearly all lithium-ion battery sites.

Site Set-up Considerations and Stabilization

The following discussion includes features and BMPs of lithium-ion battery sites. BMPs and set-up features will be site-specific and may or may not apply to each site.

At a lithium-ion battery site one of the first determinations that should be made is whether the batteries at the site are damaged/DDR batteries. The DOT guidance[8] for determining if a battery is DDR or not offers both visual indicators and relies on knowledge of use/misuse of the battery. It is unlikely that an OSC would encounter a known, undamaged battery situation, but if it does present, consult the DOT guidance. In most emergency response and removal cases, due to the lack of background knowledge at a site, it is impossible to have knowledge of previous physical or electrical damage, or exposure to water or heat, of the batteries involved in the site. For this reason, the default determination should be that all batteries at a removal site are DDR batteries.

DDR lithium-ion batteries should be stored a safe distance (minimum of 75-feet according to ERG Guide 147 evacuation requirements for immediate precautionary measures) from other hazardous materials, and/or the general public. If the lithium-ion battery material becomes involved in fire and gases and smoke are emitted, the safe distance should be increased (up to a minimum of 330-feet in all directions according to ERG Guide 173 or 174 evacuation requirements for immediate precautionary measures). Consideration should be given to prevent “macro propagation” (propagation from battery pack/module to neighboring battery packs/modules) during a cascading thermal runaway. Consideration should be given to segregation/compartmentalization of batteries. Batteries should be grouped in such a way as to limit the size of any fire/smoke plume resulting from unexpected thermal runaway.

It is suggested that the appropriate fire department, HazMat Team, and/or state environmental agency tour the site to gain awareness of the operations in case of emergency and provide input on the management of damaged lithium-ion batteries, if applicable.

Other site set-up considerations are:

- Safe ingress/egress for workers and emergency services should be implemented so that in the event an of an emergency, workers can quickly evacuate and firefighting resources will have sufficient space needed to respond.
- Distance from residents, schools, daycares, houses of worship, cultural sensitivities, businesses, and vegetation. Heavily populated areas should also be taken into account, such as a busy road where traffic control or a detour may be needed during operations to maintain public safety.
- Work should be conducted in a well-ventilated area, preferably outdoors.
- Having a windsock and meteorological station on-site will provide an understanding of hyper-local weather conditions.
- Allow ample space to separate batteries from each other to prevent macro propagation during an emergency. Also consider space for workers and equipment as site clean-up progresses.

[8] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-03/DDR-brochure.pdf

Storage

Containerized or caged storage solutions should be considered to secure DDR batteries that will not immediately be de-energized to reduce the threat of fires when site is not occupied. Open top roll-off boxes with weighted expanded metal sheeting are one example of a storage solution for reducing risks at a DDR battery site. Steel drums with open bungs and loosed ring clamp/bolt-fastener is another example of a storage solution for smaller volumes of batteries/cells. Submersion of damaged batteries in water (with a measure to prevent projectile activity) is another storage option to be considered as continuous contact with water will assist in preventing propagation.

Precipitation management should be considered to prevent any unwanted battery contact with water . Contact with water may cause a battery to short circuit and enter thermal runaway. Batteries that are exposed to water are considered DDR batteries and short exposures to water may damage the batteries without allowing for the discharge of energy. Intentional submersion during a planned de-energizing process or as a site stabilization measure is an acceptable practice. Management of batteries may involve the need to label devices, containers, modules, or multi-cell packs. The use of Tyvek house wrap may be necessary, especially during wildfire response work, to allow containment of loose batteries, an outer packaging of contaminated battery modules/packs, and control of any sharp edges. The wrap also allows for hand marking the package or placing identifiers (i.e. bar codes, RFID tags, parcel number) on the outside package for easier management.

Figure 10. Pool with batteries? (LEFT photo) BESS/ESS power wall units collected from the Maui Wildfires are stored in tyvek wrapping to minimize spread of toxic ash . Expanded metal mesh is placed on top and weighted with sandbags to prevent energetic cylindrical cell launching, which could cause a brush fire (RIGHT photo).

Battery Pack Disassembly

Battery pack disassembly of DDR batteries may not be necessary when the battery pack is small enough to ship in appropriate packaging and cells can be de-energized without pack removal.

Disassembling battery packs or BESS/ESS batteries may be necessary to adequately evaluate the condition of the individual cells contained inside the pack or to prepare for the de-energizing process. Some battery casings are effective at preventing moisture infiltration and thus should be removed in preparation for the de-energizing process. A disassembly operation (to remove battery casings) will need to be carefully planned to ensure the safety of workers. The size of the battery packs will dictate disassembly operations. These operations may include an excavator, a disassembly/deconstruction pad, an emergency brine bath, a scrap metal bin, a fire suppression system such as a tank and pressurized hose line and enough personnel to manage the operation safely. Appropriate level of protection (discussed in the Health and Safety section above) should also be implemented depending on the operation and status of the batteries. Electrical arcing and/or thermal runaway is LIKELY to be encountered during disassembly operations.

Some examples of a need for disassembly include, but are not limited to:

- Energized damaged batteries need to be de-energized, but the battery pack appears/is waterproof and prevents de-energizing while intact.
- To conduct a visual evaluation of the condition of the battery cells inside the pack to determine the next step forward.
- When the battery cells are not energized but need to be deconstructed for shipment purposes.
- When an OSC determines battery cells need to proceed to the battery deconstruction process.

Figure 11. An Arieal view of the lithium-ion battery disassembly area at the 2023 Maui Wildfire response.

Figure 12. An excavator with thumb peels open a BESS/ESS system revealing the cylindrical cells inside, water is applied to suppress dust at the 2023 Maui Wildfire Response.

De-energizing and Brining

De-energizing is not required for batteries that are not DDR. De-energizing is not a regulatorily required step for DDR batteries prior to shipment and disposal, and does not change the DDR shipping requirements. However, EPA recommends de-energizing DDR batteries prior to shipment as a BMP due to the known instability of DDR batteries discussed in the *Lithium- Ion Battery Failures and Fires* section of this document. This instability could lead to thermal runaway reactions on site, in transit or even at the disposal facility. In addition, OSCs typically handle larger volumes of batteries at emergency responses and removal sites, which increases the opportunities for failures to occur. Multiple incidents both at EPA and non-EPA sites and during transit of DDR batteries support this practice.

Placing DDR batteries in a brine solution is a method to reduce the voltage of batteries. which reduces the risk of thermal runaway. OSCs may consider doing a small-scale treatability study to determine the efficacy of de-energizing in brine for their site-specific situation prior to full scale operations at large battery sites.

Another method of reducing battery voltage is by using a commercially available battery discharge unit. However, their practical use during emergency responses and removal actions may be limited or inefficient when addressing large quantities of lithium-ion batteries or when those batteries are damaged to the extent that the internal wiring of the battery pack may be non-functional.

Appropriate battery discharge method selection should consider the size of the batteries and the amount of damage the batteries have sustained (i.e. do the battery packs appear to have all the internal wiring and BMS intact).De-energizing batteries can reduce the charge held in cells from approximately 4 volts to 0.5 volts or less. By reducing the charge, the risk of fire and arcing is greatly mitigated on site, in transit and at a disposal facility. Achieving a reduced voltage below 1V is considered successful de-energizing.

Brining discussion:

De-energizing by brining involves submersion of batteries into a salt (brine) solution. If the batteries are in a device (e.g. computer, vape pen, etc), the batteries should be removed from the device prior to being submerged in the brine solution. Once submerged the batteries undergo an electrolysis reaction that reduces the charge. This reaction is likely to generate hydrogen gas. Consideration should be given to the brining container to manage the potential to accumulate an explosive atmosphere. A typical brine solution is 5-10% Sodium Chloride (NaCl), however research is ongoing to determine the optimal Brine. Sodium Bicarbonate (NaHCO3) has been shown to be much less effective in on-going studies by EPA. Other solutions, 5% NaOH and 5% $FeSO_4$ for example have shown to be effective at discharging energy rapidly with minimal corrosion of the battery cells. This research is on-going and may be shared further in the future. For the most up to date information, the Lithium-Ion Battery Task Force - Research Subgroup may be contacted. Batteries may need to remain in the brine solution from 4 hours to several weeks depending on the battery type and condition and brine solution chosen. A multimeter can be used to periodically monitor voltage of batteries as they are de-energized and to determine when the batteries are fully discharged and ready for packaging. Depending on the brine solution chosen, corrosion of the batteries may make accurate DC voltage measurements difficult to obtain.

Brine solutions typically do not need to be changed out through multiple rounds of batteries being discharged. The best way to monitor the effectiveness of the brine solution is based on the results of the batteries discharging. Research is ongoing regarding discharging efficiencies and data may be uncovered to indicate that conductivity could be used to monitor the effectiveness of the brine solution, but a minimum conductivity value has not been identified yet. Once de-energizing operations are complete or if a brine solution is determined to be spent, the brine solution should be characterized for disposal. Experience at previous EPA sites has shown the brine solution to be characterized as non-hazardous via the Toxicity characteristic leaching procedure (TCLP) analytical method, however it is still recommended to characterize via TCLP at future sites if possible. One study has shown metals, that are not typically part of the TCLP analysis may be present in a brine solution at concentrations that could impact environmentally sensitive areas and may exceed state water quality standards.

Some battery types do not lend themselves to discharge through brining. Batteries with small tabs, like pouch cells, or wires as the main connection electrodes, like some cylindrical cells that are used in small consumer products such as vape pens, may not discharge well in a brine solution. The corrosion caused by a NaCl brine solution rapidly damages the small electrodes and does not allow the electrolysis reaction to occur. It is possible that less corrosive brines will be effective on these battery types but they have not yet been tested.

Battery Deconstruction aka Creating “Not Batteries”

Deconstruction is the process of taking batteries and physically modifying them to the point that they no longer meet the EPA and DOT definitions of a battery, thereby changing the regulatory standards that apply to the material which is now “not batteries”.

