



INCIDENT COMMAND SYSTEM PUBLICATION

Lithium-Ion Battery Emergencies Operational Guidelines
ICS 1150

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This Document contains information relative to the Incident Command System (ICS) component of the National Incident Management System (NIMS). This is the same Incident Command System developed by FIREScope. Additional information and documentation can be obtained from the following source:

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INTRODUCTION

Fires involving battery-powered devices are becoming an exponential concern as the applications for battery cells include various products and even assist in powering the electric power grids. Battery cells can be found in laptops, cell phones, power tools, electric vehicles, scooters, mobile devices, and power storage/generation plants. Over the last several years, the technology for using battery cells as a power source has increased dramatically, making the potential for battery emergencies more likely. Across the nation, civilian injuries and deaths associated with battery emergencies have increased. Equally concerning, the fire service has reported increased injuries related to fires and explosions involving batteries. Emergencies of this type also have a distinct exposure potential for all responders involved.

The objective of this Operational Guideline is to provide guidance to all members of the fire service and the broader response community regarding the hazards associated with battery cells. Although battery cell failure may be considered rare, when it does occur, toxic smoke is released, and cell failure can happen within seconds, causing the potential for ingestion, absorption, and inhalation injuries. To successfully mitigate these emergencies, responders must be familiar with battery cell construction, battery cell failure, proper handling techniques, safety precautions, mitigation strategies, and post-incident considerations. Understanding these factors will enhance firefighter safety, reduce property damage, and ensure that the first responder members are prepared for all battery emergencies.

BACKGROUND

To ensure responders mitigate battery emergencies as safely as possible, they must understand battery cell construction and technology. This may be best understood by training on the exact terminology of battery systems.

The basic building block of battery terminology is the term cell. A cell is the individual battery component we often call a battery. A battery is a source of electrical power consisting of electrochemical cells with external connections for powering electrical devices. Cells can take many forms and come in a variety of sizes. Cells may be single-use or rechargeable.

When multiple cells are assembled, they are referred to as a module. A module is a set of battery cells connected or encapsulated within an outer casing to protect the cells. A module can be limited to just a few cells, such as the nine-cell module in an ordinary remote-control car, or many thousands of cells that make up a Battery Electric Vehicle (BEV). Other forms of battery-powered vehicles include Plug-In Hybrid Electric Vehicles (PHEV), Hybrid Electric Vehicles (HEV), and Fuel Cell Electric Vehicles (FCEV) (FCEV uses a Hydrogen Fuel Cell).

When multiple modules are assembled, they make up a battery pack. The electric battery pack is composed of numerous individual cells configured into several modules, which finally make up the BEV battery pack. Vehicles powered by battery storage can range in size from small carts to large commercial vehicles.

An electrolyte describes any material within a cell that cools, lubricates, and diffuses the electron energy. Some battery cells use acid, some use a paste-like substance, and others use a complicated mixture. All electrolytes used today are designed to resist the formation of tiny crystals that build up over time. The crystals, known as dendrites, can shorten the lifespan and effectiveness of a cell.

An anode is a negative electrode and is one of the essential parts of a battery cell. It's usually made of a metal that oxidizes and sends electrons to the cathode (the positive electrode). This process is an electrochemical reaction that produces electrons (think electricity). Like an anode, a cathode is also one of the electrodes in a battery cell. However, a cathode is called the positive electrode because it gains electrons rather than loses them. Therefore, anodes oxidize (lose electrons) while cathodes reduce (gain electrons).

Battery cells used in electronic devices commonly have a Battery Management System (BMS). This system is used to maintain the health of the cell. Vehicles, phones, computers, etc., use the BMS to prevent cell abuse. The BMS monitors the percentage of available energy and runs cycles to limit the accumulation of crystals in the battery. Some battery cell systems use an external BMS, such as the Motorola HXE Battery Module charger. Other battery systems do not have an internal or external BMS and are at the most risk of cell failure.

Batteries designed for a single use are referred to as a "primary battery". Most primary batteries can accurately be referred to as alkaline cells. However, some primary cells use lithium as the metal to hold electrons. Many of these cells have two layers composed of a substance containing the electrons and a second layer, the rod. Electrons move through the paste, up the rod, and out to the connections that power your device. An electrolyte and a case form an outer layer to dissipate heat and contain the cell's contents. You will notice that these cells can sometimes leak in a device. The oily substance you see is usually the electrolyte.

Secondary batteries describe the battery cells and modules, often referred to as rechargeable batteries. They are often called lithium-ion battery cells. Other materials have also been used, but lithium-ion is the leading technology. These cells can take many forms and provide power for watches, drills, scooters, cars, and extensive fixed

facilities. Regardless of size or shape, all secondary batteries are composed of layers of alternating materials, allowing the electrolyte to dissipate the heat generated by the movement of energy.

Hazards for all incidents with Lithium-Ion Batteries:

Batteries may rupture and vent toxic, flammable gases and/or explode violently when the gases ignite, when subject to the following:

- Thermal – Hot or Cold temperatures.
- Physical – Impacted, crushed, or pierced.
- Electrical – Overcharging or forced discharge, including internal manufacturing defects or internal short-circuiting. For example, using aftermarket mismatched charging systems for secondary batteries.
- Drying after being wet.

It may be difficult to discern if a lithium-ion battery pack or cell is compromised.

Note: A thermal imaging camera cannot be consistently relied upon to determine if a Lithium-Ion battery pack or cell is compromised because there may not be a detectable heat signature upon failure. Once abused, a battery cell can fail at any time.

Thermal Runaway. When the stable state of batteries/cells rapidly fails due to increased heat from charging or external conditions such as fire, the cell transitions from a stable state to an unstable state and then to catastrophic failure of the cell. Once thermal runaway begins it may propagate (spread, domino effect) to the adjacent battery cells. Thermal runaway can occur at any time without warning.

