Firefighters Injured Following Toxic Exposure During Electric Vehicle Lithium-ion Battery Thermal Runaway Event – California

Executive Summary

Figure 1. Damaged electric vehicle at the scene of the incident. Photograph provided by the fire department.

On April 11, 2025, at approximately 22:00, a Tesla Model 3 struck a tree in a single-vehicle crash in a residential neighborhood. Firefighters were dispatched for a motor vehicle accident with major injury. Soon after arrival on scene, responding personnel realized that the vehicle’s lithium-ion battery pack had been severely damaged, with battery cells scattered across the roadway. Damaged lithium-ion batteries can experience thermal runaway, a self-accelerating failure that produces heat and can release flammable gases, toxic fumes, or cause fire or explosion. Due to the concern for potential thermal runaway, the incident was upgraded to a Level II (moderate) HAZMAT response.

After arrival of HAZMAT team members, there were approximately 15 fire department personnel on scene. After extrication of the vehicle’s driver, firefighters began cleanup efforts, placing battery cells into 55-gallon water-filled drums. After the battery cells were removed from the roadway, firefighters were instructed that they could begin doffing their personal protective equipment (PPE). Simultaneously, a tow truck arrived and began moving the damaged vehicle. As the vehicle was being loaded onto the tow truck, the portion of the damaged battery that remained in the vehicle entered thermal runaway and released a large smoke plume. The plume enveloped some of the firefighters, who had removed their PPE and were no longer breathing from a controlled air source, or “on air”. Firefighters reported immediately experiencing a “metallic” “acrid” taste. The duration of firefighter exposure to the smoke plume varied by firefighter, ranging from a few seconds to five minutes. Shortly afterward, five firefighters began experiencing serious health effects, with three receiving treatment in the emergency department that night and two the following morning. At the time of this investigation in the spring of 2026, four of the affected firefighters remained out of work due to ongoing symptoms from this exposure. Their primary symptom has been shortness of breath on exertion that prevents them from performing essential firefighting job functions. The department has reviewed and updated their standard operating guidelines to prevent similar future incidents, as the number of electric vehicles on the road continues to increase.

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Key Recommendations

NIOSH offers the following recommendations to reduce the risk of toxic exposure and the risk of injury and/or illness among firefighters responding to electric vehicle and lithium-ion battery incidents, at this and other fire departments across the country. Many of our recommendations cite relevant National Fire Protection Association (NFPA) standards, which are periodically updated. Please note that it is our practice to cite the version of each standard in effect at the time of the injury. Each incident is unique, and our recommendations might not apply in every circumstance.

- *Key Recommendation #1: Ensure firefighters operating within established hazard control zones at all damaged vehicle incidents are protected from respiratory hazards by requiring the use of self-contained breathing apparatus (SCBA) in potentially hazardous, unknown, or immediately dangerous to life or health (IDLH) atmospheres. For confirmed electric vehicle (EV) and lithium-ion battery (LIB) incidents, maintain respiratory protection for personnel within the hazard control zones throughout EV/LIB suppression, handling, and removal when thermal runaway or battery off-gassing remains possible.*
- *Key Recommendation #2: Fire departments should identify hazard control zones for each EV/LIB incident using a risk assessment method, such as HAZMAT incident modeling software, that incorporates environmental and structural factors.*
- *Key Recommendation #3: Train firefighters on the signs and indicators of a thermal runaway event in EVs/LIBs and the associated physical and chemical hazards.*
- *Key Recommendation #4: Firefighters should be familiar with symptoms of EV/LIB exposure and should seek medical care immediately if experiencing symptoms after a response. Fire Departments should develop procedures for reporting, documenting, and medically evaluating firefighters who experience symptoms following potential exposure during EV/LIB incidents consistent with NFPA 470 and OSHA 1910.*
- *Key Recommendation #5: Firefighters should conduct on-scene preliminary exposure reduction, isolate PPE, and store contaminated gear outside of the passenger compartments of vehicles according to NFPA 1850.*
- *Key Recommendation #6: Ensure standard operating procedures for handling damaged EVs/LIBs follow NFPA Standards and manufacturers' recommendations.*
- *Key Recommendation #7: Firefighters should undergo an annual physical examination to assess fitness for duty. Existing departmental policy regarding annual examination for HAZMAT team members should be enforced.*

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Introduction

On April 11, 2025, firefighters (FFs) were exposed to a smoke plume produced by the lithium-ion battery (LIB) pack of a Tesla Model 3 that entered thermal runaway following a motor vehicle collision. Five FFs sought medical care for severe health effects related to the exposure, and as of the time of this investigation in the spring of 2026, four of these FFs were still unable to return to duty due to ongoing symptoms.

Between February 17 and March 20, 2026, occupational health and safety specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated this incident. NIOSH investigators interviewed the following people:

- Department leadership
- FFs
- Medical providers
- City health and safety officials

The NIOSH investigators reviewed the following documents:

- Fire department (FD) preliminary summary report (Green Sheet)
- FD standard operating procedures for electric vehicle fires
- Medical records of 5 FFs
- LIB storage policy from FD
- Map of the location of the incident
- National Fire Incident Reporting System records
- Photographs of the incident
- Respiratory protection program information from FD

Fire Department

The department is a career FD that responds to incidents involving fires, medical emergencies, hazardous materials, and technical and water rescues. The FD operates 24 fire stations across 8 districts from which it deploys 24 engine companies, nine truck companies, 19 Advanced Life Support ambulances, a rescue company, three swift water rescue teams, and two HAZMAT response teams. Fire suppression companies are staffed with a Captain, an Engineer, and two FFs. The FD is responsible for approximately 145 square miles and responds to approximately 110,000 calls each year, providing service to approximately 530,000 residents and over 20,000 businesses in the city. The FD houses an established emergency medical services (EMS) division that responds to over 90,000 medical calls annually. The EMS Division works as a stand-alone division within the fire department and is overseen by a deputy chief and operates within the policies and procedures of the city, fire department and local EMS authority. The EMS division delivers both Advanced Life Support and Basic Life Support services, staffing a minimum of one firefighter-paramedic and one firefighter-emergency medical technician (EMT) to each unit. The FD employs more than 760 uniformed personnel. The FD follows a shift configuration of 48 hours on duty followed by 96 hours off duty.

Membership and Training

Requirements to join the FD include possession of a high school diploma or GED, age of 21 by academy completion date, possession of a California Class C Driver's license, and satisfactory completion of a background investigation, medical evaluation, and drug test. Candidates must also possess a valid Candidate Physical Ability Test (CPAT) certificate at the time of appointment issued within 12 months from the start date at the Fire Academy. They must reside within 35 air miles from designated coordinates, maintain facial hair requirements, and adhere to the smoke-free workplace policy. Those entering as Fire Recruits must successfully complete the FD-sponsored Fire Academy, through which they will gain NFPA 1010 Firefighter I and II training as well as EMT certification. Following the academy, recruits are encouraged to pursue paramedic training. Throughout employment as firefighter-paramedics and firefighter-EMTs, the EMS division holds regular training to maintain skills and certifications. This includes multi-company and multi-agency drills that may include law enforcement and hospital staff to train for large scale events.

Preplacement/Periodic/Return to Work Medical Evaluations

Every new FF undergoes a pre-placement physical examination after they receive a conditional job offer, but prior to beginning work. These exams are coordinated by the Risk Management division of the city's Human Resources Department and are conducted at one of several local medical offices contracted by the city. Investigators did not receive information on what these examinations involve. The city does not receive any specific exam results, but rather a form that simply indicates that the candidate is medically "acceptable without restrictions," "acceptable with restrictions," or "ineligible" for service.

The department does not have a requirement for annual medical examinations for its members. The department periodically offers comprehensive department-sponsored physical exams, provided through a third-party company, but availability is dependent on grant funding.

Per department policy, HAZMAT team members are supposed to undergo a baseline physical examination on entry to the program, followed by annual physical examinations to assess fitness for duty. OSHA Standards also state that “Members of an organized and designated HAZMAT team and hazardous materials specialists shall receive a baseline physical examination and be provided with medical surveillance” as described in OSHA 1910.120(f) [OSHA 2025]. The FFs interviewed for this investigation were HAZMAT team members and reported undergoing an initial examination upon assignment to the team. However, they stated that they have not consistently received annual exams subsequently. The components of the initial exam also seemed to vary between members, with some receiving a more comprehensive assessment than others. City management notes that the annual exam policy for HAZMAT members has not always been followed in recent years. Per city management, members are offered another physical exam when exiting the HAZMAT program, though it is not mandatory. This usually occurs upon retirement.

After a FF experiences an on-duty exposure, one of the department’s two EMS officers is notified. An exposure report is then completed and sent to the city’s Human Resources office. If a FF is transported to the hospital after an on-duty incident, all chiefs receive a notification. If needed, the notified EMS officer will meet the FF at the hospital. Per city management, there was at one point a plan for all FFs who experienced an exposure to visit a contracted occupational health provider for evaluation, but the volume of occupational health visits overwhelmed this program. Therefore, the plan transitioned to FFs seeking care only if they self-assess and decide they need it.