Due to DOT regulations for shipping DDR batteries, there may be instances where site safety, safety during transport, and material/cost efficiency will be improved by deconstructing batteries into “not batteries”. Battery deconstruction will not always be a necessary step at lithium-ion battery responses and sites but is an option subject to the discretion of the OSC.

The deconstruction process is considered treatment under RCRA. Therefore, OSCs will need to consider this regulation as a CERCLA ARAR at an EPA lithium-ion battery site. Deconstruction of batteries without EPA OSC oversight, or a treatment permit, is not allowed under RCRA.

Deconstruction will likely be required when incidents occur in an area where shipment on a vessel is necessary to transport batteries to the final disposal facility. Recently, shipping companies have been restricting the shipment of DDR batteries on their vessels due to the unpredictable nature of them. Deconstruction may also be appropriate when the scale of the incident is so large that meeting the DDR shipping restrictions would be too costly or time inefficient.

DOT defines a lithium-ion battery or cell in 49 CFR 171.8 as: a rechargeable electrochemical cell or battery in which the positive and negative electrodes are both lithium compounds constructed with no metallic lithium in either electrode. A lithium-ion polymer cell or battery that uses lithium-ion chemistries, as described herein, is regulated as a lithium-ion cell or battery.

EPA defines a battery in 40 CFR 273.9 as: a device consisting of one or more electrically connected electrochemical cells which is designed to receive, store, and deliver electric energy. An electrochemical cell is a system consisting of an anode, cathode, and an electrolyte, plus such connections (electrical and mechanical) as may be needed to allow the cell to deliver or receive electrical energy. The term battery also includes an intact, unbroken battery from which the electrolyte has been removed.

To deconstruct batteries effectively, so that they no longer meet the two definitions above, heavy equipment or industrial grinders/shredders can be used. Excavators with a thumb can be used to deconstruct pouch and prismatic cells by puncturing them with the bucket teeth. A smooth drum roller can be used to deconstruct cylindrical cells by crushing. A battery grinder/shredder appropriately sized for the battery cell type may also be used if available. **<u>Batteries should not be deconstructed unless they have been de-energized first</u>**. A deconstruction area should be built to prevent spread of contamination and to contain any cells that may not have been completely de-energized prior to deconstruction.

At the 2023 Maui and 2025 Southern California Wildfires the following deconstruction area was set up. A 8-foot x 20-foot 1-inch thick steel plate was placed in an area devoid of nearby vegetation. Ecology blocks were placed on 3 sides of the steel plate and lined with 2 layers of Visqueen plastic with tarp as the top layer for added rip protection. A vibratory roller was positioned at the entrance to the area. Steel drums were staged nearby to receive crushed “not batteries.” A pressurized water hose was staged nearby to address any fire emergencies. Personnel used shovels to spread batteries in a thin layer on the steel plate and to recover the “not battery” material. Personnel also inspected the “not battery” material to ensure complete destruction. Care should be taken to not overload the crush pad with batteries as some may get lost and not be fully deconstructed. Testing may be necessary to determine the optimal loading rates. Several passes with the roller may be necessary to achieve complete deconstruction of all batteries. Water can be captured by using straw waddle under the Visqueen to create a berm at the open end of the processing pad.

At the 2025 Southern California Wildfires a shredding operation was also implemented. The shredding operation uses an industrial size shredder that is loaded from the top through a hopper. The material is ground into fine pieces before dropping into a bucket. In Southern California, drums of deenergized batteries were loaded from the top, out of a drum, while the final material would fall into a skid steer bucket under the shredder so the material could be loaded for transport. Additional options could include using a conveyor belt system to automate and regulate the loading process.

Deconstruction operations, especially if material is processed too finely, may create significant amounts of dust. Metal dusts can be considered a combustible dust at low µm levels. As particulate sizes get smaller (100 microns or smaller) explosion risk increases. Small particulate sizes are also more hazardous when inhaled and are more difficult to contain. Engineering controls should be established to manage fugitive dust and constantly reassessed for risk during relevant operations.

Large-scale deconstruction operations have not been completed outside of EPA wildfire responses though some recent sites may attempt this operation.

Figure 13. An example layout of a deconstruction area by crushing.

Figure 14. A still photo of deconstruction taking place.

Figure 15. Final Product of deconstruction by crushing.

Figure 16. Final product from battery shredder/grinder.

Figure 17. Example of shredding operation.

Shipping

Shipping Damaged, Defective, or Recalled (DDR) Lithium-Ion Batteries

The shipment of DDR batteries is regulated by DOT under 49 CFR 173.185(f). DDR batteries are defined as:

Lithium cells or batteries that have been damaged or identified by the manufacturer as being defective for safety reasons, that have the potential of producing a dangerous evolution of heat, fire, or short circuit (e.g., those being returned to the manufacturer for safety reasons) may only be transported by highway, rail, or vessel. These cells or batteries are strictly **forbidden for transportation by aircraft**.

Furthermore, they must be packaged according to the provisions of 49 CFR § 173.185(f), which include:

- Placing the cell or battery in individual, non-metallic inner packaging that completely encloses the cell or battery
- Surrounding the inner packaging with cushioning material that is non-combustible, electrically non-conductive, and absorbent
- Packaging the inner packaging in Packing Group I performance level packaging. Note that only one inner packaging may be placed in an outer packaging (i.e., only one cell or battery per package)
- Marking the outer package with an indication that the package contains a damaged battery, in addition to any other required marks and labels on the package https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2023-07/Lithium%20Battery%20Guide.pdf

There are four ways to ship DDR lithium-ion batteries. They are:

- Fully regulated as described above and further outlined in 49 CFR § 173.185(f)
- Special Permit
- Emergency Waiver
- Outside of commerce

The regulations for shipping DDR batteries make the shipment of a large amount of DDR batteries time consuming, resource intensive, and expensive. Shipping DDR batteries using methods other than fully regulated may be selected to ease the regulatory burden while still safely and legally moving/shipping batteries. These mechanisms are discussed below.

Emergency Waiver

Emergency Waiver Order – This is a waiver that is typically issued from DOT to EPA when doing Stafford Act Emergency Support Function #10 (ESF-10) work under the National Response Framework. It enables workers to collect hazardous materials and transport them to a central staging area without complying with DOT Hazardous Materials Regulations (HMR). This waiver is issued to facilitate a rapid response and recovery in a disaster area and the specific allowances will be described in the Waiver. An example is provided from the 2023 Maui Wildfire response as an attachment to this document, see Attachment 5. This Order does not allow for special exemption from the HMR for shipping from staging to disposal facility.

USDOT Special Permit

- A number of special permits already exist with companies for shipping DDR batteries outside of the DOT DDR regulations discussed above (Call2Recycle, Labelmaster, Kulr, etc). Existing special permits can be searched here. Typically, the special permit has been issued to a company that manufactures the shipping container. In that case, the special permit will describe the appropriate use of the packaging and any limitations on the weight or watt-hours of the batteries that can be shipped.

- Some EPA Emergency and Rapid Response Services (ERRS) contractor companies may already have a special permit that they have applied for on previous sites that may be usable on other sites.
- Some special permits require the user to be "made party to" a special permit before they can use it. Other special permits may allow the user to use the special permit as long as they follow all of the requirements described in the special permit.
- If a special permit does not exist that meets the needs of the site, EPA can apply for a special permit that is specific to the site. DOT will review the permit application and respond with questions or approval.
  - On a CERCLA Emergency Response the timeline between application and approval may be as short as a week or two.
  - During a CERCLA time-critical removal, especially a responsible party led removal, the application process may take closer to 90 days as the permit has to be posted for public comment.
  - Site-specific special permits are not able to be used from site to site, and each site would need to apply for the permit. The permit development process typically requires an attorney to help draft the document and the OSC should be in close coordination with a regional DOT representative to facilitate the approval process.
  - If there is not a regional DOT representative involved with the site, OSCs can reach out through the EPA RRT or directly to Eddie Murphy at DOT/PHMSA (eddie.murphy@dot.gov).

Shipping outside of commerce

DOT regulations define when the hazardous materials regulations apply, but also discuss some functions under which they do not apply. The function that is relevant for OSCs is as follows:

- 49 CFR 171.1(d) - Functions not subject to the requirements of the HMR
  - (5) Transportation of a hazardous material in a motor vehicle, aircraft, or vessel operated by a Federal, state, or local government employee solely for noncommercial Federal, state, or local government purposes.
- EPA has not used this option in practice although it was discussed as an option at the 2025 Southern California Wildfires response. The outcome of that discussion was:
  - If a government employee drives a government vehicle they are generally considered not "in commerce"
  - If a government contractor is driving, or potentially if the vehicle is not a wholly government owned vehicle, the transportation would be considered "in commerce".
  - Additional information may be needed to successfully implement this shipping option.

Shipping Deconstructed "not batteries"

Shipping of "not batteries" should follow a similar process to shipping any other waste. The waste should be characterized for shipment according to DOT Hazard Class.

Experience at EPA wildfire responses has shown that “not batteries” can still produce hydrogen at low levels. An evaluation at the 2023 Maui wildfires assessed the material for hazard class 4.3: Dangerous when wet due to the “not battery” material being damp as a result of dust control. The evaluation that was used was the –United Nations (UN) N.5 Test for Water Reactive Materials that emit flammable or toxic gas. It was determined that the parameters of this test were not met and therefore a 4.3 placard was not necessary.

Future sites may want to consider, and characterize, this generation of hydrogen gas as it is not fully understood at this time. Hydrogen is suspected to be released from lithium-ion batteries under several conditions: during charging and discharging, through electrolyte decomposition, and when moisture contacts the anode. Field tests have shown that even after fully fire-consumed lithium-ion battery material, as well as non-fire-damaged material that was destroyed and dried, hydrogen can persist and cannot be completely eliminated. Modified performance packaging was used to allow hydrogen to vent while in transit. Specifically, Drums with PVC snorkels and loosed ring clamps/fasteners, cubic yard boxes with plastic cover and gas filter, and lined roll-off boxes with well ventilating tops and liners secured to address fugitive dust concerns.