Usually, there is a “pop” or rupture sound heard preceding thermal runaway with flammable and toxic gases, which may appear as a white smoke/vapor cloud venting moments/seconds prior to ignition.

Water may not prevent a battery from entering thermal runaway. If battery cells are exposed or outside the battery case, water may provide a cooling effect on the adjacent battery cells. This cooling may reduce propagation to other cells.

A dry chemical extinguisher is ineffective for any type of lithium-ion-related extinguishment. CO2 extinguishing agents can be used to aid in cooling batteries and electrical components with some propagation control.

Flammable and Toxic Gases. Lithium-ion batteries in thermal runaway produce many different gases. These gases combine to form a flammable, explosive, and toxic atmosphere. Toxicity and flammability levels vary depending on specific battery technology and manufacturer. Known chemicals include, but are not limited to, Hydrogen (H₂), Carbon Monoxide (CO), Carbon Dioxide (CO₂), Oxygen (O₂), Hydrogen Fluoride (HF), and Volatile Organic Compounds (VOC). Particulates that include metals also pose an exposure threat. All of these chemicals highlight the necessity of respiratory protection and full PPE during all phases of a battery emergency.

Unexpected Re-ignition. Lithium-Ion Batteries are known to unexpectedly re-ignite at any time without warning after all visible fire has been extinguished. Reignition is a common occurrence and should be expected. This can occur at any time after initial battery failure. Exposure consideration is necessary and critically important when storing any size damaged battery.

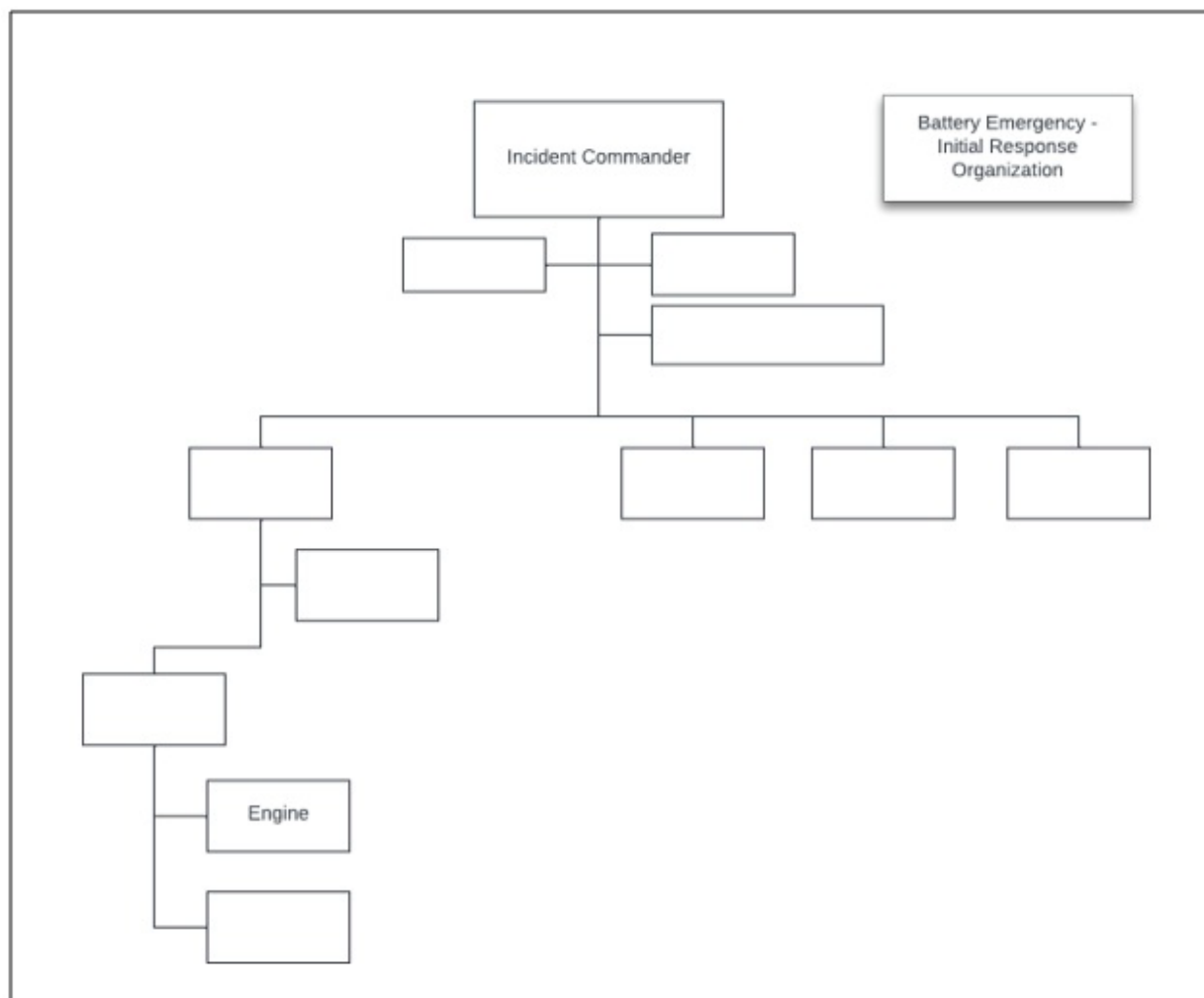
Explosive force. As noted in several incidents across the nation, lithium-ion batteries have ruptured and ignited with such force that walls were blown down, resulting in structural damage and extensive fire spread.

Stranded energy. Battery systems have the ability to retain an amount of energy even during failure. This energy is commonly called stranded energy. This energy can pose an electrical or explosion hazard to responders, even if a shut-off switch has been used.