No written return-to-work policy was available for review but per discussion with department leadership, if a FF is injured on duty, they must undergo medical evaluation before resuming their usual duties. For members missing work for non-workplace injuries or medical issues, the requirement for a return-to-work medical evaluation depends on the specific injury or illness. Heart and lung disease reportedly have more stringent return-to-work exam requirements than non-cardiopulmonary illnesses and injuries. If the illness or injury is work-related, the return-to-work evaluation is processed through the city’s workers’ compensation program. If it is not work-related, the FF must work with their personal physician to arrange medical evaluation. The examining physician may deem the FF “suitable” for return to duty, “suitable with restrictions,” or “not suitable.”

Investigation

On April 11, 2025, at 22:04, crews were dispatched for a motor vehicle accident (MVA) involving an electric vehicle (EV). The weather conditions were clear with light winds from the south/southwest ranging from 4–13 miles per hour, and an approximate temperature of 63°F (17°C). The initial dispatch was for an MVA with major injury, passenger entrapment. Upon arrival at 22:09, the Battalion Chief from Battalion 1 — who served as the initial Incident Commander (IC1) and Medic 1 (M1) — discovered a single EV had struck a tree and was heavily damaged from a front-end collision (Figure 1). At 22:14, Engine 1 (E1) arrived on scene. Some later reports characterize this incident as an “EV fire” and describe the LIB thermal runaway event as a “reignition.” However, during interviews, FFs who responded to the incident consistently report that the vehicle did not exhibit flaming at any point during the event. Initial reports also described the vehicle as a Tesla Model S. However, the vehicle’s Vehicle Identification Number (VIN) indicates that it was a Tesla Model 3. Determination of the exact vehicle model allowed investigators to incorporate battery size into plume modeling for this

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report. However, rapid on-scene determination of vehicle model can be difficult and is not required for firefighter decision making [Barowy et al. 2026].

Crews identified one occupant in the vehicle and were able to successfully extricate them by cutting the passenger-side door. The PPE worn for this phase of the response is unknown, but standard procedure for this uncomplicated part of the response was assumed to be turnout gear. E1 crews initiated patient care. At 22:18 M1 transported the patient to the emergency room, arriving at 22:33. A timeline of this incident describing arrival and departure times of personnel is available in the Appendix.

On-scene personnel identified the risk for LIB thermal runaway. They noted over 400 battery cells from the vehicle's battery pack scattered across the roadway, some of them making a popping sound and producing small whiffs of smoke. IC1, located at the established incident command post (ICP), approximately 150–200 feet from the vehicle, consulted with the Shift Commander and the Captain managing the HAZMAT program (C1) and requested backup. At 22:38, the incident was upgraded to Level II HAZMAT, with HAZMAT Engine 1 (HM1), HAZMAT 2 (HM2), and Special Operations 1 (SO1) dispatched to the scene. There were no noticeable winds, and the crews were unaware of the wind direction. Command and the HAZMAT units positioned themselves approximately 200 feet north of the EV incident. As additional crew were dispatched, Captain 2 (C2) arrived on scene, met with IC1 to discuss the plan and was briefed on the potential exposure hazards of the incident.

As shown in Figure 2, a hot zone was created at 50–75 feet (within the red line), as well as a 150–foot support zone (yellow line), and a full evacuation zone at 300 feet (blue line). The decision was made not to notify area residents because "sheltering in place" was already occurring due to the late hour and street access being blocked at both ends.

Figure 2. Map of the incident indicating the zones established around the damaged vehicle, as well as the locations of personnel. (*Image provided by the fire department.)*

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At approximately 22:55 an Assistant Chief (IC2) self-dispatched and took over as IC while IC1 moved over to engine and suppression work. A plan was developed to clean up the incident while maintaining the safety of on-scene personnel and the public. First, FFs were instructed to collect loose battery cells from the roadway, place them in 55-gallon drums filled with water, and take them off site. A flatbed truck (T1) was called at 01:20 to assist with cleanup efforts. Upon arrival, T1 parked approximately 300 feet away from the incident due to the debris field on both sides of the road, which included individual battery cells. Due to generally known risks associated with EV batteries, crews actively working in the hot zone were instructed to don SCBA respiratory protection.

IC2 sent FF1 and FF2 as the entry team to de-energize the EV battery by cutting the first responder loops. It is unknown if the battery management system was functioning. First responder loops are low voltage harnesses and when cut, shut down the high voltage system outside of the battery. The manufacturer's guidance for first responders states that "disconnecting and safely de-energizing the vehicle's battery during extraction is necessary" [Tesla, 2026]. The manufacturer cautions that first responders should always assume that "all high voltage components are energized" [Tesla, Inc., 2017]. Guidance from fire department incident documentation states that the loop should only be cut if the "action supports life safety or rescue and can be performed safely;" it further cautions the loops should not be cut if the "battery pack is smoking or showing other signs of instability" as the system may still be cooling the battery thus preventing an escalation. In this situation, it is unclear if the battery pack was showing any signs of instability.

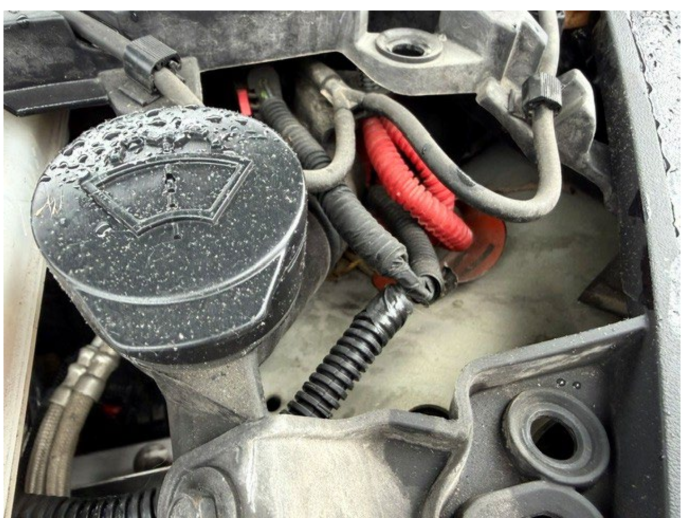

Figure 3a. Tesla First Responder Loops
(Photo by NIOSH)

Figure 3b. Tesla First Responder Loops
(Photo by NIOSH)

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FF1 went back into the support zone and sent in another 2-person crew including FF2 to load the loose battery cells into drums. Once all the batteries were cleared from the road, IC1 felt it was safe to call in the tow truck to remove the EV. The drums containing the loose battery cells became noticeably warm, so FF1 and FF2 used a thermal imaging camera to ensure the contents and drums were not becoming too hot for transport. FFs also used acidity and fluoride detection papers to assess smoke from the drums and reportedly had negative findings. The tow truck arrived on scene. While crews were loading the drums onto T1, the tow truck driver loaded the EV onto the tow truck. Some FFs, believing that the incident was over, doffed their PPE in the designated support zone and began to break down the scene.

During movement of the EV onto the tow truck, its damaged battery entered thermal runaway. Thermal runaway is defined by the United States Fire Administration (USFA) as a “rapid uncontrolled release of heat energy from a battery cell that creates more heat than it can effectively dissipate” [USFA 2025]. LIB cell thermal runaway produces toxic decomposition products, a complex mixture of gases, vapors, and fine particles, collectively referred to as a smoke plume. The flammable gases and vapors from thermal runaway, commonly referred to as “battery gas,” often ignite to produce fire behavior unique to LIBs, but in this case, the battery gas reportedly vented without flaming [Barowy et al. 2026]. Personnel on scene reported seeing a white smoke plume begin to emanate from the EV as it was loaded on the tow truck.

Personnel present at the scene consistently described the smoke plume as dense and low-lying, noting that rather than dissipating upward like typical smoke or steam, it traveled primarily horizontally across the ground. They reported no signs of black smoke and no hydrocarbon combustion. Water from E1 was promptly applied to the vehicle battery pack.

A HAZMAT Captain (C3) was parked 250–300 feet away from the EV, at the command post, but did not have a direct line of sight due to the curvature of the street. C3 was 150 feet from the command post when he heard over the radio that “reignition” had occurred. C3 walked over to the command post to get a visual and heard radio communication indicating that “knockdown” had occurred. C3 assumed from this information that there had been a fire, which was now out. He started to walk back to his vehicle but then noticed that the white cloud was not moving like normal steam and was not dissipating. He began running to distance himself but was overtaken by the plume for an estimated 3–5 seconds. Crews from E1 were upwind and not wearing SCBA at the time of the plume, the tow truck driver was approximately 15–20 feet upwind of the vehicle, and two members who were still wearing SCBA were approximately 30–40 feet downwind (wind conditions were looked up following the incident from a weather application as no noticeable winds were observed by crews). Crews staged approximately 200 feet away, off air, realized they were downwind as the plume moved in their direction. C1 immediately ordered everyone to back up to at least 350 feet away.