Disposal

Like all removal sites, final disposal of waste is a key factor in the timeline of the site. Due to the emerging nature of lithium-ion battery clean-ups, disposal is more challenging than normal. Many of the hazardous waste disposal facilities may have special restrictions on accepting batteries or may have never done it before. Recycling facilities may have restrictions on the type of batteries, the method of field processing, and the shipping containers they will accept.

Recycling

- The currently preferred disposal method for batteries is to send them for recycling. However, recycling of battery waste often costs considerably more than other disposal options and recycling facilities may have restrictions on their acceptance of the waste that may impact field operations.
- For recycling of batteries to be a viable option, you will likely need to answer “yes” to at least the following questions:
  - Can the batteries be adequately segregated by chemistry? Does the battery appear fully or mostly intact? (i.e. not burned beyond recognition with metal electrodes poking out of the battery casing)?
  - Are the batteries free of contamination from other waste (or easily decontaminated)?
- Coordination with recycling facilities may highlight other questions that need to be answered before they can accept the material.
- Batteries that have been deconstructed into “not batteries” may be able to be recycled. Close coordination with a recycling facility will be needed and costs to recycle “not batteries” may be higher than disposal.
- OSCs should begin the request for proposals (RFP) process for recycling early or as soon as approximate volumes of each battery chemistry is known. Once a recycling facility has been selected, coordinate directly with that facility to understand the necessary segregation steps if multiple battery chemistries exist at the site (necessary segregation will vary depending on

the recycling facility). In addition, engage the selected facility on limitations on field processing (e.g. selection of the brine solution or possible deconstruction options).

- OSCs should ensure that a request for certificates of recycling is included in the RFP document to preclude waste being shipped to a recycler but not being recycled in a timely manner.

Landfill Disposal

- There may be times where segregation of battery chemistries is impossible and a recycling facility will not accept the waste. Most disposal facilities will not accept intact batteries, whether they have been de-energized or not. However, there are exceptions, and the batteries will likely need to be disposed of at a hazardous waste landfill. For example, in Region 4 the hazardous waste facility in Emelle, AL will accept batteries that have been macro encapsulated. To ship the batteries macro encapsulated requires a special permit from DOT.
- Batteries that have been deconstructed into "not batteries" can be disposed of at a hazardous or non-hazardous landfill (depending on hazardous waste characterization results). The disposal facility may request testing beyond normal waste characterization prior to accepting the waste (e.g. the disposal facility for Southern California Wildfires conducted a site leachate reactivity test prior to accepting the waste)
- The Off-Site rule is applicable to DDR batteries and deconstructed, not-batteries for disposal and/or recycling. It is applicable for the recycling cases because the recycling process includes the process of "reclaiming" "spent material." 40 CFR 261.2(c).

Community Involvement and Media Relations

Because lithium-ion batteries are an emerging threat and there have not been many sites involving them, there are not many examples of fact sheets available to use as templates. Generally, an OSC can use similar descriptions as an industrial/plastics fire when discussing LIB sites with the media or public.

For example:

- "No amount of smoke is good for you. Stay out of the smoke."
- "If you are outside and you smell smoke, move indoors."
- "Attempt to stay upwind of the smoke. Standing under the smoke plume may still result in exposure."

Local fire departments will typically follow ERG for buffer, evacuation, and shelter in place decisions. Air monitoring can be conducted for ongoing/real-time assessment of hazards to the public to inform evacuation or shelter in place decisions. Most of the air monitoring instruments are not chemical specific and air sampling results may take several days to come back from a lab.

Two wildfire response-specific fact sheets are attached as examples but may not be applicable depending on the type of lithium-ion battery site you are working on, see Attachment 6.

Helpful Links and Additional Resources

- response.epa.gov/R4LithiumIonBatteryOutreach
- https://www.phmsa.dot.gov/lithiumbatteries
- https://www.epa.gov/recycle/used-lithium-ion-batteries
- https://www.usfa.fema.gov/downloads/pdf/publications/electric-vehicle-fire-rescue-response-operations.pdf

Attachment 1: Wildfire Response Job Hazard Analysis

2023 Maui Wildfires

U.S. Environmental Protection Agency, Region 9

Emergency Response Section

JOB HAZARD ANALYSIS #7: Power Walls / Lithium Batteries

JHA		
JHA #: 007	**Name of Task:** Power Walls / Lithium Batteries	**Location:** 2023 Maui Wildfires
Task Description: Managing power walls and lithium batteries		**Task Duration:** Daily

Physical Hazards							
Hazard	**Source**	**Control Measures**	**Exposure Potential**				
			H	**M**	**L**	**Unk**	**N/A**
Stored Energy (Electricity) / Fire and Explosion	1. Electric/Power supply lines 2. Power walls (Tesla and other brands or homemade versions) 3. Lithium batteries	1. Ensure all electrical power has been shut off/disconnected from the power wall: a. Licensed/certified electrician to verify power status. 2. Ensure no backfeeding to the power wall (i.e., solar panels or any other device that could potentially be feeding energy to or drawing energy from power wall). 3. Isolate the energy storage system (i.e., power wall) after verification that all energy to the system has been shut off or disconnected. 4. Prepare power wall for transportation: • Partially burned, Partially insulted, intact, but suspected insulted power walls: - Use SCBA for respiratory protection along with Flame-Resistant (FR) clothing. Completely charred or Completely charred and bulged power walls: – Use organic vapor/acid gas filters along with Flame-Resistant (FR) clothing. • Wrap powerwall in fireblankets (e.g., Bridgehill). • If any reaction occurs during handling, immediately drop the power wall and vacate the area to a safey place. • Place in transport vehicle and secure in place using straps or other equipment. • Ensure fire extinguisher and pressurized water sprayers are available during transport. 5. Transport power wall to secure staging area for further processing: • Coordinate with local fire department prior to transport. • If reaction occurs during transport, park vehicle immediately in a location with minimal fire risk (to the extent possible); call fire department (dial 911) immediately for assistance.					

		• Maintain fire readiness (fire extinguishers and pressurized water sparyers to cool container during transport in the event of reaction/fire situation).					
Chemical Exposure	By-product of fires involving lithium batteries	See Chemical Hazards section below					

Biological Hazards							
Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
COVID-19 Exposure	Unknown	Follow COVID-19 protocols					

Chemical & Radiological Hazards							
Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
Hydrogen Fluoride	By-product of fires involving lithium batteries	1. Partially burned, Partially insulted, intact, but suspected insulted power walls: - SCBA required for respiratory protection while handling power walls. – Completely charred or Completely charred and bulged power walls: organic gas/acid gas filters required for respiratory protection. 2. FR clothing required for potential fires. 3. In the event a reaction occurs during handling, immediately drop the power wall and vacate the area to safety. 4. Notify the fire department (dial 911).					

PPE				
Level A	Level B Partially burned, Partially insulted, intact, but suspected insulted power walls -(SCBA for respiratory protection combined with FR clothing)	Level C Completely charred or Completely charred and bulged power walls: (Organic gas/acid gas filters required for respiratory protection combined with FR clothing.)	Level D Mod	Level D

Other
None

2023 Maui Wildfires

U.S. Environmental Protection Agency, Region 9

Emergency Response Section

JOB HAZARD ANALYSIS #8: EV Battery Removal and Transport

JHA		
JHA #: 008	**Name of Task:** EV Batteries	**Location:** 2023 Maui Wildfires
Task Description: Managing EV batteries		**Task Duration:** Daily

Physical Hazards – EV Battery Removal							
Hazard	**Source**	**Control Measures**	**Exposure Potential**				
			H	**M**	**L**	**Unk**	**N/A**
Overhead Hazards	Burned out structure debris	Situational awareness. Hard hat					
Trip Hazards	Burned out structure debris	Situational awareness, test footing prior to stepping on unknown area					
Electrocution	Energized power lines. Charged EV battery.	Assume all electric lines and appliances are energized. Evaluate EV battery prior to handling.					
Traffic	Vehicles traveling in work areas	Situational Awareness. High visibility vests					
Fall Hazard	Open septic field or tree root burnout	Situational Awareness. Mark deep fall hazards with caution tape and orange spray paint					
Falling Trees	Burned out trees	Situational Awareness. Observe Arborist markings trees. Avoid hazardous tree fall zones. Cease work with wind speeds of 20mph.					
Puncture Risk	Sharp objects in debris	Situational Awareness. Leather work gloves.					
Heavy Equipment	Crush zones during vehicle rotation	Situational Awareness. Spotter usage.					
Pinch Points	Cutting metal/Jaws of life	Situational Awareness. Use leather work gloves.					
Heat Stress	Working in protective suits	Follow Work/Rest schedules. Stay Hydrated					
Lifting Injuries	Lift heavy batteries and equipment	Use propped lifting techniques. Use two man lift for heavy objects Do not carry heavy objects far distances					