ORGANIZATION

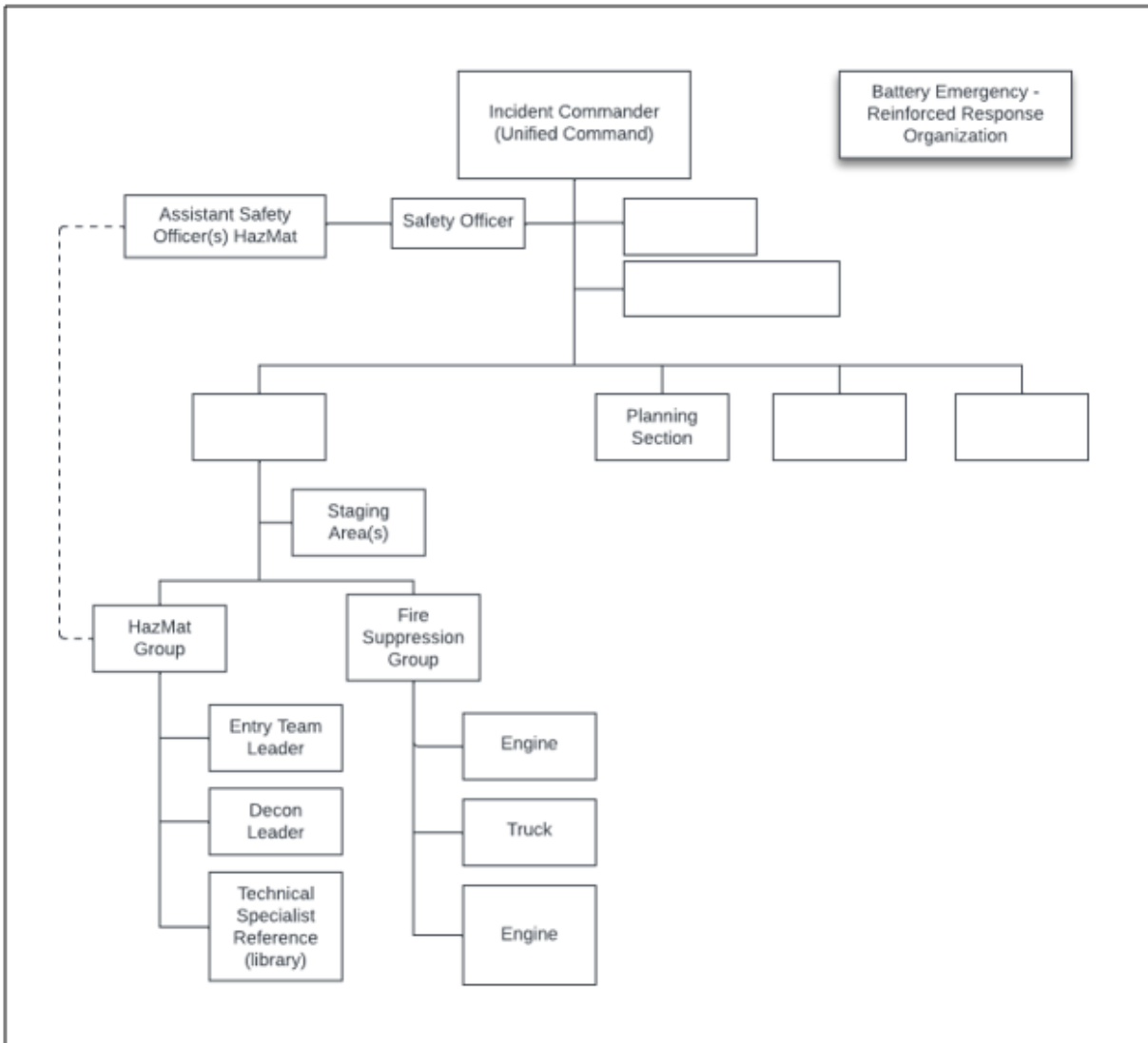
This response guidance is applicable during incidents involving consumer products, micro-mobility emergencies, BEVs, and fixed facility installations.