Crews began evacuating the scene as quickly as possible. A 150-foot charged hoseline attached to HM1 was approximately 100 feet from the EV and needed to be bled (release trapped air or water) and be disconnected. As the large plume moved in their direction and eventually overtook them, FF1, FF2, and FF3 worked to disconnect the hoseline. These FFs had already doffed their SCBA. FF1 and FF2 moved closer to the EV, walking to the hose nozzle and back while in the smoke plume. FF2 stated he tried to hold his breath while doing this to avoid breathing in the smoke. The FFs experienced difficulties disconnecting the hoseline so the task took longer than usual. FF3 stood outside the driver's side of HM1 to assist the driver back into the nearby parking lot to turn around and vacate the area of the plume. C2 reports spending 4–5 minutes in the plume while assisting in breakdown of the scene and evacuation of the rigs.

C2, C3, FF1, FF2, and FF3 were exposed to the smoke plume without respiratory protection. The circumstances and duration of their exposure are detailed in Table 1. All began experiencing negative health effects of the exposure while still on scene. However, they continued working through the conclusion of this incident. FF3 became acutely ill and was transported directly from the scene to the emergency department (ED). FF2 and C3 were also seen in the ED that night. FF1 and C2 presented for care the following morning.

Additional medic (M2) and engine (E3) crews arrived on scene to follow the tow truck and HAZMAT to storage. Approximately 15 minutes following the plume onset, after it had dissipated, T1 left the scene with the battery cell-filled 55-gallon drums. HAZMAT crews followed the truck with the drums to the city lot where they would be stored. The tow truck driver was instructed by IC2 to leave the tow truck and EV on the road if it again experienced thermal runaway while in route and more resources would be called in to create another HAZMAT incident. The EV was taken to a yard where other EVs that have been in accidents are stored. The crews ensured there was ample space around the vehicle and that nothing flammable was nearby. IC1 also briefed employees at the storage yard on what to do if the vehicle again experienced thermal runaway.

Staffing of the initial incident included 4 members on E1, 4 on T1, 2 on M1, and 1 Battalion Chief (IC1). At the time of the thermal runaway, staffing had been upgraded to 4 on E1 (E1 was located 20–50 feet upwind), 2 on M1, 4 on HM1, 4 on E3, 4 on T1, and 3 chief officers.

During this event, decision-makers acted based on the best information available at the time. Emergency response to EV and LIB incidents remains an evolving field. Scientific understanding of the hazards continues to develop alongside rapidly advancing battery technologies. As research, incident experience, and industry guidance expand, recommendations and operational practices will likely continue to be refined.

Medical Findings

FF1, FF2, FF3, C2, and C3 sought medical care for injuries sustained during this response. At the time of their interview for this investigation, approximately 11 months after the incident, FF1, FF2, C2, and C3 remained out of work due to ongoing health effects of their injuries. FF3 experienced acute illness but fortunately recovered without complication and returned to work within days of the incident.

FF1 is a 41-year-old male firefighter, FF2 is a 37-year-old male firefighter-paramedic, and FF3 is a 33-year-old female firefighter-EMT. C2 is a 48-year-old male with 26 years of experience in the fire service, and C3 is a 54-year-old male with 25 years of experience. Though some of these individuals report having previously held jobs in other fields of work, none reported working with hazardous materials in their other jobs, or having occupational exposures not associated with firefighting.

Description of Symptoms

An in-depth interview of each affected FF was conducted to develop a comprehensive picture of their activities during this response and their post-exposure health effects. Their medical records pertaining to this incident were requested and reviewed with the FFs' consent. The symptoms reported by each FF during the interview and documented in their medical records were similar, though not identical. Table 1 summarizes each FF's on-scene activities, the circumstances of their exposure, and their acute symptoms, as determined through interview and medical record review.

Table 1. Summary of personnel, their activities, and their acute clinical presentation after exposure to the EV's thermal runaway smoke plume

Personnel	On-Scene Activity Summary	Acute Symptom Summary
FF1	• Was caught in smoke plume while attempting to disconnect charged hoseline from E3 approximately 100–150 feet from EV • In plume for 3–5 minutes without respiratory protection	• Experienced metallic taste, burning throat, burning eyes, runny nose, coughing to clear throat, overproduction of mucous • Initially returned to the station, did not immediately seek care • Woke up after 4 hours of sleep due to coughing up white sputum • Went to ED for evaluation the following morning
FF2	• Was caught in smoke plume while attempting to disconnect charged hoseline approximately 100–150 feet from EV • In plume for 2–3 minutes without respiratory protection	• Experienced immediate metallic taste, throat pain, lightheadedness • Went directly from accident scene to ED

FF3	• Was caught in smoke plume while attempting to disconnect charged hoseline approximately 100–150 feet and assisting with spotting of HM1 during backing at 350 feet away • In plume for 2–3 minutes without respiratory protection	• Experienced immediate metallic taste • Two minutes into drive to storage lot, experienced intense nausea and multiple episodes of vomiting • Transported immediately to ED by EMS for evaluation
C2	• Stationed at command post approximately 250 feet away from the EV • Was at command post breaking down equipment at the conclusion of the response when overtaken by smoke plume • In plume for 4–5 minutes without respiratory protection	• Reported bitter, acidic taste in mouth and scratchy throat while on scene • After several hours, throat was feeling more painful • Went to ED for evaluation the following morning
C3	• Was stationed at the command post approximately 250 feet away from EV at the time of exposure • Heard there was EV "reignition" so walked closer to get a visual • Realized that the smoke plume was not behaving like typical smoke and ran to try to get out of the way • Was caught in the plume without respiratory protection for 3–5 seconds	• Reported immediate metallic taste in mouth • Experienced nausea but no vomiting • Went directly from incident scene to ED

The only acute symptom experienced by all affected FFs was an immediate metallic taste upon encountering the smoke plume. This taste was further described by different individuals as "acrid," "acidic," and "like pennies." The tow truck driver and 4 FFs on E1 that were positioned 50 feet upwind did not report experiencing this symptom, so it appears that only personnel downwind of the EV at the time of the thermal runaway experienced the metallic taste.

FF1, FF2, C2, and C3 also experienced varying degrees of mucous membrane irritation, primarily manifesting as throat pain while on scene. FF3 did not report throat irritation but instead developed nausea with vomiting. Notably, FF3 reported developing a migraine earlier that day, and though by the time of her shift she felt well enough to work, she believes it is possible that the smoke plume exposure exacerbated her existing migraine symptoms.

FF2, FF3, and C3 proceeded directly from the scene to the ED for evaluation. FF3 was transported via ambulance. FF2 and C3 followed driving the engine. FF1 and C2 felt well enough to return to the station that night but decided to be evaluated in the ED the next morning. All received basic laboratory testing, including a complete blood count and blood chemistries assessing electrolyte levels and markers for kidney and liver function. All labs were normal. They also underwent chest x-ray, which revealed clear lungs with no sign of pathology. The affected FFs reported that ED staff acknowledged their concern about LIB exposure but were unsure how to assess for or manage potential sequelae. None of the FFs received testing for toxic metal exposure in the ED.

FF3 was discharged home after several hours in the ED. At an occupational health clinic follow-up 3 days later, FF3 was experiencing only residual fatigue, with complete resolution of nausea and vomiting and no interim development of additional symptoms. FF3 was recommended to take one rotation off but was otherwise able to return to work without issue and has experienced no lasting ill effects from this exposure. FF1, FF2, C2, and C3 were also evaluated at an initial occupational health clinic visit within a few days of their exposure. Like FF3, they were instructed that they could return to work once they were feeling well enough. However, unlike FF3, their symptoms worsened over the subsequent weeks. They developed worsening dyspnea on exertion, cough, fatigue, palpitations, and reported measuring elevated heart rates even at rest. Within approximately a month, each had experienced new-onset hypertension, or elevated blood pressure, and each eventually required initiation of blood pressure medication. At follow-up visits in the occupational health clinic, they were restricted from duty pending further evaluation.

Months after the initial injury, affected FFs developed brain fog, irritability, and other mood changes. Along with persistent dyspnea on exertion, these behavioral health effects contributed to a decline in overall quality of life. They attributed some late-onset symptoms to their post-exposure treatment, noting bothersome medication side effects in some cases.

With a sample size of only 5 FFs and variability between presentations, it is not possible to state conclusively from available information the typical health effects after a LIB or EV exposure. However, similarities between FFs are observed. A timeline showing the general pattern of symptom onset among affected FFs is presented in Figure 4.