Physical Hazards – EV Batteries							
Hazard	**Source**	**Control Measures**	**Exposure Potential**				
			H	**M**	**L**	**Unk**	**N/A**
Stored Energy (Electricity) / Fire and Explosion	1. Electric/Power supply lines 2. EV high-voltage and low-voltage batteries	1. Ensure all electrical power has been shut off/disconnected from EV vehicle: a. Licensed/certified electrician to verify power status. 2. Ensure no backfeeding to the EV vehicle (i.e., solar panels or any other device that could potentially be feeding energy to or drawing energy from EV vehicle). 3. Isolate the energy storage system (i.e., EV battery) after verification that all energy to the vehicle has been shut off					

		or disconnected. 4. Remove EV battery from vehicle using methods identified in the SOP; methods may include rotating vehicle (on side or completely flipped over) using heavy equipment, cutting metal using “Jaws of Life”, removing bolts or other metal fasteners (see physical hazards above). 5. Prepare EV battery for transportation: • Active thermal event or poorly ventilated area - SCBA required for respiratory protection along with Flame-Resistant (FR) clothing OR Standard EV battery removal - organic gas/acid gas filters required for respiratory protection along with Flame-Resistant (FR) clothing. • Wrap EV battery in fireblankets (e.g., Bridgehill) or place loose material in drum with bung off. • If any reaction occurs during handling, immediately drop the EV battery and vacate the area to a safey place (upwind). • Place in transport vehicle and secure in place using straps or other equipment. • Ensure fire extinguisher and pressurized water sprayers are available during transport. 6. Transport EV battery to secure staging area for further processing: • Notify local fire department if thermal or other event occurs that requires a response. • If reaction occurs during transport, park vehicle immediately in a location with minimal fire risk (to the extent possible); call fire department (dial 911) immediately for assistance. • Maintain fire readiness (fire extinguishers and pressurized water sparyers to cool container during transport in the event of reaction/fire situation).					
Chemical Exposure	By-product of fires involving lithium batteries	See Chemical Hazards section below					

Biological Hazards

Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
COVID-19 Exposure	Unknown	Follow COVID-19 protocols					

Chemical & Radiological Hazards

Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
Alkaline Ash and Battery	Remnants of burned out	Personal Data Ram worn by perimeter personnel. MultiRae monitoring by screening team. P100 respirators on EV					

Materials	structures and battery materials	battery removal crew					
Asbestos	Remnants of burned out structures	Personal Data Ram worn by perimeter personnel. MultiRae monitoring by screening team. P100 respirators on EV battery removal crew					
Flamable and Combustable gases	Batteries	Well ventilated area. P100 respirators and proper eye protection (i.e., goggles). If ventilation concerns, switch to SCBA.					
Acid gases	Batteries	P-100 respirators, acid-proof gloves					
Lead acid	Batteries	Tyvek suites, acid-proof gloves					
Hydrogen Fluoride	By-product of fires involving lithium batteries	1. Active thermal event or poorly ventilated area - SCBA required for respiratory protection OR Standard EV battery removal - organic gas/acid gas filters required for respiratory protection. 2. FR clothing required for potential fires. 3. In the event a reaction occurs during handling, immediately drop the EV battery and vacate the area to safety. 4. Notify the fire department (dial 911).					

PPE				
Level A	**Level B** Active thermal event or poorly ventillated area. (SCBA for respiratory protection combined with FR clothing)	**Level C** Completely charred or completely charred and bulged EV battery: (Organic gas/acid gas filters required for respiratory protection combined with FR clothing.)	**Level D Mod**	**Level D**

Other
None

NOTES:

From draft SOP on EV Reconnisance – Hazards and required PPE are listed as:
Many hazards exist when performing reconnaissance of burned vehicles. Some of these hazards include sharp edges, broken glass, puncture hazards, structurally unsafe walls, beams, and roofs, high voltage hazards, toxic dust, compromised trees, heat/cold stress, and many more. The recommended PPE for this task is: long sleeve pants and shirts, hardhat, safety toe boots with steel shank, cut resistant gloves, eye protection, high visibility vests, and a dust mask or respirator. Higher level PPE such as Tyvek and boot covers is recommended when conditions require entry into ash footprints.

From draft SOP on EV Battery Removal – Hazards and required PPE are listed as: Numerous chemical and physical hazards are present during vehicle battery recovery. Chemical hazards include acid gases and occasional lead-acid. Physical hazards are heavy lifting of responder tools, sharp metal, fire, heat, ash and dehydration. The PPE level utilized is Level C with half-face respirator utilizing acid gas/P100 dual cartridge, flame retardant clothing (FRC), cut resistant gloves, hard hat and safety glasses. Tyvek suits are only utilized during lead acid battery removal.

Draft - JHA

JHA #: TBD	**Name of Task:** Shredding with Taskmaster Shredder (Model: TM2342)	**Location:** 2025 SoCal Wildfires
Task Description: Shredding/grinding of lithium batteries		**Task Duration:** Daily

Physical Hazards

Hazard	Source	Control Measures	Exposure Potential H	M	L	Unk	N/A
Stored Energy (Electricity) / Fire and Explosion	Electric/Power supply lines Energy Storage Systems (Tesla and other brands or homemade versions) Lithium batteries	• Risk of stored energy should be low since the batteries should have been discharged prior to shredding/grinding.					
Being pulled into shredder	Rotating shredder blades	• Identify and understand parts of the equipment which may cause crushing, pinching, rotating or similar motions. • Assure guards are in place to protect from these parts of equipment during operation. • Never operate the shredder without the hopper in place. • Never place hands, arms, or other body parts into hopper while shredder is in operation. •Never wear ill-fitting, baggy or frayed clothing when working around or on any of the drive system components. •Never wear ID lanyard while operating the grinder.					
Cuts or loss of limbs or digits	Mechanical jamming and/or failures	• ***ABSOLUTELY NEVER PLACE HANDS, ARMS, OR OTHER BODY PARTS INTO EQUIPMENT TO REMOVE A BATTERY JAM OR FIX A FAILURE!*** • Always shutdown and follow lock out procedures on equipment before performing necessary activities to remove jams or repair the equipment. • Shut off and lock out power on electrically driven machines and wait for all moving parts to stop before servicing, adjusting, or repairing.					
Projectiles from shredder	Kickback of batteries and/or material from powerwalls	• Assure guards are in place to protect from these parts of equipment during operation. • Never operate the shredder without the hopper in place.					

		• SHOULD PERSONNEL STAND X FEET AWAY??? Manual says clear people away from the area.					
Electrocution	Electric shock when operating shredder	• Use licensed electricians to hook up / disconnect electrical feed circuits. • Inspect all electrical wiring from generator to the shredder daily for structural integrity, ground continuity, and damaged insulation. • Cover or elevate electric wire or flexible cord passing through work areas to protect from damage from heavy equipment operation. • Inspect all electrical power circuits prior to commencing work.					
Chemical Exposure	By-product of fires involving lithium batteries	See Chemical Hazards section below					

Biological Hazards

Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
N/A	N/A	N/A					

Chemical & Radiological Hazards

Hazard	Source	Control Measures	Exposure Potential				
			H	M	L	Unk	N/A
Hydrogen Fluoride	By-product of fires involving lithium batteries	• Partially burned, partially insulated, intact, but suspected insulated power walls: - SCBA required for respiratory protection while handling power walls. – Completely charred or Completely charred and bulged wall mounted energy storage system : organic gas/acid gas filters required for respiratory protection. • FR clothing required for potential fires. • In the event a reaction occurs during handling, immediately drop the power wall and vacate the area to safety. • Keep a fire extinguisher next to the shredder.					

PPE

Level A	Level B	Level C	Level D Mod	Level D
	Partially burned, Partially insulated, intact, but suspected insulated power walls -(SCBA for respiratory	Completely charred or Completely charred and bulged power walls: (Organic gas/acid gas filters		

	protection combined with FR clothing)	required for respiratory protection combined with FR clothing.)		

Other

None

Attachment 2: Air Monitoring Table

Instrument Guidance | Regulatory Guidance | Reference

Target Compound[1]	Instrument	Detection Level	IP	Conversion	Occupational Action Levels: TWA	Occupational Action Levels: IDLH	AEGL-1: 1-hr	AEGL-1: 4-hr	AEGL-1: 8-hr	PAC-1: 15-min TWA	ERPG-1: 1-hr	Air Sampling: Media	Air Sampling: Method	Air Sampling: Flow Rate/ Total Volume
Gas/Vapor Monitoring for Batteries: Lithium Ion														
Hydrogen	Dräger Tube MultiRae/AreaRae MultiRAE/AreaRAE H_2 Sensor	0.2-2%, 0.5-3% 0-100% LEL, 0-30% O_2 0-1000 ppm	15.43 eV	1 ppm = 0.82 mg/m^3	<19.5% O_2 (simple asphyxiant)	NA	NA	NA	NA	NA	NA	Gastec Detector Tube, Hydrogen, 0.5-2% Vol, 810-30	OSHA CSI	NA
Hydrofluoric Acid (Hydrogen Fluoride)	AreaRAE Pro HF Sensor Dräger Tube pH Paper SPM Flex	0.5-10 ppm 0.5-15 ppm, 10-90 ppm 0-14 0.4-20 ppm	15.98 eV	1 ppm = 0.82 mg/m^3	PEL = 3 ppm REL = C 3 ppm, ST 6 ppm TLV = C 2 ppm, ST 0.5 ppm	30 ppm	1 ppm	1 ppm	1 ppm	1 ppm	2 ppm	Cartridge – two 37-mm diameter cellulose nitrate, one filter impregnated with NA_2CO_3 225-9031	NIOSH 7906	1-2 L/min; 15-1000 L
Carbon Monoxide	MultiRAE/AreaRAE Pro CO Sensor Dräger Tube Dräger Chip	0-500 ppm, 0-2000 ppm ext range 5- 150 ppm, 100-700 ppm 5-150 ppm	14.01 eV	1 ppm = 1.15 mg/m^3	PEL = 50 ppm REL = 35 ppm, C 200 ppm TLV = 25 ppm	1200 ppm	83 ppm*	33 ppm*	27 ppm*	75 ppm	200 ppm	Five-layer aluminized gas sampling bag, 262-01	OSHA ID 210	1 L/min; 2-5 L
Particulate														
Particulate	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 15 mg/m^3 (total), 5 mg/m^3 (respirable) TLV = 10 mg/m^3 (total), 3 mg/m^3 (respirable)	NA	NA	NA	NA	10 mg/m^3	NA	Filter (total) Cyclone + Filter (respirable)	NIOSH 0500 (total) NIOSH 0600 (respirable)	1-2 L/min (total); 7-133 L 1.7-2.5 L/min (respirable); 20-400 L
Particulates (both monitoring and sampling) for metals in Batteries: Lithium Ion														
Manganese	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 5 mg/m^3 C REL = 1 mg/m^3, 3 mg/m^3 C TLV = 0.02 mg/m^3 (resp)	500 mg/m^3	NA	NA	NA	3 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Copper	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.1 mg/m^3 (fume), 1 mg/m^3 (dust) REL = 0.1 mg/m^3 (fume), 1 mg/m^3 (dust) TLV = 0.2 mg/m^3	100 mg/m^3	NA	NA	NA	3 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7029	1-3 L/min; 50-1500 L
Nickel	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 1 mg/m^3 REL = 0.015 mg/m^3 TLV = 1.5 mg/m^3 (respirable)	10 mg/m^3	NA	NA	NA	4.5 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7300	1-4 L/min; 5-1000 L
Cobalt	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.1 mg/m^3 REL = 0.05 mg/m^3 TLV = 0.02 mg/m^3	20 mg/m^3	NA	NA	NA	0.18 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7027	1-3 L/min; 30-1500 L
Carbon Black	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 3.5 mg/m^3 REL = 3.5 mg/m^3 Ca TLV = 3 mg/m^3	1750 mg/m^3	NA	NA	NA	9 mg/m^3	NA	Filter (total) Cyclone + Filter (respirable)	NIOSH 0500 (total) NIOSH 0600 (respirable)	1-2 L/min (total); 7-133 L 1.7-2.5 L/min (respirable); 20-400 L
Lithium	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.025 mg/m^3 REL = 0.025 mg/m^3 TLV = 0.05 mg/m^3 C	0.5 mg/m^3	NA	NA	NA	0.025 mg/m^3	0.025 mg/m^3	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Aluminum	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 15 mg/m^3 REL = 10 mg/m^3	NA	NA	NA	NA	NA	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Radiation[2]														
Radiation	Model 192 Micro R Exposure Rate Meter Ludlum Model 2241-2 w/ 44-9 Pancake Probe Ludlum Model 2241-3 w/ 44-9 Pancake Probe Ludlum Model 2241 w/ 43-90 Alpha Scintillator Ludlum Model 26-1 Integrated Frisker Model 2241 w/ Model 44-10 NaI Detector	0-5,000 μR/hr 0-9,999 R/hr or 999,000 cpm 0-9,999 R/hr or 999,000 cpm 0-9,999 R/hr or 999,000 cpm 0-500 mR/hr or 0-1999 μSv/h 0-9,999 R/hr or 999,000 cpm	NA	NA	10 μR/hr 300 cpm 300 cpm 300 cpm NA 300 cpm	NA	NA	NA	NA	NA	NA	RADeCO Filter Paper (2")	RSSOP 209/501	α = 2500 ft^3 β/Y = 1250 ft^3