Initial Response



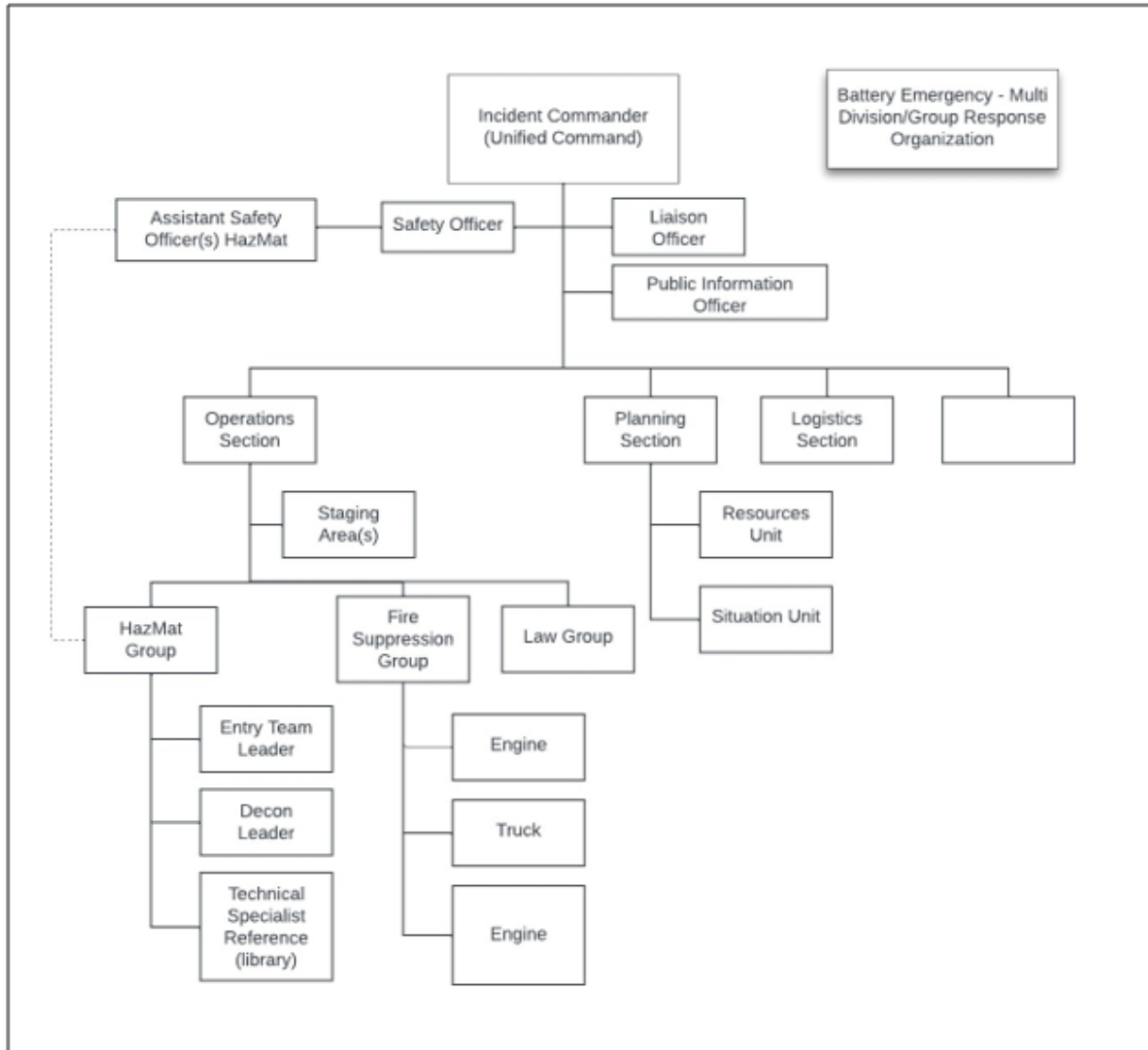
During the initial response to a battery emergency of any size or scope, all responders must focus on basic incident recognition and First Responder Operations (FRO) skills. A single resource must recognize the inhalation and thermal hazards that battery cells pose at any size. During this initial response, a resource will operate within their department's policy and consider upgrading the incident to a HazMat response. Not every lithium-ion battery incident will require a HazMat response. Considerations for when a HazMat response is recommended include, but are not limited to, complexity of the incident exceeds the training and capability of the on-scene resources, damaged batteries requiring stabilization, need for extensive air monitoring, and/or evacuation or shelter-in-place orders are given.

Reinforced Response



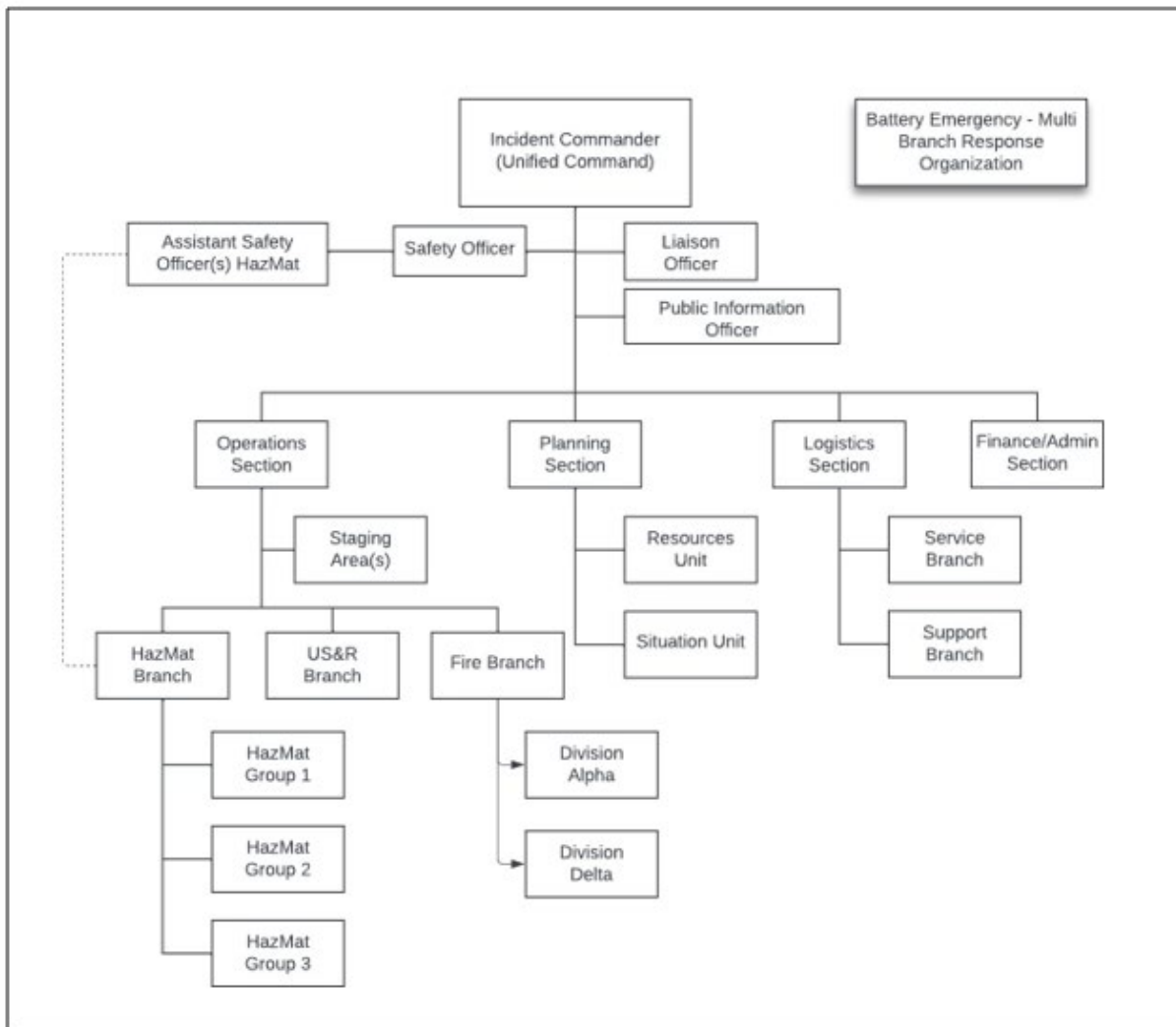
During a reinforced response, a single FRO-trained resource has asked for additional FRO-trained resources and a HazMat response to reinforce a life safety mission. The additional fire resources will assist with the need for FRO tasks. The reinforced HazMat response will begin to provide atmospheric monitoring and notification to adjoining agency partners and specialty resources. During the reinforced response, a resource must operate within its department's policy.