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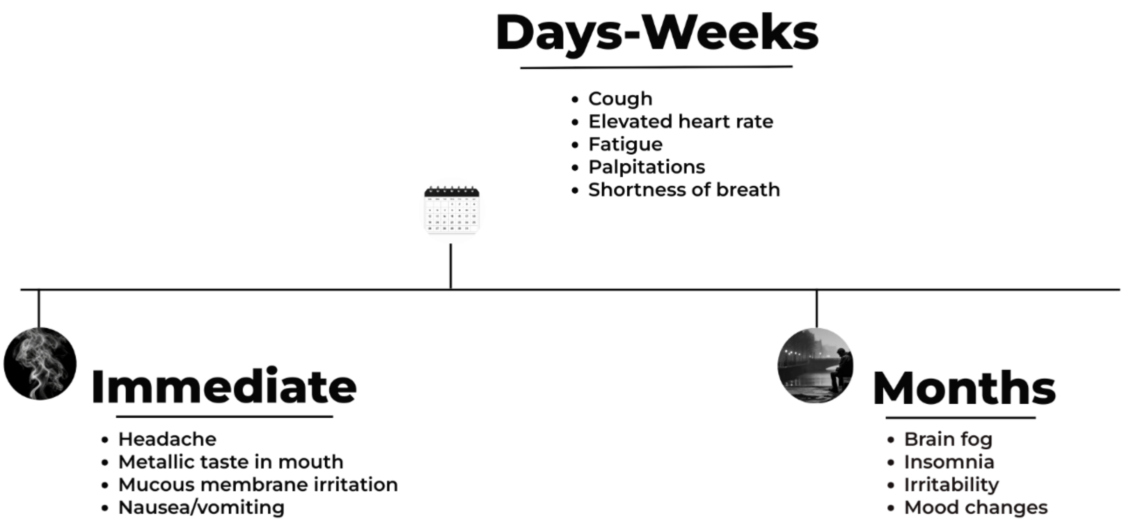
Figure 4. Timeline of selected signs and symptoms experienced by the affected firefighters



At the time of this investigation, the affected FFs had been living with the health effects of this exposure for almost a year. In that time, they experienced many signs and symptoms, of varying timing and intensity. To describe the key medical findings of this investigation as clearly as possible, the narrative description of FF's signs and symptoms focuses primarily on those common to most or all FFs. A full accounting of the number of FFs reporting each sign and symptom included in the medical questionnaire is provided in the Appendix.

Notably, several additional personnel present at the scene experienced symptoms consistent with an exposure but did not seek medical care. Therefore, they had no medical records for review and were not categorized as affected. These persons were interviewed on their role in the incident as members of department leadership, and they mentioned their symptoms during interview. One noted a metallic taste in his mouth on-scene, and then headache, nausea, dyspnea, and fatigue shortly afterward. He had mostly recovered within 4 days after the incident, though had persistent fatigue for several months. Another noted a metallic taste, followed shortly by flulike symptoms. A sore throat and body aches lasted approximately 2 days and then resolved. Their on-scene activities and symptoms are documented in the Appendix. Several others present at the scene reported a metallic taste, but they did not develop any additional symptoms. During interviews, several FFs noted a trend of members "catching a cold" or having flulike symptoms after a fire involving LIBs, though the numbers of such FFs were not documented.

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Medical Findings

The severity of health effects experienced by each FF was evaluated objectively with physical examination, measurement of vital signs including oxygen saturation, imaging, and pulmonary function testing (PFT).

Findings on physical examination were minimal throughout the illness course. Three FFs were noted to have erythema, or redness, of their throat on initial examination in the ED. One of these FFs then developed blistering on the roof of his mouth within approximately 1 week after the incident. This open lesion required treatment with medicated mouth rinses and took weeks to heal. None of the affected FFs displayed any other skin rashes or contact burns.

Lung auscultation findings were generally normal. However, at an early occupational health visit, C3 had diminished breath sounds at the lung bases, indicating decreased air entry. Despite normal findings on an examination of the lungs, FF1 displayed hypoxia requiring prescription of supplemental oxygen starting approximately 3 months after the incident. FF1 experienced blood oxygen desaturation to 86% during 100-meter ambulation and required 2 liters per minute of supplemental oxygen with exertion to maintain blood oxygen saturation ≥ 90%. This supplemental oxygen requirement was ongoing at the time of this investigation. The other FFs were able to maintain oxygen saturations above 90% without supplemental oxygen but reported readings lower than what was typical for them prior to this exposure. For example, C3 reported a self-measured oxygen saturation of 90% immediately after the incident. FF2 had measurements of 92–93% measured at multiple medical visits. Overall, though only FF1 required oxygen supplementation, all four who experienced long-term health effects seemed to have had a decrease in oxygen saturation from their baseline after the incident, particularly when measured during ambulation.

FFs in this case were evaluated with a variety of chest imaging modalities, including chest x-ray, computed tomography (CT), high-resolution CT for more detailed images of the lung tissue, and CT angiography for visualization of pulmonary blood vessels. Imaging results were mixed, with some FFs having consistently normal imaging and some with detectable lung abnormalities. C2 underwent CT angiography of the chest approximately 2 months after exposure, which identified bilateral dependent atelectasis of the lower lungs with no abnormal interstitial thickening. This is a nonspecific finding that indicates the alveoli, or air sacs, in the lower lungs are not fully expanding, but it does not indicate why. The lack of interstitial thickening means that there does not appear to be scarring of the lung tissue. Per C2's pulmonology specialist, this indicated that his lung parenchyma (alveoli and supporting tissue) was not damaged, though the airways leading to the alveoli might not be functioning properly. On high-resolution CT, C3 was found to have similar lung findings, with bilateral lower lobe opacities interpreted as compatible with atelectasis or pneumonitis and mosaic attenuation of the left lower lobe. Mosaic attenuation is a way of describing a patchy appearance on CT imaging. Although it has multiple causes, it is commonly associated with dysfunction of small airways and air trapping that is seen in asthma or chronic obstructive pulmonary disease (COPD).

PFT provided one of the clearest objective measurements of lung injury in this case. Each FF had several PFTs performed in the months after their exposure. Although baseline PFT results were not available for review, each FF reported prior normal PFTs, most recently during a department-sponsored physical approximately 1.5 years before the incident. Three affected FFs reported a history of childhood asthma not requiring treatment in many years, and two reported a history of obstructive sleep apnea. All are lifelong nonsmokers, and none reported a prior COPD diagnosis. PFT results from April (3 days after the incident) to December 2025 were available for FF1, C2, and C3 (Figure 5).

Forced vital capacity (FVC) is the total amount of air a person can exhale after a full breath. An FVC value lower than expected for a patient's age, sex, and body size indicates possible restrictive lung disease, in which the lungs cannot fully expand during inhalation. An example of a restrictive lung disease is pulmonary fibrosis, which causes stiffening of the lung tissue. Forced expiratory volume at one second (FEV1) is the amount of air that can be exhaled in the first second of forcible exhalation. An FEV1 value lower than expected could indicate the presence of an obstructive lung disease that prevents air from moving out of the lungs efficiently. An example of an obstructive lung disease is COPD, where damaged alveoli lose elasticity and do not expel air effectively during exhalation. It is possible for a single individual to have coexisting restrictive and obstructive lung disease.

Treating pulmonologists diagnosed each FF with reactive airway disease (RAD) secondary to inhalation injury. RAD is an obstructive process, in which an inciting factor like exercise or smoke exposure causes bronchospasm and difficulty breathing. In between bronchospasm episodes, breathing can be normal. This is consistent with the intermittent nature of the FFs' symptoms; they would sometimes feel well at rest but then would have episodes of extreme dyspnea with exertion or after smoke or pollen inhalation. Interestingly, only C2 showed improvement in their PFT results after bronchodilator administration. All values reported above are pre-bronchodilator measurements.
At the time of RAD diagnosis, their medical providers expressed that this condition could improve with time and that symptomatic management with inhalers and pulmonary rehabilitation could provide some relief while the FFs waited for their lungs to heal. However, improvement has been very slow, and at the time of interview in early 2026, their respiratory symptoms were still debilitating.