For guidance only. These tables do not supersede a SSHASP at any time or on any response.
Particulates normally are monitored and sampled for metals associated with battery fires.
[1] Does not include all pollutants associated with this type of event, only the most common pollutants with the lowest action levels. Depending on the chemical of concern, certain Dräger tubes and chips can be used. In addition
[2] Standard EPA Emergency Response Protocol is to screen for radiation with a Micro-R at all emergency responses. If readings are three times background, responders consult with a Health Physicist. Additional radiatio
AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-
ERPG-1 is the acute exposure concentration of the general population for up to 1 hour associated with effects expected to be mild or transient.
PAC-1 is based on the applicable AEGL-1, ERPG-1, or TEEL-1 value
http://www.epa.gov/oppt/aegl/pubs/chemlist.htm
http://www.cdc.gov/niosh/npg/npgsyn-a.html
http://wiser.nlm.nih.gov/
http://www.skcinc.com/
TN-114/TN-106
Dräger-Tube & CMS-Handbook 18th Edition
Electric vehicle batteries are typically lithium ion and lithium polymer. Electric vehicle batteries may also be nickel cadmium, nickel metal hydride, and lead acid.
*AEGL-2 - There is no AEGL-1 for this compound.
**PIDs are non-specific detectors and cannot differentiate one VOC from another, even with CFs applied. See RAE PID Correction factor guidance document TN-106 for more information.
***DustTrak DRX and DustTrak II are non-specific detectors and cannot differentiate one particulate from another.

Acronyms:

≥ – greater than or equal to
< -- less than
% – percent
ACGIH – American Conference of Governmental Industrial Hygienists
AEGL – acute exposure guideline levels
C -- ceiling
Ca – carcinogen
CDC – Centers for Disease Control and Prevention
cpm -- counts per minute
CO – carbon monoxide
NA – not available/applicable
NIOSH – National Institute for Occupational Safety and Health
O_2 -- oxygen
OSHA – Occupational Safety and Health Administration
PAC – protective action criteria
PEL – permissible exposure limit (OSHA)
PID – photoionization detector
ppm – parts per million
EPA – U.S. Environmental Protection Agency
ERPG – emergency response planning guideline
eV – electron volt
HF -- hydrogen fluoride
IDLH – immediately dangerous to life and health
IP – ionization potential
L -- liters
LEL -- lower explosive limit
L/min -- liters per minute
MCE -- mixed cellulose ester membrane
mg/m3 – milligrams per cubic meter
mm -- millimeter
NA_2CO_3 -- sodium carbonate
R/hr -- Roentgens per hour
REL – recommended exposure limit (NIOSH)
S -- skin notation (compound may be absorbed
SPM – single-point monitor
SSHASP – site-specific health and safety plan
ST -- short term
TEEL – temporary emergency exposure limit
TLV – threshold limit value (ACGIH)
TWA – time-weighted average
μg/m^3 – micrograms per cubic meter
μm -- micrometer
μR/hr -- micro Roentgens per hour
VOC -- volatile organic compound
Vol. -- volume

Instrument Guidance | Regulatory Guidance | Reference

Target Compound[1]	Instrument	Detection Level	IP	Conversion	Occupational Action Levels		AEGL-1			PAC-1	ERPG-1	Air Sampling		
					TWA	IDLH	1-hr	4-hr	8-hr	15-min TWA	1-hr	Media	Method	Flow Rate/ Total Volume
Gas/Vapor Monitoring for Batteries: Lithium Ion														
Sulfur Dioxide	MultiRAE/AreaRAE SO_2 Sensor Dräger Tube Dräger Chip SPM Flex	0-20 ppm ≥0.1-3 ppm ≥0.4-10 ppm 0.01-2.5 ppm	12.3 eV	1 ppm = 2.62 mg/m^3	PEL = 5 ppm REL = 2 ppm, ST 5 ppm TLV = ST 0.25 ppm	100 ppm	0.2 ppm	0.2 ppm	0.2 ppm	0.2 ppm	0.3 ppm	Preloaded Cassette, MCE, Coated, Sodium Carbonate, 225-9005	NIOSH 6004	0.5-1.5 L/min; 4-200 L
Hydrocyanic Acid (Hydrogen Cyanide)	MultiRAE/AreaRAE HCN Sensor Dräger Tube Drager Chip pH Paper SPM Flex	0-50 ppm 0.5-50 ppm, 5-50 ppm 2-50 ppm 0-14 0.2-30 ppm	13.6 eV	1 ppm = 1.1 mg/m^3	PEL = 10 ppm S REL = ST 4.7 ppm S TLV = 4.7 ppm S	50 ppm	2 ppm	1.3 ppm	1 ppm	2 ppm	NA	Sorbant Tube soda lime and glass fiber filter, 226 28	NIOSH 6017	0.05-0.2 L/min; 2-90 L
Hydrochloric Acid (Hydrogen Chloride)	AreaRAE HCl Sensor Dräger Tube Drager Chip pH Paper SPM Flex	0-15 ppm 0.2-3 ppm, 5-50 ppm ≥1-25 ppm 0-14 0.2-20 ppm	12.74 eV	1 ppm = 1.49 mg/m^3	PEL = C 5 ppm REL = C 5 ppm TLV = C 2 ppm	50 ppm	1.8 ppm	1.8 ppm	1.8 ppm	1.8 ppm	3 ppm	Cartridge - two 37-mm diameter cellulose nitrate, one filter impregnated with NA2CO3 225-9032	NIOSH 7907	2 L/min; 30-600 L
Hydrogen Sulfide	MultiRAE/AreaRAE H_2S Sensor Dräger Tube Dräger Chip SPM Flex MultiRAE/AreaRAE PID**	0-100 ppm, 0-1000 ppm ext. range ≥0.2-6 ppm ≥0.2-5 ppm 0.001-9.999 ppm 0-2000 ppm	10.46 eV	1 ppm = 1.4 mg/m^3	PEL = C 20 ppm, 50 ppm (10 mins) REL = C 10 ppm (10 mins) TLV=1ppm, ST 5ppm	100 ppm	0.75 ppm	0.36 ppm	0.33 ppm	0.51 ppm	0.1 ppm	Sorbent Tube, Silica Gel For Hydrogen Sulfide Sulfer Dioxide, 266-177	OSHA 1008 NIOSH 6013	0.05 L/min; 12 L 0.1-1.5 L/min (0.2 L/min rec); 1.2-40 L
Ammonia	AreaRAE NH_3 Sensor MultiRAE NH3 Sensor Dräger Tube[2] Dräger Chip[2] SPM Flex MultiRAE/AreaRAE PID*	0-100 ppm 0-100 ppm 2-30 ppm 2-50 ppm 0.01-150 ppm 0-2000 ppm	10.18 eV	1 ppm = 0.7 mg/m^3	PEL = 50 ppm REL = 25 ppm, ST 35 ppm TLV = 25 ppm, ST 35 ppm	300 ppm	30 ppm	30 ppm	30 ppm	30 ppm	25 ppm	Sorbent Tube, Silica Gel, 226-10-06	NIOSH 6015, NIOSH 6016	0.1-0.2 L/min; 96 L max
Formaldehyde	MultiRAE/AreaRAE PID** MultiRAE Pro HCHO Sensor Dräger Tube	0-2000 ppm 0-10 ppm 0.5-5 ppm, 0.2-2.5 ppm	10.88 eV	1 ppm = 1.23 mg/m^3	REL = Ca 0.016 ppm, C 0.1 ppm (15-min) PEL = 0.75 ppm, ST 2 ppm	20 ppm Ca	0.9 ppm	0.9 ppm	0.9 ppm	0.9 ppm	1 ppm	Sorbent Tube, Silica Gel, High Purity, 226-119	NIOSH 2016	0.03-1.5 L/min; 1-15 L
Phosphoryl Fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Cartridge – two 37-mm diameter cellulose nitrate, one filter impregnated with NA_2CO_3 225-9031	NIOSH 7906	1-2 L/min; 15-1000 L
Phosphorus Pentafluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA	2 ppm	NA			
Phosphorus Trifluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.2 ppm	NA			
Particulates (both monitoring and sampling) for metals in Batteries: Lithium Ion														
Zinc Oxide	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 5 mg/m^3 (fume), 15 mg/m^3 (total dust), REL = 5 mg/m3, 10 mg/m3 ST (fume); 5 mg/m3, 15	500 mg/m^3	NA	NA	NA	10 mg/m^3	NA	0.8µm PVC filter in open- face cassette, 225-807	NIOSH 7502	1-3 L/min; 10-400 L
Cadmium	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.1 mg/m^3 REL = Ca TLV = 0.01 mg/m^3 (dust), 0.002 mg/m^3 (respirable)	9 mg/m^3 Ca	0.10 mg/m^3	0.063 mg/m^3	0.041 mg/m^3	0.1 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7048	1-3 L/min; 25-1500 L
Lead	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.05 mg/m^3 REL = 0.05 mg/m^3 TLV = 0.05 mg/m^3	100 mg/m^3	NA	NA	NA	0.15 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7300, NIOSH 7301	1-4 L/min; 50-2000 L
Silver	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.01 mg/m^3 REL = 0.01 mg/m^3 TLV = 0.1 mg/m^3 (dust, fume)	10 mg/m^3	NA	NA	NA	0.3 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Antimony	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.5 mg/m^3 REL = 0.5 mg/m^3 TLV = 0.5 mg/m^3	50 mg/m^3	NA	NA	NA	1.5 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Tin	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 2 mg/m^3 REL = 2 mg/m^3 TLV = 2 mg/m^3	100 mg/m^3	NA	NA	NA	6 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Barium	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.5 mg/m^3 REL = 0.5 mg/m^3	50 mg/m^3	NA	NA	NA	1.5 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Iron	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 1 mg/m^3 REL = 1 mg/m^3 TLV = 1 mg/m^3	NA	NA	NA	NA	1.8 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L
Thallium	TSI DustTrak II*** TSI DustTrak DRX*** GILAIR-3, GILAIR-5, PCXR8, AirChek XR5000, AirChek Touch 220-5000TC Aircon-2	0.001-400 mg/m^3 0.001-150 mg/m^3 NA NA	NA	NA	PEL = 0.1 mg/m^3 REL = 0.1 mg/m^3 TLV = 0.02 mg/m^3 (resp)	15 mg/m^3	NA	NA	NA	0.06 mg/m^3	NA	Preloaded Cassette, MCE, 0.8um, 37mm, 3 Piece, PRE- BANDED, 225-3-01	NIOSH 7301	1-4 L/min; 100-2000 L