Multi-Division/Group Response



During a Multi-Division/Group response, several groups have been filled as needed. Resources that were initially reinforced have now been expanded into full Divisions/Groups. Incidents of this type often extend past the initial operational period. Planning and Logistics Sections support resources during multi-operational periods. Additional expanded support may be needed.

Multi-Branch Response



The Multi-Branch Response organization model is most useful during incidents with a large scope, large geographic footprint, prolonged operation, or multijurisdictional response. This model has been effectively used for fixed facility installations, complex large-scale incidents involving large battery systems, and others. The Multi-Branch response allows for multiple HazMat Groups and complex Branches. Incidents of this type should be expected to require multiple operational periods and a significant recovery phase as the incident is stabilized and transferred to a responsible party.

PREVENTION GUIDANCE

Several agencies offer guidance on preventing battery system failures of any size. Responders must be aware of applicable general industry standards, national consensus standards, and applicable fire/building codes. These codes and standards will vary for fixed facilities and other battery systems.

PREPAREDNESS GUIDANCE

A common recommendation from leaders in battery emergency preparedness includes the widespread use of devices certified by National Recognized Testing Laboratories (NRTL), such as Underwriters Laboratories (UL).

RESPONSE GUIDANCE

Firefighters will encounter battery energy systems of all sizes during all-hazard responses. The following guidance provides best practices for small cells, vehicles, and fixed facilities.

Micro-Mobility and Consumer Products Response Guidance

Firefighters are encountering failed small cells and modules during various incidents. Failed cells can be found in micro-mobility devices such as scooters, hoverboards, and small consumer products. When failed cells are encountered, the following best practices minimize damage to surrounding property while maximizing firefighter and public safety.

Use water to extinguish the fire. Flames from a failed cell should be cooled with a direct application of copious amounts of water. Note that a cell in thermal runaway may produce toxic gases and greater than normal heat, energy, smoke, and fire. Water application should continue until conditions are stabilized. A failed cell may produce its own oxygen, meaning that even smothered, submerged, or thoroughly soaked cells may still produce smoke, fire, and toxic gases.

Lithium-ion batteries or mobility devices involved in fire, found within a fire area, or subjected to elevated temperatures must be moved from the area in which personnel will be operating. The original location of stray cells should be documented for later investigative purposes if needed. This should be accomplished before overhaul operations begin. When a Lithium-Ion Battery or mobility device fire involves a serious injury, fatality, or potential crime, all personnel operating should be aware of the need for scene preservation prior to the arrival of Fire Investigators.

When possible, prior to an overhaul in the area of the lithium-ion battery or mobility device, personnel should conduct a diligent search for stray battery cells. These individual cells may have become dislodged from the battery pack during the fire or by the hose stream during extinguishment.

Firefighters must not place the lithium-ion battery pack or cells in the pocket of their PPE. All firefighters should be aware that popping, hissing, and/or white smoke/vapor can be an indicator of immediate battery cell failure.

When possible, personnel should move the lithium-ion batteries using a non-conductive tool (i.e., a shovel with a wooden handle) or other method that doesn't require firefighters to carry cells in their hands. Some agencies have a heavy fabric carrier/fire blanket for this purpose.

The batteries or mobility device should be moved to a location of the following nature until it can be appropriately packaged for disposal or otherwise mitigated by Hazmat:

- Outside the structure, away from firefighting operations
- Bathroom tub in a fire apartment, with all cells fully submerged in water.
- Sink large enough that all cells can be fully submerged in water.
- A garbage pail or bucket large enough that all cells are capable of being fully submerged in water.

*The submerged cells will produce Hydrogen, an explosive gas. Ventilation must be considered.

When the above options are not practical, the Incident Commander may remove the batteries or mobility device via a fire apartment window.

When the battery or mobility device is in a location that makes removal via fire apartment window not practical, such as in an upper-story apartment in a high-rise, the Incident Commander may move the batteries or mobility device to a different location on the fire floor and ensure the batteries are protected by a charged hose line. The charged hose line will remain in place until overpacking/mitigation procedures have been completed by Hazmat.

A lithium-ion battery should NOT be moved in an elevator with any personnel at any time. Elevators may be required to remove damaged cells. If necessary, elevators will need to be controlled and monitored.

Vehicle Fire Response Guidance

Any all-hazard response to vehicles that use any form of electrical energy should adhere to basic safety principles that include:

- Spot the apparatus and approach the incident from upwind and uphill when possible.
 - Throughout the incident, make every attempt to remain upwind of the incident, even in the recovery phase.
- Identification of the energy system involved.
 - Electrical.
 - Hybrid Electrical/Combustion engine.
 - Hydrogen/Compressed Natural Gas.
 - Other non-petroleum-based fuel.
- Immediately check for trapped victims.
- Ensure all personnel are wearing full structure fire PPE with a donned SCBA.
- If safe, chock the wheels or use some other form of vehicle stabilization. Never assume the vehicle is powered off and will not move. Vehicles powered by electrical motors move silently. Never assume they are powered off. Vehicles can move quickly and unexpectedly.