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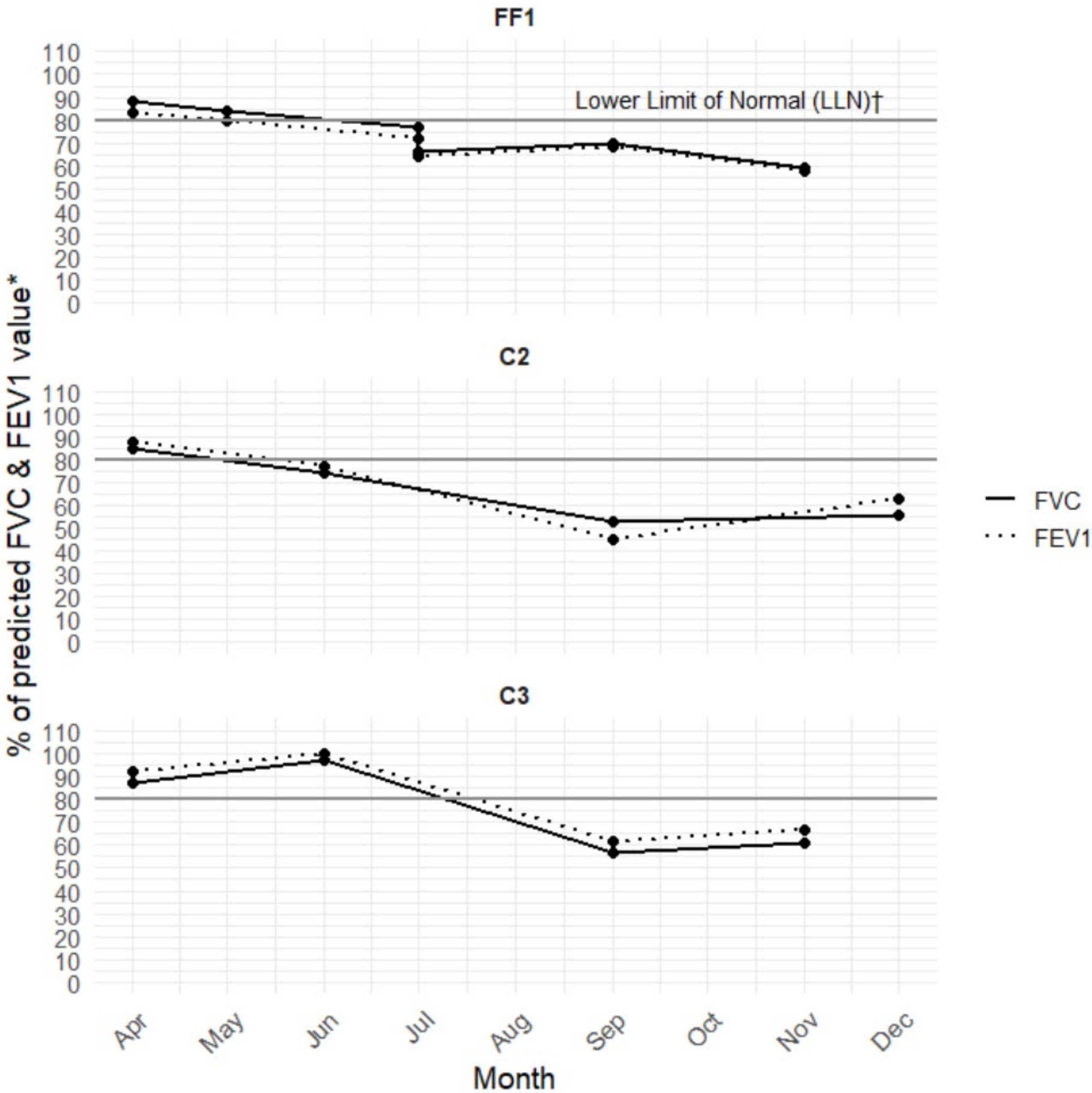
Figure 5. Graph of changes over time in pre-bronchodilator forced vital capacity (FVC) and forced expiratory volume at one second (FEV1) in three affected firefighters, 2025



*A predicted value for FVC and FEV1 is reported in each firefighter's medical record, and is based on age, height, sex, and ethnicity.

†The lower limit of normal (LLN) is reported in the medical record and is defined as the 5th percentile of predicted values (Z-score –1.645). For each of these firefighters, the LLN is approximately 80% of the predicted value of both FVC and FEV1.

None of the FFs took antihypertensive medication before this incident. All reported previously normal blood pressures. Within approximately a month after this incident, FF1, FF2, C2, and C3 were experiencing elevated blood pressures. Most readings at medical appointments were around 140/90 mmHg, but some readings were as high as 160/100. C3's blood pressure was especially difficult to control, requiring initiation of multiple antihypertensive medications. He noted numbness and tingling in his hands and feet which he associated with episodes of high blood pressure.

Multiple FFs reported palpitations and tachycardia, or a high heart rate, developing within a few days after this incident. Cardiac evaluation with electrocardiography, treadmill stress testing, transthoracic echocardiography, and coronary artery calcium computed tomography were consistently normal aside from incidental findings. No cardiac etiology of chronic dyspnea was discovered for any FF. Hypoxia itself can cause tachycardia as the body works to deliver a limited oxygen supply to its tissues, so it is possible that heart rate elevations were a response to low blood oxygen saturation. This cannot be determined conclusively, however, as oxygen saturation was not measured and documented during episodes of tachycardia.

Blood testing was performed on multiple occasions for each FF, including a "Metals Acute Poisoning Panel" testing for cadmium, chromium, cobalt, molybdenum, nickel, selenium, arsenic, antimony, tellurium, zinc, copper, and mercury. The first FF to undergo blood testing for metals had the sample collected approximately 95 hours after exposure to the smoke plume. The last had their sample collected 16 days after exposure. The results were not revealing, with detectable levels in the normal range of elements expected to be found in the human body, like copper and zinc. Each FF also had a detectable but low level of antimony present in their blood. Results of this metal testing are detailed in the Appendix.

Complete blood counts, looking at levels of red and white blood cells and platelets, were consistently normal for all FFs. Kidney function and electrolyte levels were also normal. Several FFs had slightly elevated transaminases, indicating possible liver cell damage, but these FFs received diagnoses of hepatic steatosis, or fatty liver disease, which could explain the abnormal liver tests and likely predated this incident.

Return to Work Medical Evaluations

FF3 was evaluated in the occupational health clinic 3 days after the incident and was recommended to take the next rotation off work to support full recovery. However, FF3 was generally feeling well, without residual symptoms, and was cleared to return to work without further evaluation or treatment.

FF1, FF2, C2, and C3 remained out of work at the time of this investigation, primarily due to their ongoing respiratory symptoms. They were frequently evaluated by an occupational health provider who assessed their work readiness.

Industrial Hygiene Assessment

EV/LIB thermal runaway events produce a complex mixture of smoke and particles containing many chemicals including metals, polycyclic aromatic hydrocarbons, acid gases, and fluoride particulates [Kesler et al. 2025]. The FFs in this case were exposed to a thermal runaway smoke plume and experienced severe health consequences. There are no existing reports detailing the signs and symptoms experienced by FFs or other first responders exposed to LIB thermal runaway; conclusions about which substance caused which sign or symptom are limited to what can be inferred from experimental data on smoke plume composition and existing medical literature on toxic exposures.

Since no environmental sampling was done at the time of the incident, it is not possible to determine the exact composition of the plume, and therefore to exactly what these FFs were exposed. However, NIOSH investigators applied modeling techniques and knowledge of battery composition to this incident. The results of that modeling are detailed here. In combination with the operational details noted in the investigation section, and the health effects detailed in the medical findings section, the modeling results might give useful information on the risks FFs face during EV/LIB responses.

Incident Modeling

NIOSH investigators used the Computer-Aided Management of Emergency Operations (CAMEO) software suite to model the incident. CAMEO was co-developed by the US Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) to assist emergency responders (e.g., fire departments) with developing emergency response plans. Two programs in this software suite were used for this model, Areal Locations of Hazardous Atmospheres (ALOHA) [EPA and NOAA 2016] and Mapping Application for Response, Planning, and Local Operational Tasks (MARPLOT) [EPA and NOAA 2017]. ALOHA is an atmospheric dispersion model used for evaluating releases of hazardous chemicals. ALOHA estimates the downwind dispersion of a chemical cloud based on the toxicological and physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release. ALOHA can be used for planning and active responses; it has also been used for epidemiologic study of chemical exposures [Jani et al. 2016]. The model generated by ALOHA was then displayed on a map of the incident location using MARPLOT, including the Acute Exposure Guideline Level (AEGL) and Immediately Dangerous to Life or Health (IDLH) threat zones (Photos 3 and 4). The ALOHA software is considered accurate within a factor of two, meaning that when ALOHA makes a prediction, the actual value in the real world may be twice as high or half as much as the prediction.

While an EV thermal runaway plume is a complex chemical mixture, hydrogen fluoride (HF) was used as the surrogate chemical for the model. Published HF yields from LIB fires range from approximately 20–200 mg/Wh [Larsson et al., 2017]. Based on the vehicle's VIN and the responding FFs' description of the batteries on scene, the Tesla Model 3 battery pack likely contained cylindrical 2170-format NMC (nickel-manganese-cobalt) cells with a battery capacity of approximately 82 kWh. This model assumes 100% involvement of the 82 kWh pack and applies the upper-bound yield of 200 mg/Wh HF, resulting in a total estimated HF mass of 16.4 kg (200 mg/Wh × 82,000 Wh = 16,400,000 mg = 16.4 kg HF). It is not known exactly how long the battery was in thermal runaway, and some of the individual battery cells on the roadway were off-gassing during cleanup. However, there was approximately 10-15 min between the call requesting a truck to escort the EV to the storage yard and when FF3 was transported to the ED, and it was reported that the plume dissipated after 15 min from the initial release. Assuming continuous release over 15 minutes, this corresponds to a release rate of approximately 1.09 kg/min. Release duration could be highly variable depending on factors such as the extent of cell propagation and percentage of battery involvement. Additionally, this model assumes continuous, steady release of HF over 15 minutes, which likely does not reflect the dynamic nature of a thermal runaway event and cell propagation; specifically, it may underestimate peak exposure during active cell propagation and overestimate concentrations during the decay phase of the event.