For guidance only. These tables do not supersede a SSHASP at any time or on any response
Particulates normally are monitored and sampled for metals associated with battery fires
[1] Does not include all pollutants associated with this type of event, only the most common pollutants with the lowest action levels. Depending on the chemical of concern, certain Dräger tubes and chips can be used. In additi
[2] Drager tubes are available at lower detection limits' however, the tubes listed have detection ranges within the action levels
AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nc
ERPG-1 is the acute exposure concentration of the general population for up to 1 hour associated with effects expected to be mild or transiei
PAC-1 is based on the applicable AEGL-1, ERPG-1, or TEEL-1 value
http://www.epa.gov/oppt/aegl/pubs/chemlist.htm
http://www.cdc.gov/niosh/npg/npgsyn-a.html
http://wiser.nlm.nih.gov/
http://www.skcinc.com/
TN-114/TN-106
Dräger-Tube & CMS-Handbook 18th Edition
Electric vehicle batteries are typically lithium ion and lithium polymer. Electric vehicle batteries may also be nickel cadmium, nickel metal hydride, and lead acic
*AEGL-2 - There is no AEGL-1 for this compound
**PIDs are non-specific detectors and cannot differentiate one VOC from another, even with CFs applied. See RAE PID Correction factor guidance document TN-106 for more informatic
***DustTrak DRX and DustTrak II are non-specific detectors and cannot differentiate one particulate from anothe

Acronyms:

≥ – greater than or equal tc
< -- less than
% – percent
ACGIH – American Conference of Governmental Industrial Hygienist
AEGL – acute exposure guideline levels
C -- ceiling
Ca – carcinogen
CDC – Centers for Disease Control and Preventior
CO – carbon monoxide
NA – not available/applicable
NIOSH – National Institute for Occupational Safety and Healt
O_2 -- oxygen
OSHA – Occupational Safety and Health Administratior
PAC – protective action criteria
PEL – permissible exposure limit (OSHA)
PID – photoionization detector
ppm – parts per million
EPA – U.S. Environmental Protection Agency
ERPG – emergency response planning guideline
eV – electron volt
HCHO - formaldehyde
HCl - hydrogen chloride
HCN - hydrogen cyanide
H2S - hydrogen sulfide
IDLH – immediately dangerous to life and health
IP – ionization potentia
L -- liters
LEL -- lower explosive limit
L/min -- liters per minute
MCE -- mixed cellulose ester membrane
mg/m3 – milligrams per cubic meter
mm -- millimeter
NH3 - ammonia
NA_2CO_3 -- sodium carbonate
REL – recommended exposure limit (NIOSH)
S -- skin notation (compound may be absorbed
SPM – single-point monitor
SSHASP – site-specific health and safety plar
ST -- short term
TEEL – temporary emergency exposure limi
TLV – threshold limit value (ACGIH)
TWA – time-weighted average
µg/m^3 – micrograms per cubic meter
µm -- micrometer
VOC -- volatile organic compound
Vol. – volume

Attachment 3: Particulate Action Level Development Memo

REGION 4
ATLANTA, GA 30303

October 6, 2025

TECHNICAL MEMORANDUM

SUBJECT: Lithium-Ion Battery Fires – Particulate Action Level Development

FROM: Adam Friedman, Toxicologist
Scientific Support Section
Superfund & Emergency Management Division

THROUGH: Tim Frederick, Chief
Scientific Support Section
Superfund & Emergency Management Division

TO: Bryan Vasser, On Scene Coordinator
Emergency Response & Preparedness Section
Superfund & Emergency Management Division

Per your request, the Scientific Support Section (SSS) has developed an action level for airborne particulate matter (PM) for use at lithium-ion battery (LIB) fire responses. This memorandum is intended to support response actions and to provide technical justification for particulate action levels described in the *Lithium-Ion Battery Response Guide*.

Introduction

As lithium-ion batteries (LIBs) have become more widely used, it has become increasingly necessary to characterize potential risks due to emissions from thermal runaways (TRs) and to develop action levels protective of both responders and members of the public. The primary airborne toxic compounds associated with LIB fires include carbon monoxide (CO), hydrogen fluoride (HF), and particulate matter (PM).

While PM has many well-documented health effects on its own, PM originating from LIB-TR emissions often contains a wide variety of metals. While the precise speciation of emitted PM varies based on the type of LIB, recent burn studies have shown that the primary metals detected in TR emissions are lithium, calcium, sodium, aluminum, manganese, nickel, cobalt, zinc, and copper. Of these, lithium (in the form of lithium hydride), manganese, nickel, cobalt, and copper are of the most concern from the perspective of human health. However, while response programs currently have ready access to real-time monitoring for gaseous pollutants and PM, the time required for analysis of airborne metals often exceeds the timeframe for decision-making during a LIB-TR response. This necessitates the development of ambient PM action levels that can be measured in real-time and accounts for potential airborne metals. The intent of these action levels is not to provide an alternative to screening levels such as Removal Management Levels (RMLs) or to develop defensible cleanup levels. Instead, PM action levels can serve as a resource for responders to use to determine when taking an action to protect workers and members of the public during an LIB-TR response is necessary.

Action Level Development Methodology

To develop LIB-TR action levels, three lines of evidence were considered before calculating a particulate action level: existing action levels for metal contaminants, type of battery chemistry likely to be present, and the proportion of metals in LIB-TR emitted PM. In the context of LIB-TR responses, action levels are used (and therefore considered in this memorandum) differently depending on whether the exposed population is a responder or a member of the public.

Recommended Exposure Levels (RELs), developed by NIOSH, are currently used by EPA responders as an action level to upgrade respiratory protection from Level D to Level C. In turn, Immediately Dangerous to Life or Health (IDLH) values are used by EPA responders as an action level to upgrade from Level C to Level B. As such, both RELs and IDLH values for metals were considered for worker exposure.

For protection of members of the public, Protective Action Criteria for Chemicals (PACs) were considered. PACs are hierarchy-based values derived from the three common public exposure guidelines: Acute Exposure Guideline Levels (AEGLs), Emergency Response Planning Guidelines (ERPGs), and Temporary Emergency Exposure Limits (TEELs). Typically, PACs are based on exposure periods of 1-hour. Minimum Risk Levels, developed by ATSDR as screening levels for non-cancer health effects, were also considered for public exposure and are presented with other considered action levels for reference, but were ultimately not considered for particulate action levels for two main reasons. For nickel specifically, at the time of writing the Toxicological Profile (and resultant MRL) have been removed while ATSDR is in the process of reevaluating acute nickel toxicity. In addition, the temporal scale of acute MRLs is on the order of 1-14 days, in contrast to the 1-hour exposure period for PACs, RELs, and IDLH values. To maintain consistency between action levels, PACs were used instead of MRLs. Table 1 shows the available action levels for each metal found in LIB-TR emissions.