Vehicle Fires require additional guidance:

- Avoid the smoke and gases whenever possible; consider the use of a Positive Pressure Ventilation (PPV) fan.
 - This guidance is especially applicable in parking garages or subterranean areas that can trap smoke and/or gases.
- Attack the fire as a normal vehicle fire until it is determined that the battery energy system is involved.
 - Attack all vehicle fires from an angle.
 - Vehicle fires with battery involvement can produce jet fire that emits from the side of the vehicle.
- After confirming the batteries are involved, notify the Incident Commander.
 - If safe to do so, allow the batteries to discharge or consume themselves.
 - Protect exposures.
 - Consider establishing an isolation zone for non-emergency personnel (330 feet¹ recommended).
 - Establish an exclusion (hot) zone by using appropriate detection. Some incidents may require the need to evacuate greater than 330 feet.
 - If extinguishment is required, secure a water supply.

¹ 330 feet or 100 meters as determined by the Emergency Response Guidebook for gases.

- Incident stabilization may require copious amounts of water, likely in the thousands of gallons.
- The use of foam is not recommended.
- If full suppression is required, consider tilting the vehicle to gain access to the underside of the vehicle where the floor pan lithium-ion battery is most likely located.
 - Crib the vehicle as it is lifted.
 - Consider Heavy Rescue Response and/or USAR response.

During all-hazard vehicle response, it may be required to locate the main lithium-ion battery pack(s)/module(s). Refer to the Vehicle Emergency Response Guide published by each respective manufacturer for the specific make and model of the vehicle for guidance. The National Highway Traffic Safety Association (NHTSA) Emergency Response Guides provides standardized emergency response information for electric-powered vehicles (<https://www.nhtsa.gov/emergency-response-guides>). A Thermal Imaging Camera should not be relied upon to determine if an incident is stabilized. When overheated cells are encountered, cooling measures should be used if necessary. Note that a module may shield the thermal signature of a failed cell.

In preparation for the vehicle to be moved to a more permanent location, such as a tow yard, several steps need to be taken to minimize the risk of re-ignition. When possible, the vehicle is safest for towing when in “neutral”. Once the incident is stabilized, if possible, locate the main disconnect to isolate power to the main lithium-ion battery. Each vehicle has a specific process for disconnecting or isolating power. Refer to the manufacturer’s guidance. This can normally be done by removing the negative terminal from the 12-volt battery and cutting the “First Responder Loop”. Never cut, crush, puncture, or open a high-voltage battery during suppression or overhaul without certified equipment operated by trained personnel. If the cells are visible due to damage, a hose stream can be applied directly to the cells and/or battery pack. Observe the battery for signs of smoke, gas (often described as white “smoke”), and/or popping noises from the failed cells. If any of these are observed, the lithium-ion battery is in thermal runaway.

Once determined that the vehicle is safe for transport, release the vehicle to the tow company, ensuring it is towed on a flatbed. Wheel lift towing may send unwanted power to the lithium-ion batteries. The tow company is responsible for properly storing the vehicle and will follow applicable internal policies.

The scene of an incident involving a vehicle with an alternative fuel source must also be left in a condition that minimizes the potential for harm to the public or other responders when the Fire Department leaves. If any lithium-ion cells have come out of the battery

pack/module and are lying on the ground, request a HazMat response. Do not touch any battery that has been removed from the battery compartment. Battery cells are considered a form of hazardous waste that should be treated and disposed of properly.

BESS response guidance

Battery Energy Storage Systems (BESS) are available in a variety of sizes that range from small home units to large commercial occupancies that can be as large as a city block. The year 2020 is a distinct date due to the implementation of NFPA 855. The following points provide guidance for these fixed facilities:

- Smoke, gas, and/or a suspicious odor emanating from a BESS can be an indication of an abnormal and hazardous condition. Battery thermal runaway fires are often preceded by smoke and/or gas.
- When responding to an incident involving the failure of a BESS, perform the following:
 - Incidents involving the failure of a BESS should default to a defensive strategy. Any other action should involve consultation with facility personnel or an emergency response plan. Most large BESS facilities are remotely monitored and have emergency contact numbers posted.
 - Only the need for rapid extraction should involve immediate action by fire department personnel.
 - Approach, spot the apparatus outside the exclusion zone, and operate uphill and upwind whenever possible. It is typically not necessary to enter a BESS facility.
 - Evacuate the area of all non-emergency personnel. Consider the need for sheltering in place downwind of an incident.
 - Do not approach the unit and attempt to open any doors. BESS has a variety of safety mechanisms. Some are designed to keep the doors shut, and some have automatic doors designed to aid in ventilation.
 - If possible, shut off the unit/system.
 - If, after consultation with facility personnel, it is determined that shut-off equipment is located within the BESS facility, don full structure fire PPE and SCBA. The gases that may be emanating are toxic.
 - Consider initiating a HazMat response.
 - Maintain a safe distance from the unit and monitor for evidence of continued smoke/gas venting or fire.
 - There may be periods of time during which the thermal runaway propagates from a battery module to an adjacent battery module. During such time, the battery may not generate visible signs of a thermal event.
 - Follow agency-specific protocol.