This model is intended to approximate this specific incident but should be considered an estimation rather than an exact replication. It reflects atmospheric conditions representative of the incident (clear skies, temperature approximately 63°F, and light winds from the south/southwest at 4 mph), with upper-bound assumptions for battery size, state of charge, and extent of battery involvement. As it was reported that 400 individual cells already had separated from the battery pack and were spread out across the roadway prior to the main battery pack entering thermal runaway, 100% battery involvement is likely an overestimation. An additional model was created with the same atmospheric conditions, battery size, and state of charge, but with only 50% battery involvement, as a comparison. Data from similar incidents were not available to compare the modeling results.

Acute Exposure Guideline Levels (AEGLs)

AEGLs are used by emergency response planners and responders as guidance for rare situations involving airborne chemical releases [EPA 2024]. AEGLs are expressed as specific concentrations of airborne chemicals at which health effects may occur. Because AEGLs are designed for community-wide exposure response planning, they are intended to protect the general public, including elderly individuals, children, and others who may be particularly susceptible, not just emergency responders. Unlike most environmental air standards, AEGLs are calculated for five exposure periods: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. AEGL levels reflect the severity of toxic effects, with Level 1 being the least severe and Level 3 being the most severe. All levels are expressed in parts per million or milligrams per cubic meter (ppm or mg/m^3) and represent concentrations above which the general population could experience the following effects:

- AEGL-3**:** Life-threatening health effects or death.
- AEGL-2**:** Irreversible or other serious, long-lasting adverse health effects, or impaired ability to escape.
- AEGL-1**:** Notable discomfort, irritation, or certain asymptomatic non-sensory effects. Effects are not disabling and are transient and reversible upon cessation of exposure.

The "threat zones," or the distances from the source, provided by ALOHA indicate where the concentration could meet or exceed the given concentration according to the model.

For HF, the threat zones corresponding to each AEGL threshold as modeled by ALOHA with the assumption of 100% battery involvement were as follows (Figure 6):

- AEGL-3 (>44 ppm [60 min]): 220 ft
- AEGL-2 (>24 ppm [60 min]): 302 ft
- AEGL-1 (>1 ppm [60 min]): 1,486 ft

With the assumption of only 50% battery involvement, the threat zones corresponding to each AEGL threshold as modeled by ALOHA were as follows:

- AEGL-3 (>44 ppm [60 min]): 157 ft
- AEGL-2 (>24 ppm [60 min]): 213 ft
- AEGL-1 (>1 ppm [60 min]): 1,053 ft

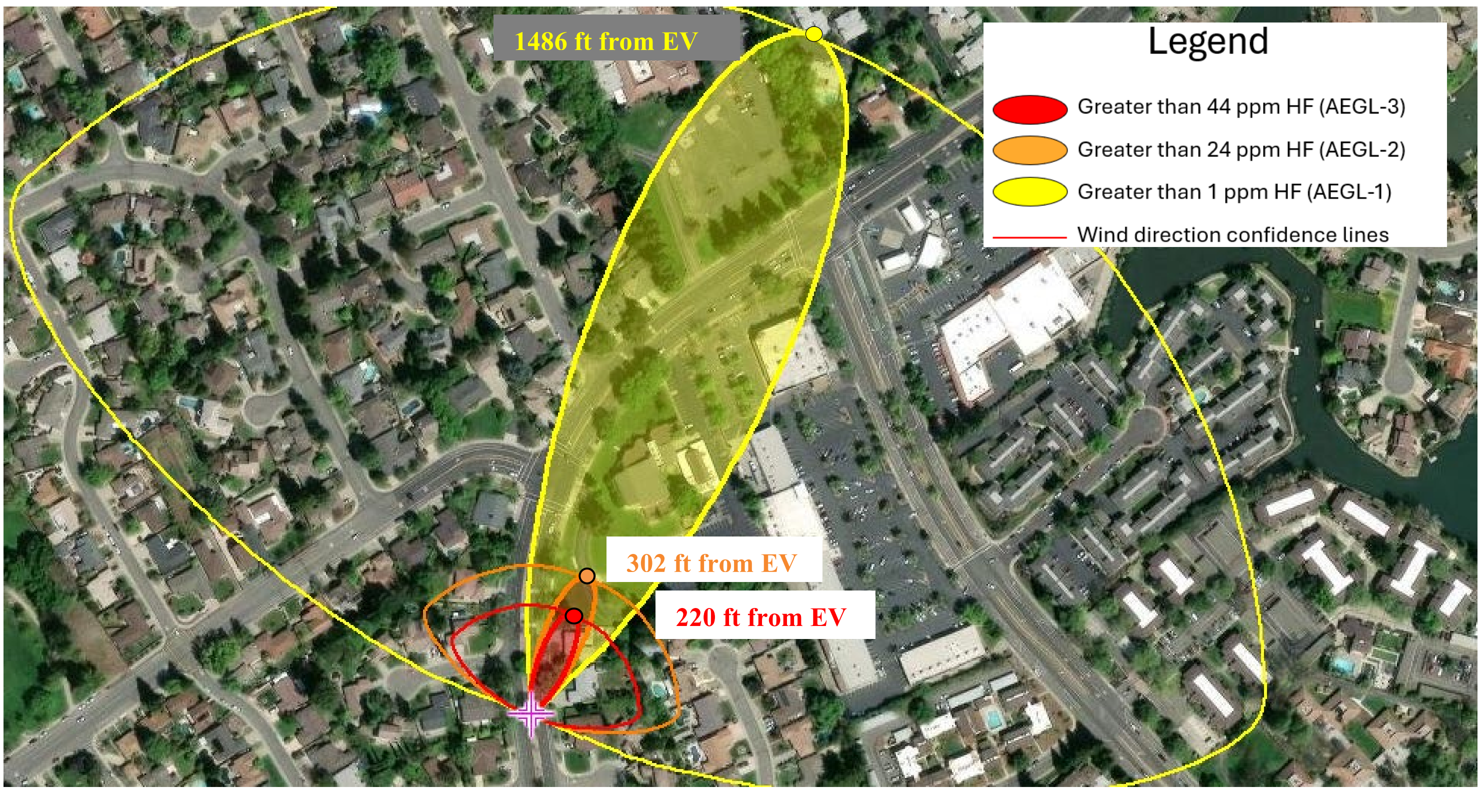


Figure 6. MARPLOT Map of AEGL [60 min] Threat Zones (100% Battery Involvement Assumption)

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NIOSH Immediately Dangerous to Life or Health (IDLH) Values

IDLH values characterize exposures to high concentrations of airborne chemicals that can rapidly cause serious health effects, including eye and respiratory irritation, irreversible injury, impaired ability to escape, or death [NIOSH 1994]. IDLH values are established to ensure that a worker can escape from a contaminated environment in the event of respiratory protection equipment failure, and to indicate a maximum concentration above which only a highly reliable breathing apparatus providing maximum protection is permitted. The IDLH for HF is 30 ppm, based on acute inhalation toxicity data in humans and animals.

The threat zones corresponding to the IDLH threshold (>30 ppm) as modeled by ALOHA (Figure 7):

- with the assumption of 100% battery involvement: 269 ft
- with the assumption of 50% battery involvement: 190 ft