Battery chemistry not only determines flame-related hazards during a LIB-TR response, but it also determines the respective proportions of metals in particulate emissions. The most common battery chemistries are Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Ferrous Phosphate (LFP), Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Manganese Rich (LMR), Lithium Nickel Cobalt Aluminum Oxide (NCA), and Lithium Titanate (LTO). Due to the large proportion of LIBs that NMC and LFP batteries make up (about 60% and 30%, respectively, or 90% of all LIB TRs collectively) and due to data availability, only emissions from NMC and LFP battery events were considered.

The proportion of metals in particulate emissions were primarily based on a burn study performed by Meister *et al.*, in May 2025. This study measured aerosol concentrations and speciation of NMC and LFP TR emissions at state-of-charge (SOC) ranging from 100% to 10% in test chambers via stainless steel probes. Table 2 presents the makeup of particulate and metals emissions. Of potentially toxic metals, lithium was the highest proportion in both battery types by a significant margin, with a higher proportion in LFP batteries. As there is not currently a toxicity value for elemental lithium, lithium hydride (LiH) was used as a surrogate compound, as this salt-like hydride is one of the compounds lithium is likely to form in ambient air. Of metals with existing toxicity values, nickel, cobalt, and manganese made up the largest proportion in NMC batteries, while zinc and nickel made up the largest proportion in LFP batteries.

Once these factors were considered, the existing action levels were scaled to the proportion of each metal in LIB-TR emissions. The resulting lowest PM concentration for each category of action level was then selected to ensure protectiveness. This was done individually for both LFP and NMC type LIBs. Additionally, the action levels based on each metal were averaged across battery types. However, to ensure protectiveness of human health, the lower of the two particulate action levels should be used if battery type is unknown.

Particulate Action Levels

Particulate action levels for each battery type, as well as the average of the two types assessed, are presented in Table 3. Action Levels are presented as a concentration of measured particulate (0.1 to 10 microns) in μg/m^3. Using the most protective action level for each battery type, SSS recommends using the following PM action levels:

- Public Exposure Guideline: 100 μg/m^3
- Elevation from Level D to Level C: 100 μg/m^3
- Elevation from Level C to Level B: 1600 μg/m^3

Primarily driven by LiH emissions, SSS recommends the following PM action levels for use when the battery chemistry is LFP:

- Public Exposure Guideline: 100 μg/m^3
- Elevation from Level D to Level C: 100 μg/m^3
- Elevation from Level C to Level B: 2000 μg/m^3

In NMC battery chemistries, nickel makes up a larger proportion of the metals emitted and therefore drives a greater proportion of the toxicity. Due to NIOSH studies finding potential carcinogenic effects of high level of nickel exposure, the REL of nickel was used for the action level elevating from Level C to Level B respiratory protection.

- Public Exposure Guideline: 160 μg/m^3
- Elevation from Level D to Level C: 160 μg/m^3
- Elevation from Level C to Level B: 1600 μg/m^3

Uncertainties and Future Recommendations

While the action levels developed in this technical memorandum are appropriate to be used as guidelines for response actions in most LIB-TR responses, there are several sources of uncertainty that should be evaluated further. As mentioned above, while LFP and NMC make up almost 90% of LIBs, there are a wide variety of other battery chemistries that could be encountered in responses that were not evaluated in this memorandum. Further burn studies should be conducted on these battery chemistries, especially on NCA batteries due to their increasing prevalence.

The burn studies referenced in this memorandum also measured metals proportions as a function of PM in test chambers. However, there are many non-incident related sources of PM found in ambient air that could inflate PM concentrations. Burn studies should be evaluated with ambient PM in consideration, and background PM concentrations should be considered when implementing these action levels.

In addition, while PACs are suitable for use as action levels to be protective of public health, further toxicological analysis of LIB-TR emission constituents is recommended. Specifically, AEGLs for lithium, nickel, manganese, and cobalt would support development of more precise relative particulate action levels derived from these metals. Similarly, the action levels developed for this memorandum were based on inhalation toxicity, and they should not be used as holistic measures of human health risk or exposure, as they do not take into account potential dermal exposure nor atmospheric deposition. Potential dermal exposure and atmospheric deposition originating from LIB fires merits further investigation. Finally, due to data availability, these action levels were derived from the proportions of metals, not total particulates, emitted from the referenced burn study. The derived action levels are protective of human health, but may be conservative.

Please contact me at 404-562-9033 or friedman.adam@epa.gov if you have any comments or questions regarding this technical memorandum.

References

Alsauskas, Oskaras, et al. “Global EV Outlook 2023.” International Energy Agency, Apr. 2023.

Maureen Meister, Shaligram Sharma, Xiaojia He, Patrick S. Chepaitis, Taryn Waddey, Mark Wilson, Vinay Premnath, Judith Jeevarajan, Marilyn Black, Christa Wright, Evaluating inhalation risks and toxicological impacts of lithium-ion battery thermal runaway emissions, Environment International, Volume 199, 2025, 109466, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2025.109466. (https://www.sciencedirect.com/science/article/pii/S016041202500217X)

Table 1. Metals Action Levels

Contaminant	PAC (1-hour)	MRL (Acute)	REL/PEL	IDLH
Li (LiH)	25		25	500
Al			10000	
Mn	3000	0.3	1000	500000
Ni	4500	0.1	15	200000
Cd	100	0.3	5	9000
Pb	150		100	100000
Co	60	0.3	50	20000
Cu	3000		1000	100000
Zn	300		5000	500000
Na	13000			
Ca				

Table 2. Percentages of Metals Emitted by Lithium-Ion Thermal Runaway

Analyte	LFP	NMC
	% of total metals assessed	
Li (LiH)	23.90	15.36
Al	4.82	6.18
Mn	0.01	0.21
Ni	0.07	0.94
Cd	0.00	0.00
Pb	0.01	0.01
Co	0.00	0.21
Cu	0.01	0.05
Zn	0.92	0.84
Na	12.99	31.79
Ca	36.94	34.98
Other	20.33	9.44

Table 3. Particulate Matter Action Levels

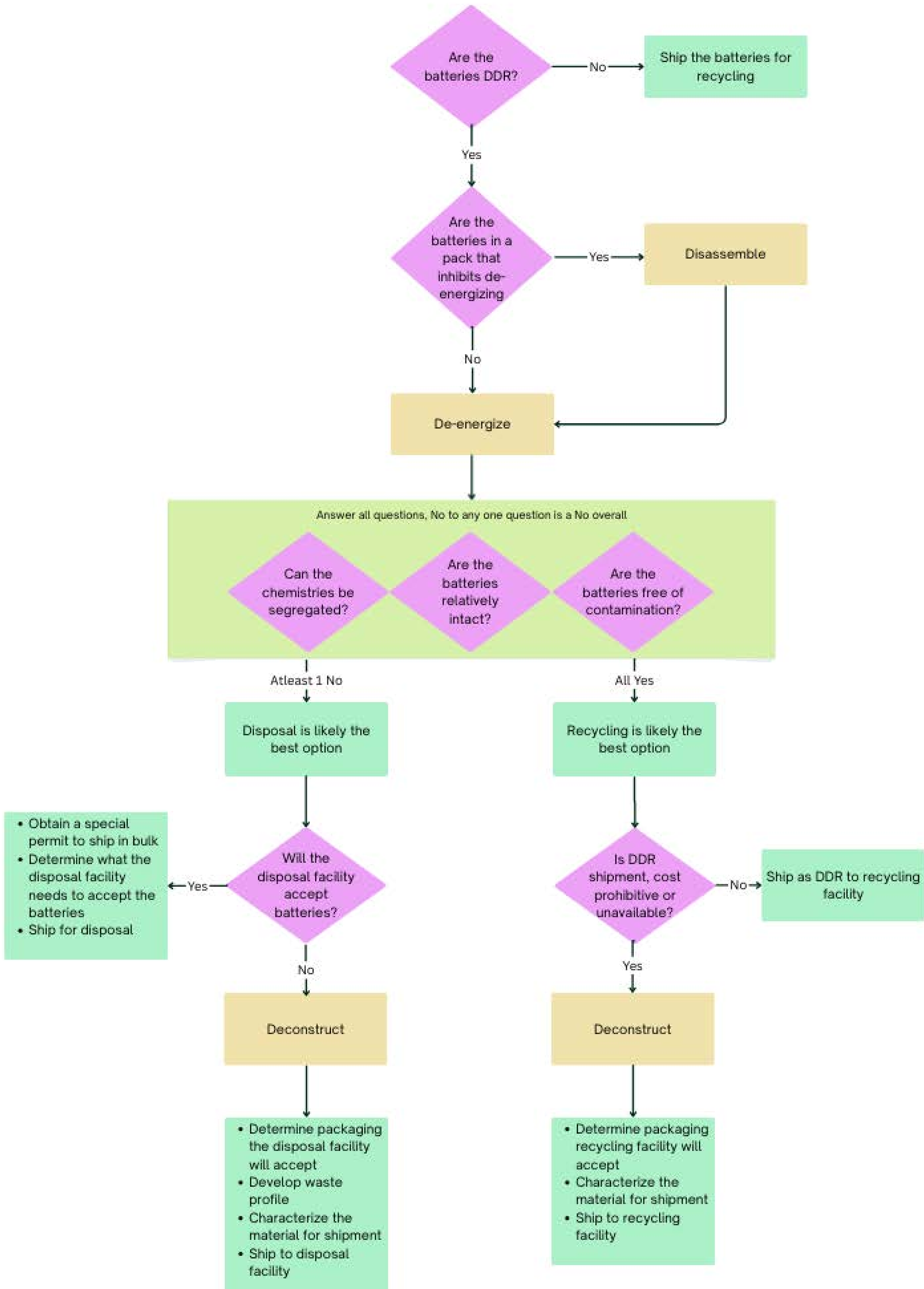
Analyte	LFP PM Action Level (ug/m3)			
	PAC	MRL	PEL/REL	IDLH
Li (LiH)	104.62	N/A	104.62	2092.39
Al	N/A	N/A	207572.07	N/A
Mn	20091780.30	2009.18	6697260.10	3348630049.52
Ni	6433483.01	142.97	21444.94	285932578.27
Cd	N/A	N/A	N/A	N/A
Pb	1199206.03	N/A	799470.69	799470685.57
Co	N/A	N/A	N/A	N/A
Cu	30236717.35	N/A	10078905.78	1007890578.21
Zn	32452.35	N/A	540872.44	54087244.30
Na	100065.63	N/A	N/A	N/A
Ca	N/A	N/A	N/A	N/A