- Allowing the failed cell(s) to burn, self-ventilate, and consume the failed pack/module is considered a best practice. Cooling exposures may be necessary.
 - Coordinate procedure with the site emergency contact or the product manufacturer.
 - Use a wide fog stream, at the lowest volume possible, to achieve the desired cooling of neighboring battery enclosures.
- There may be periods during which the thermal runaway propagates from the battery module to additional battery modules. During such time, the battery may not generate visible signs of a thermal event, although the event can still be active, and the battery can flare up.
- Allow the battery pack to cool down. Expect incidents of this type to require multiple operational periods. The need for resources required to monitor an incident involving a BESS will fluctuate during the cool-down period.

Portable power stations, battery generators and residential BESS that are not permanently mounted to a building may be treated similarly to a micro-mobility device. These can range from small portable power stations with built-in inverters to large portable residential BESS systems. Consider removing these from the occupancy to an isolated area if possible and safe to do so while wearing full structural PPE including SCBA.

RECOVERY GUIDANCE

A response to an incident involving alternative fuels, and specifically battery energy storage of any size, is not complete until damaged cells are removed from the scene. The true termination of an incident will require the collaboration of a variety of partner agencies. An incident involving batteries is complete when the threat to the public and environment is zero.

Responders will rely on agency-specific notification procedures to coordinate the response of partner agencies. The following agencies are provided as a resource:

- Law Partners - Local Law Enforcement and State Law Enforcement provide the necessary authority for criminal activity. Note that the California Highway Patrol currently has authority over state highways.
- CUPA - The State of California is divided into Certified Unified Protection Agencies (CUPA) jurisdictions. These agencies provide oversight for California Tier II fixed facilities that have reportable quantities of hazardous materials.

- HazWaste Disposal - All Cities, Counties, Districts, and Authorities having jurisdiction (AHJ) have a certified hazardous waste disposal agency. This agency will provide for the proper disposal of damaged battery cells.
- Department of Toxic Substance Control (DTSC) - DTSC exists to protect California's people, communities, and environment from toxic substances, to enhance economic vitality by restoring contaminated land, and to compel manufacturers to make safer consumer products.
- Environmental Protection Agency (EPA) - A State and Federal agency responsible for large-scale incidents. An On-Scene Coordinator (OSC) can provide a connection between the local responders and state and Federal resources.

This list is not exhaustive. Many other partner agencies will support the overall response and recovery effort of a battery emergency. Developing relationships and training with partner agencies prior to an emergency is a best practice that has been shown to result in more efficient emergency management.

Personnel Position Descriptions

All responders to any phase of an emergency involving Lithium-Ion Batteries or other forms of energy must be aware of the hazards associated with these systems. Lithium-ion battery incidents should include a risk management analysis. The appropriate hierarchy of controls must be implemented to guide actions and the development of an incident action plan. Additional training is available to enhance the capability of a responder.

Incidents involving Lithium-Ion Batteries have many variables. Actions taken should be based on a risk assessment of the conditions presented.

FIRST RESPONDER OPERATIONS - Members trained to the level of First Responder Operations (FRO) should be trained and equipped to engage in rescue and suppression activities while acknowledging the hazards associated with battery emergencies. FRO-trained members can be involved in the stabilization of scenes and the overhaul of incidents involving lithium-ion batteries.

HAZMAT TECHNICIAN/SPECIALIST - Members trained to the level of HazMat Technician or Specialist will be involved in air monitoring that can more accurately determine the nature of the atmosphere surrounding damaged cells. Technicians and Specialists can support the Incident Commander's decision-making process, which includes protective actions. These members can coordinate the notification of appropriate partner agencies.

HAZMAT ASO - Members trained to the level of Assistant Safety Officer (ASO) HazMat are able to provide site safety plans (ICS 208 HM). These members can assist incident commanders with strategy and tactics during incidents. Incidents that are determined to require a HazMat response must have an ASO-HM.

EQUIPMENT

All firefighters assigned to any duties near a damaged cell should wear structural firefighting PPE, including SCBA in operation, at all times when working near damaged lithium-ion batteries. Due to the rapid re-ignition danger when cells have been exposed to mechanical, thermal, or electrical insult, full PPE with a donned facepiece should be worn until the incident commander, through the risk management process, determines that a decreased level of respiratory protection will not result in hazardous exposure to employees.

Explosive, flammable, and toxic atmospheres will be present during these incidents. Consider identification, mitigation, and ventilation to address hazardous atmospheres.

During the overhaul phase of an incident, all responders should avoid moving cells by hand, even when wearing structural firefighting gloves. Full structure fire PPE with a donned SCBA should be used during overhaul. A long-handled tool can be used to move cells to a containment area or to an approved packaging meant for disposal. A containment area can be defined as a place where cells can be fully submerged individually.

Following an incident, all PPE and equipment used in the response should be decontaminated by following department policy. At a minimum, follow the CalOSHA adopted NFPA standard for PPE laundering and maintenance.

Persons involved in the recovery phase of an incident must be aware of the potential for sudden failure of cells. Despite the best efforts of all responders, cell failure can take place with little or no warning.

RECOMMENDED EQUIPMENT LIST

The equipment necessary to successfully identify and mitigate a battery emergency of any scale are currently available on standard fire department apparatus. The minimum equipment required includes the following:

RESPIRATORY PROTECTION: Self Contained Breathing Apparatus is required when operating near abused cells of any size. The sudden emission of toxic gases can only be adequately mitigated with full SCBA protection.

FULL STRUCTURE FIRE PPE: Traditional thermal-rated Structure Fire PPE is required due to the thermal threat that can appear with or without warning.

CELL CARRYING EQUIPMENT: All responders will require a variety of tools to carry cells from discharged locations to a collection point. This equipment could include shovels, fabric carrying tarps, buckets, etc. These tools will prevent firefighters from handling damaged cells by hand.

GAS MONITORING EQUIPMENT: A gas monitoring device is recommended. Users of a four-gas or equivalent device must be aware of the limitations of these kinds of devices. Gases related to battery emergencies may not always be detected by traditional four-gas monitoring devices that are calibrated to O₂, LEL/UEL, CO₂, and H₂S.