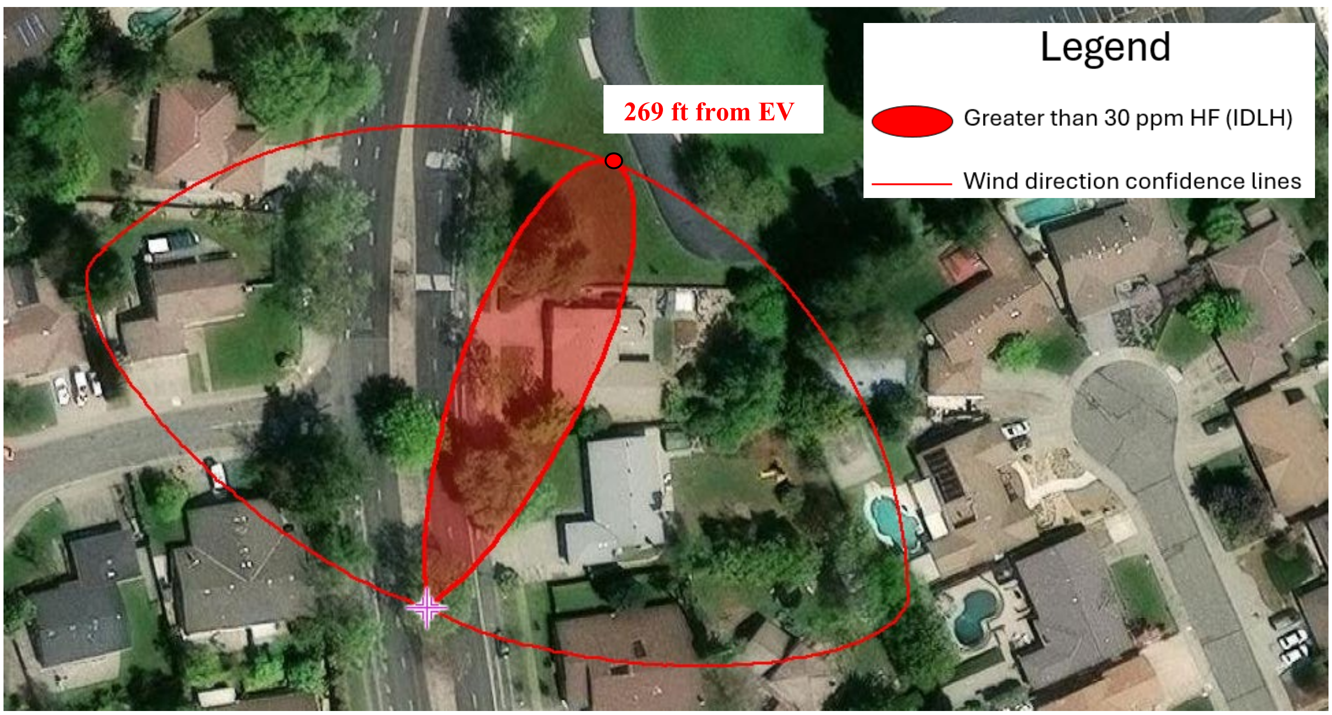

Figure 7. MARPLOT Map of IDLH Threat Zone (100% Battery Involvement Assumption)

Modeling Conclusions

According to this model, the plume concentration at the AEGL-3 value could extend approximately 220 ft downwind of the EV and the plume concentration at the IDLH level could extend approximately 269 ft downwind of the EV if 100% of the battery had been involved. Based on the modeling results and the responders' self-reported locations during the plume event, FF1, FF2, FF3 C2, and C3 may have been exposed to HF concentrations within the IDLH range (>30 ppm HF) and/or AEGL-3 range

(>44 ppm HF) without respiratory protection for several seconds or up to several minutes. These concentration ranges are associated with the potential for irreversible or other serious long-lasting health effects, as well as an impaired ability to escape.

The resulting health effects and self-reported locations of the FFs support the findings of this model. This also indicates that a 75 ft exclusion zone where SCBA use is required if smoke or fire are visible from the battery, as described in the department's updated EV standard operating procedures, would have been unlikely to prevent this exposure incident.

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Discussion

Lithium-ion Batteries, EVs, and the Emerging Risk to the Fire Service

Electric vehicles are gaining in popularity globally and in the United States. The Organisation for Economic Co-operation and Development's (OECD) 2023 report on global EV use noted 26 million EVs in use worldwide in 2022. From 2021 to 2022, the percentage of all vehicle sales worldwide that were EVs rose from 9% to 14% [OECD 2023]. At least one source projects that by 2035, EVs will be up to 42% of the vehicle fleet in the United States [Archsmith 2022]. Lithium-ion batteries are also found in electric scooters and bicycles. While fires involving internal combustion engine vehicles also pose potential health risks to FFs and other first responders, EV incidents are an emerging risk.

There is medical literature on the human health effects of exposure to the possible individual components of an EV thermal runaway smoke plume, including metals and HF or particulate fluoride. For example, acute inhalation exposure to metals such as cobalt, nickel, and manganese can cause chemical pneumonitis and acute respiratory distress; systemic absorption may cause cardiac arrhythmias, neurotoxicity, and multi-organ dysfunction [Gerhardsson 2022; Kunimasa et al. 2011; O'Neal and Zheng 2015]. Lithium metal can cause alkaline chemical burns and heat-producing chemical reactions upon contact with moisture on skin or mucous membranes, potentially causing tissue damage [Clare and Krenzelok 1988; Nicoll et al. 2016]. HF exposure poses severe risks through both inhalation and dermal routes, causing immediate tissue damage and delayed systemic fluoride toxicity that can result in life-threatening hypocalcemia and cardiac effects [Caravati 1988]. There is also some data indicating that particulate matter from EV combustion may be more mutagenic than particulate matter from other types of fires [Kim et al. 2025]. There are no case reports, however, describing health effects from occupational exposure to the mixture of components of an EV thermal runaway plume.

Experiments involving controlled burns of EVs with air and surface sampling for smoke plume components have simulated firefighter positioning to explore the possible degree of exposure to certain hazardous elements [Kesler et al. 2025; Barowy et al. 2026]. Experiments cannot, however, perfectly replicate the scene of a real LIB or EV incident. For example, the experiments in Kesler et al. [2025] used propane burners to ignite the car. In the incident described in this report, there was no vehicle fire; it appears to have been a thermal runaway event from a physically damaged battery without evidence of flaming. Therefore, it is difficult to say whether experimental results from a different mechanism of battery damage involving a vehicle fire accurately reflect the exposures sustained by FFs during this response. There is also evidence that suggests different battery fire extinguishment methods may impact the release of contaminants into the air [Barowy et al. 2026]. Additionally, shifting wind direction and velocity, PPE worn, and other factors could change an individual firefighter's risk of illness. A comprehensive description of the events surrounding this incident and the resulting health effects experienced by FFs is important to understanding the degree of risk posed to FFs and identifying measures to prevent similar exposures in the future. While the department in this case upgraded the incident to Level II HAZMAT, not all EV or LIB-related events involve a HAZMAT response, and all firefighters regardless of HAZMAT team membership might be at risk of exposure.

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Electric Vehicle Battery Systems Configuration

EVs are powered by high-voltage lithium-ion battery packs, consisting of hundreds to thousands of individual cells forming modules inside a reinforced enclosure. The battery pack and enclosure configuration inside the vehicle varies by manufacturer and model, but they are commonly located under the passenger compartment. The individual battery cells may be cylindrical, prismatic, or pouch-style and use different lithium-ion chemistries (e.g. nickel manganese cobalt [NMC], lithium iron phosphate [LFP], or nickel cobalt aluminum [NCA]). Hybrid electric vehicles and plug-in hybrid electric vehicles also contain lithium-ion battery packs that can present similar hazards, although they are usually much smaller than the battery packs in fully electric vehicles. While battery design varies, they all have the potential to undergo thermal runaway if damaged in an accident, or from overheating or overcharging. Not all EV fires initially involve the battery, but the battery may become involved if the battery enclosure is damaged or the cells overheat.

In the case of this incident, the EV battery enclosure was underneath the passenger compartment. During the collision, the battery enclosure was damaged, ejecting individual cells from the battery pack on to the roadway and leading to thermal runaway of the main battery pack when the vehicle was being loaded onto the tow truck. While on-scene personnel do not need to know the vehicle model to make decisions about hazard protection, this information can provide more detailed understanding of the incident and could inform hazard modeling results.

Reactive Airway Disease and Occupational Asthma

After evaluation of their history, physical examination, imaging, and PFT findings, all four FFs with respiratory symptoms in this case were diagnosed with RAD by their treating physicians. The term “reactive airway disease” itself is nonspecific and refers to airway dysfunction attributable to a variety of causes. In this case, the FFs’ medical providers attributed their reactive airways to LIB smoke plume exposure. Importantly, it is not clear from this exposure or from the available literature which component of the smoke plume is primarily or completely responsible for the FFs’ respiratory symptoms. Suspected substances based on prior research include HF or particulate fluoride as well as nickel, lithium, and cobalt. More than one substance may be contributing to the injury.

Some patients with RAD are diagnosed with asthma. Asthma is a disease of the airways characterized by airway hyperresponsiveness, intermittent bronchospasm, and airflow obstruction, with airway inflammation and mucus hypersecretion, leading to shortness of breath and wheezing [Porsbjerg et al. 2023]. In cases where asthma is caused by occupational exposure, it is called work-related asthma. Work-related asthma can also be diagnosed when a patient with a pre-existing asthma diagnosis experiences worsening of their symptoms as a result of their work. A subset of work-related asthma, occupational asthma (OA), is diagnosed when a worker develops new-onset asthma after an exposure at work [CDC 2025, NIOSH 2026]. Tarlo and Malo [2014] described features associated with reactive airways dysfunction syndrome (RADS), which is a subset of OA that is caused by a single large irritant exposure. Features of RADS include:

1. Either a history of new-onset asthma or recurrence of childhood asthma

2. Symptom onset related to one or more high-level exposures

3. Symptom onset typically ≤24 hours after exposure but sometimes up to a few days after exposure

4. Exposure to very high concentration of gas, fume, or spray with known irritant properties, or highly irritating dust in some cases

5. Airway hyperresponsiveness or reversible airflow obstruction

6. Symptoms persistent for ≥3 months

7. No prior history of lower respiratory tract symptoms

Literature on OA associates its development with exposure to a wide variety of substances [Brooks et al. 1985]. Workers with pre-existing atopic asthma (the type of asthma commonly diagnosed in childhood), a history of cigarette smoking, and certain genetic risk factors are predisposed to developing work-related asthma. However, the likelihood of disease onset ultimately depends on occupational factors, including the specific agent involved and the intensity of exposure [Tarlo and Lemiere 2009].