Analyte	NMC PM Action Level (ug/m3)			
	PAC	MRL	PEL/REL	IDLH
Li (LiH)	162.81	N/A	162.81	3256.20
Al	N/A	N/A	161710.51	0.00
Mn	1443475.15	144.35	481158.38	240579191.68
Ni	477195.20	10.60	1590.65	21208675.34
Cd	9978957.42	29936.87	498947.87	898106167.76
Pb	2805770.91	N/A	1870513.94	1870513938.75
Co	28391.36	141.96	23659.47	9463786.85
Cu	5865214.15	N/A	1955071.38	195507138.46
Zn	35688.24	N/A	594803.98	59480398.11
Na	40899.69	N/A	N/A	N/A
Ca	N/A	N/A	N/A	N/A

Analyte	Average Action Level (ug/m3)			
	PAC	MRL	PEL/REL	IDLH
Li (LiH)	133.71	N/A	133.71	2674.30
Al	N/A	N/A	184641.29	0.00
Mn	10767627.72	1076.76	3589209.24	1794604620.60
Ni	3455339.10	76.79	11517.80	153570626.80
Cd	9978957.42	29936.87	498947.87	898106167.76
Pb	2002488.47	N/A	1334992.31	1334992312.16
Co	28391.36	141.96	23659.47	9463786.85
Cu	18050965.75	N/A	6016988.58	601698858.33
Zn	34070.29	N/A	567838.21	56783821.21
Na	70482.66	N/A	N/A	N/A
Ca	N/A	N/A	N/A	N/A

Attachment 4: Lithium-Ion Battery EPA Site Management Decision Tree

Lithium-Ion Battery EPA Site Management Decision Tree



Attachment 5: 2023 Maui Wildfire DOT Emergency Waiver Order

United States Department of Transportation
Pipeline and Hazardous Materials Safety Administration

Environmental Protection Agency, Region 9
75 Hawthorne St.
San Francisco, CA, 94105

United States Coast Guard, District 14
300 Ala Moana Blvd., Room 9-204
Honolulu, HI, 96850-4982

Emergency Waiver Order No. 26

Docket No. PHMSA-2023-0055

EMERGENCY WAIVER ORDER

In accordance with the provisions of 49 U.S.C. § 5103(c), the Associate Administrator for the Office of Hazardous Materials Safety within the Pipeline and Hazardous Materials Safety Administration (PHMSA) hereby declares that an emergency exists that warrants issuance of a Waiver of the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) to persons conducting operations under the direction of Environmental Protection Agency (EPA), Region 9 (75 Hawthorne St. San Francisco, CA, 94105) and United States Coast Guard (USCG), District 14 (300 Ala Moana Blvd., Room 9-204, Honolulu, HI, 96850-4982) within the emergency areas of the Hawaii Wildfires in the State of Hawaii. The Waiver is granted to support EPA Region 9 and USCG District 14 in taking appropriate actions to prepare for, respond to, and recover from a threat to public health, welfare, or the environment caused by actual or potential oil and hazardous materials incidents resulting from the Hawaii Wildfires.

On August 10, 2023, the President issued a Major Disaster Declaration for the Hawaii Wildfires for the State of Hawaii (DR-4724-HI).

This Waiver Order covers all areas identified in the declaration, as amended. Pursuant to 49 U.S.C. § 5103(c), PHMSA has authority delegated by the Secretary (49 CFR 1.97(b)(3)) to waive compliance with any part of the HMR provided that the grant of the waiver is: (1) in the public interest; (2) not inconsistent with the safety of transporting hazardous materials; and (3) necessary to facilitate the safe movement of hazardous materials into, from, and within an area of a major disaster or emergency that has been declared under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (42 U.S.C. § 5121 et seq.).

Given the continuing impacts caused by the Hawaii Wildfires, PHMSA's Associate Administrator has determined that regulatory relief is in the public interest and necessary to ensure the safe transportation in commerce of hazardous materials while the EPA and USCG execute their recovery and cleanup efforts in the State of Hawaii. Specifically, PHMSA's Associate Administrator finds that issuing this Waiver Order will allow the EPA and USCG to conduct their Emergency Support Function #10 response activities under the National Response Framework to safely remove, transport, and dispose of hazardous materials. By execution of this Waiver Order, persons conducting operations under the direction of EPA Region 9 and

USCG District 14 within the emergency areas of the Hawaii Wildfires are authorized to offer and transport nonradioactive hazardous materials under alternative safety requirements imposed by EPA Region 9 and USCG District 14 when compliance with the HMR is not practicable. Under this Waiver Order, non-radioactive hazardous materials may be transported to staging areas within 50 miles of the point of origin. Further transportation of the hazardous materials from staging areas must be in full compliance with the HMR.

This Waiver Order is effective immediately and shall remain in effect for 60 days from the date of issuance.

Dated: August 14, 2023

William S. Schoonover
Associate Administrator for Hazardous Materials Safety
Office of Hazardous Materials Safety
Pipeline and Hazardous Materials Safety Administration

Attachment 6: Lithium-Ion Battery Wildfire Response Fact Sheet Examples

Los Angeles Wildfires

Lithium-ion batteries burned by wildfires

The U.S. Environmental Protection Agency (EPA) has been assigned by the Federal Emergency Management Agency (FEMA) to remove lithium-ion batteries affected by the Los Angeles County wildfires.

This includes battery:

- recovery
- safe transportation
- processing (de-energizing)
- safe disposal

Use extreme caution when returning to your property

Your home may have damaged or destroyed lithium-ion batteries, lithium-ion battery energy storage systems, and electric and hybrid vehicles.

- ✓ **The batteries should be considered extremely dangerous**, even if they look intact.
- ✓ **Lithium-ion batteries can spontaneously re-ignite, explode, and emit toxic gases and particulates even after the fire is out.**

Household Items with Lithium-Ion Batteries:

Other examples:

- Electric/hybrid vehicles
- Electric bikes
- Hoverboards
- Wheelchairs
- Digital cameras
- Home alarms
- Power banks or stations
- Game controllers
- Home energy storage systems
- Personal mobility device
- Scooters
- Drones
- Tablets
- Power tools
- Vaping devices

If you hear a popping, hissing noise, or see smoke or fire:

1. Do not attempt to extinguish or smother the battery.
2. Leave the area immediately.
3. Move upwind at least 330 ft (the length of a football field) and **call 911**.

- **Do not** touch fire-damaged products with lithium-ion batteries – they can ignite.
- **Do not** start, move, tow, or charge a fire-damaged electric/hybrid vehicles (EV, PHEV, HEV). These will be assessed by EPA hazardous material professionals.
- **Do not** use or start a fire-damaged residential energy storage or house battery. These will be assessed by EPA hazardous material professionals.
- **Do not** enter enclosed spaces with lithium-ion battery products.
    - Gasses and vapors from damaged lithium-ion batteries can build up in enclosed spaces (such as a garage, shed, basement, or closet) and may produce an explosive environment.

- **DO** call our hotline if you encounter a lithium-ion battery while re-entering your property and/or are unsure if a lithium-ion battery was damaged.

epa.gov/california-wildfires

For questions about this work or **if you have an electric or hybrid vehicle and/or a battery energy storage system in the burn zone**, call the EPA hotline at:

1-833-R9-USEPA
(1-833-798-7372)

Lithium-Ion Batteries

Returning Home After the Park Fire

Use caution when returning to your property

- **All lithium-ion battery products can be dangerous in homes affected by fire** (or high heat from a fire) – even if these products do not look like they were damaged.
- **Lithium-ion batteries can re-ignite, explode, and emit toxic gases even after the fire is out.**

Products with lithium-ion batteries

- Electric/hybrid vehicles
- Electric bikes, scooters, hoverboards
- Wheelchairs
- Personal mobility device
- Home alarms
- Power banks or stations
- Home energy storage systems
- Power tool batteries
- Drones
- Game controllers
- Digital cameras
- Headphones
- Cell phones
- Laptops
- Tablets
- Calculators
- Vaping devices

Protect yourself from lithium-ion batteries

- **If you hear a popping noise or see smoke**, these may be signs of a lithium-ion battery on fire.
  1. **Do not attempt to extinguish or smother battery.**
  2. Leave the area immediately.
  3. Move upwind at least 330 feet (length of a football field) and **call 911.**

- **Do not** touch products with lithium-ion batteries – they can ignite.
- **Do not** start, move, tow, or charge an **electric/hybrid vehicle if it was near a fire.** Contact the manufacturer or certified installer for guidance and recommended safety actions.
- **Do not** use or start a **residential energy storage system or house battery**. Contact the manufacturer or certified installer for guidance and recommended safety actions.
- **Do not enter enclosed spaces** with lithium-ion battery products. Explosive gas can build up from damaged lithium-ion batteries in enclosed spaces (for example, inside a garage, shed, or closet).

Questions?

Butte County: 530-552-4000 | www.buttecounty.net/2021/Park-Fire
Tehama County: 530-527-8020 | www.tehama.gov/park-fire-recovery-information/
Lithium-ion battery safety: https://go.cdph.ca.gov/batterysafety