CONCLUSION

It's imperative that all first responders are aware of the associated risks in encountering an incident involving a battery emergency. All members should operate in a manner prepared for the potential of the rapid production of toxic and flammable gases involving any type of battery configuration. By increasing the understanding of cell construction, battery cell failure, and battery hazards, first responders will be more prepared to operate safely and effectively. Following standard operating procedures and understanding mitigation factors will ensure a successful overall outcome. Knowing which resources to request and which partner agencies to notify will allow for an effective response and minimize risk when dealing with battery emergencies. Statewide standardized lithium-ion battery emergency training should be disseminated statewide to responders.

GLOSSARY

Assistant Safety Officer (ASO): A person certified as a hazmat assistant safety officer assists the Incident Safety Officer and ensures the safety of personnel involved in hazardous materials incidents.

Battery Cell: An individual battery can be grouped together with several other batteries to build a battery module. Cell components include the anode, cathode, electrolyte, and separator. Electrolyte materials in lithium-ion batteries are often flammable.

Battery Energy Storage System (BESS): Rechargeable batteries that can store energy from different sources and discharge it when needed. Typically mounted at a fixed facility.

Battery Electric Vehicle (BEV): A fully electric vehicle that uses only battery power to operate.

Battery Management System (BMS): A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack) by facilitating the safe usage and a long life of the battery in practical scenarios while monitoring and estimating its various states (such as state of health and state of charge), calculating secondary data, reporting that data, controlling its environment, authenticating or balancing it.

Battery Module/Pack: A subassembly consisting of a group of cells connected either in a series and/or parallel configuration, with or without protective devices and monitoring circuitry.

Carbon Dioxide (CO₂): Colorless, odorless, tasteless gas. Heavier than air. At high concentrations, it can displace oxygen and act as an asphyxiant. During battery emergencies, CO₂ may be present in the atmosphere and be an asphyxiation hazard.

Carbon Monoxide (CO): Colorless, odorless, tasteless, flammable, and highly poisonous gas. During battery emergencies, it can be found at concentrations well above its IDLH of 1200 ppm and above its lower explosive limit (LEL).

Cell Reignition: physical damage or thermal damage resulting in an immediate or delayed thermal runaway event in individual battery cell(s) that is typically unpredictable in terms of time even after battery cells have cooled to ambient temperature.

First Responder Operations (FRO): All firefighters in California are trained to the hazardous materials FRO level.

Fuel Cell Electric Vehicle (FCEV): Also known as a hydrogen fuel cell vehicle. A type of vehicle that uses hydrogen as a fuel to generate electricity through a fuel cell. Firefighters can expect to find batteries and hydrogen in these vehicles.

Hybrid Vehicle (HEV): Hybrid vehicles are vehicles that use both battery power and some other form of flammable or combustible liquid or gas, the most common being gasoline.

Hydrogen (H₂): Colorless, odorless, tasteless, lighter-than-air gas not detectable by humans. It is highly flammable and explosive with a nearly invisible flame. Not soluble in water. During battery emergencies, hydrogen will be present, providing for the potential of a highly flammable and explosive atmosphere.

Hydrogen Sulfide (H₂S): Hydrogen sulfide (also known as sewer gas or swamp gas) is a colorless gas known for its pungent "rotten egg" odor at low concentrations. It is extremely flammable and highly toxic.

Hydrogen Fluoride (HF): Colorless, strong irritating odor. Highly soluble in water. During battery emergencies, hydrogen fluoride may be a byproduct of battery cell failure. Its presence may produce an acutely toxic atmosphere.

Insults: Damage to battery cells that can lead to failure. Types of damage include crushing, penetration, over-charging, internal short circuits, over-discharging, and overheating.

Micro-Mobility Device: A battery-operated device intended to transport a person. Examples include electric bikes, scooters, hoverboards, wheelchairs, skateboards, mopeds, golf carts, etc. For the purpose of this SOG, this also includes small consumer-level devices (phones, battery-operated tools, power packs, vape pens, etc.).

Oxygen (O₂): Colorless, odorless, tasteless gas. During battery emergencies, oxygen may be a byproduct of battery failure, which can sustain combustion even when submerged or smothered.

Plug-in Hybrid Electric Vehicle (PHEV): A plug-in hybrid electric vehicle (PHEV) is a type of hybrid electric vehicle that combines a gasoline engine with an electric motor and a rechargeable battery. Unlike conventional hybrids, PHEVs have larger batteries that can be charged by plugging into an external power source, allowing for a significant portion of the vehicle's driving range to be covered by electricity alone.

Portable Power Station: A battery generator that is not permanently attached to a structure. Products like this are transportable, mobile, and vary in size. Many have built in inverters and range in size from small portable units to large rack assemblies.

Positive Pressure Ventilation (PPV) fan: During battery emergencies, PPV fans can be utilized to disperse flammable and toxic gases to prevent explosive atmospheres and exposures.

Propagation: The spreading of fire between Lithium-Ion battery cells is initiated by a thermal runaway event.

Stranded Energy: Even after the battery packs/modules are severely burned, they may still retain a high-voltage electrical charge.

Thermal Runaway: Lithium-ion (Li-ion) battery thermal runaway occurs when a cell, or area within the cell, achieves elevated temperatures due to thermal damage, mechanical damage, internal/external short-circuiting, or electrochemical abuse. This elevated temperature releases energy, which in turn further increases the temperature. It is a phenomenon known as a positive feedback loop in which the lithium-ion cell enters an uncontrollable, self-heating state.

Volatile Organic Compound (VOC): Flammable, toxic, and carcinogenic chemicals that easily evaporate into the air at room temperature. During battery emergencies, VOCs can be found in the atmosphere, creating a toxic and flammable environment.