FF1, who had perhaps the most serious respiratory sequelae of this exposure with a new need for supplemental oxygen, reported a history of childhood asthma. This could have predisposed him to development of reactive airway disease after an occupational exposure later in life. However, other FFs who reported asthma diagnoses in childhood did not develop hypoxia. In this case, a history of asthma in childhood did not seem to predict development of severe respiratory symptoms after LIB smoke plume exposure, though the number of involved FFs is small and does not allow generalization to the broader firefighter population. It is possible that proximity to the smoke plume source and length of time spent in the plume are more significant factors than personal health history in determining the severity of health effects.

Primary prevention of work-related asthma involves avoidance of exposure to irritants or sensitizing agents. In the case of firefighting work involving LIBs and EVs, this means development of standard operating guidelines for a safer approach to these incidents and FF education on the risks of exposure and importance of recognizing when a fire or other incident involves a LIB. Treatment of irritant-induced OA is the same as management of non-occupational asthma, though elimination of the causal exposure is critical [Trivedi et al. 2017].

Occupational Toxic Metal Exposure and Metal Fume Fever

Metal exposure is a risk in many industries, with health effects of exposure to metals described in the scientific literature. Commonly discussed metals associated with occupational exposure include antimony, arsenic, chromium, lead, mercury, and nickel, though this list is not exhaustive. Nickel, cobalt, lithium, and aluminum are components of many EV batteries. Some metals, including cobalt, copper, and zinc, are necessary in small amounts for normal human body function, but are toxic in large enough quantities.

Metal fume fever is an occupational disease that presents with flu-like symptoms after inhalation of metal oxides, most commonly zinc oxide. It is well-described in galvanized metal welders but can also affect workers exposed to other metals including nickel, copper, manganese, and chromium. Symptoms of metal fume fever usually begin within hours after an exposure and then resolve within several days. Notably, metal fume fever can present with an initial metallic taste signaling inhalation exposure, followed by throat irritation, and later development of fever, chills, malaise, fatigue, and cough [Truncale 2015]. The FFs in this case were not diagnosed by their treating physicians with metal fume fever. However, if FFs develop a self-limited flu-like illness shortly after a response involving possible metal fume exposure, this diagnosis could be considered.

In this case, the FFs had a "Metals Acute Poisoning Panel" blood test performed after the incident to assess for metal exposure. This test assessed levels of antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, selenium, tellurium, and zinc. These results, detailed in the Appendix, were not diagnostic of any single high-level exposure.

It is possible that the blood metal levels were affected by the length of time between exposure and sample collection. The first FF to undergo blood testing for metals had the sample collected approximately 95 hours after exposure to the smoke plume. The last FF to undergo testing did not have a sample collected until 16 days after exposure. The length of time a metal will remain detectable in serum after exposure varies widely between metals, and persistence in the body can be affected by route of exposure, e.g. inhalation vs. ingestion. Nickel, of particular interest in this case, has a serum half-life approximately 28 hours when it enters the body through drinking water or food [ASTDR 2024; Sunderman et al. 1989]. This case was more consistent with an inhalation exposure. While soluble forms of nickel distribute into the bloodstream after absorption, less soluble forms of nickel tend to remain in the lungs longer [Sunderman et al. 1989]. If the FFs in this case did indeed have an inhalational nickel exposure, the results of their blood testing could have been affected by the exact nickel compound they encountered, which is unknown in this case.

Hydrogen Fluoride

Experiments involving controlled burns of EVs showed HF and fluoride particulate in the combustion products of the vehicles [Kesler et al. 2025]. HF gas is corrosive and can cause severe burns on contact. Symptoms of HF inhalation exposure can include eye, nose, throat, and skin irritation, as well as cough and lung tissue damage [ASTDR 2003a]. After a refinery accident in 1987 that released a large amount of HF into the community, 42.3% of those exposed who underwent pulmonary function testing had an FEV1 less than 80% of the predicted value [Wing et al. 1991].

The exact composition of the smoke plume inhaled by the FFs in this case is unknown but based on prior experimental results measuring the composition of EV smoke and the known health effects of HF inhalation, it is possible that HF contributed to their mucous membrane irritation and respiratory symptoms. Additionally, the modeling results described above support the possibility of exposure to

HF.

Urine fluoride testing can be used to determine if a person has been exposed to high levels of fluoride, but the testing must be performed soon after the suspected exposure as fluoride is eliminated from the body within a few days [ASTDR 2003b].

Mental Health After Injury

Mood changes, irritability, memory impairment, and brain fog were late developments in the affected FFs' illness course, but they had a significant impact on daily functioning and quality of life. Though exposure to certain metals can have neurological impacts, the above symptoms, which developed months after this incident, do not appear to be directly caused by a toxic exposure. Rather, they seem to be a secondary effect, precipitated by extended illness, debilitating physical symptoms, and prolonged involuntary time off work.

Peer support has been shown to contribute to firefighter resilience in the face of difficult or traumatic circumstances [Dangermond et al. 2023, Song et al. 2020]. Sentiments to this effect were documented in the medical records. A provider note reported that one FF "expresses desire to return to work and values social connection with coworkers" and "finds camaraderie with coworkers to be a significant source of emotional support."

Mental health care designed to address the stresses of firefighting work is important. There is abundant literature on the effects of work-related traumatic experiences on FFs. However, this case underscores the need to support FFs who are unable to work because of occupational illness or injury. This need may be particularly important when the absence from work is prolonged and involuntary. These injured FFs are removed from their usual support system, from the feeling of camaraderie and shared purpose that work provides, and might have additional stress from feeling suddenly unable to support their coworkers or provide for their families.

Recommendations

As medical literature advances, so do operational guidelines. Departments across the country are developing standard operating procedures for response to incidents involving LIBs and EVs. Topics of interest are establishment of a perimeter, decontamination procedures, and PPE recommendations. Hopefully, this report will assist departments in crafting their own guidelines for response to these incidents, while highlighting the severity of the potential health effects if exposure does occur.

NIOSH offers the following recommendations to reduce the risk of serious injury or death from toxic exposures during response to LIB or EV incidents among firefighters at this and other fire departments across the country.

Recommendation #1: Ensure firefighters operating within established hazard control zones at all damaged vehicle incidents are protected from respiratory hazards by requiring the use of self-contained breathing apparatus (SCBA) in potentially hazardous, unknown, or immediately

dangerous to life or health (IDLH) atmospheres. For confirmed electric vehicle (EV) and lithium-ion battery (LIB) incidents, maintain respiratory protection for personnel within the hazard control zones throughout EV/LIB suppression, handling, and removal when thermal runaway or battery off-gassing remains possible.

Discussion: EVs are not always readily identifiable during emergency operations, particularly when vehicles are heavily damaged or involve hybrid systems. In addition, both EV and internal combustion engine vehicle (ICEV) incidents can generate hazardous combustion products and other respiratory hazards. Therefore, the initial and ongoing incident risk assessment should consider the potential for an EV/LIB hazard even when the vehicle type cannot be immediately confirmed. When hazardous or potentially hazardous atmospheres are present or suspected, firefighters should use SCBA in accordance with department procedures and applicable standards. While some personnel might be able to stage out of the smoke plume (see Recommendation #2), others will need to approach the vehicle in order to fully assess the scene and possibly render aid to vehicle occupants. SCBA use protects these personnel. Although there is currently no NFPA standard that specifically addresses SCBA use for EV/LIB incidents, NFPA 1550, *Standard for Emergency Responder Health and Safety*, requires SCBA use when operating in IDLH atmospheres, potentially IDLH atmospheres, unknown atmospheres, hazardous atmospheres, and during overhaul operations [NFPA, 2024]. NFPA 1550 further states that, at minimum, a NIOSH Approved® SCBA should be worn prior to entry into post-fire environments and for at least 2 hours following extinguishment [NFPA, 2024]. However, a damaged EV battery can reignite many hours or even days after initial extinguishment if there is stranded energy in the remaining battery pack. Responders should be prepared for a thermal runaway event (including off-gassing and fire) when moving or handling the battery, which may include donning respiratory protection prior to handling. While the investigators recognize this incident was not a typical fire scene, the evolving understanding of hazards associated with damaged EV/LIB systems warrants a high level of caution.

As the incident evolves, the risk assessment should be continually updated to account for changing conditions. At incidents involving suspected or known EVs or LIBs, firefighters operating where they may be exposed to thermal runaway plumes, battery off-gassing, smoke, or changing wind conditions should remain on air or have SCBA available for immediate use if operating outside the hazard area. Thermal runaway and toxic gas releases can occur suddenly with little or no warning, making delayed respiratory protection ineffective. In this incident, firefighters disconnecting the hoseline had removed their SCBA because they believed they were operating far enough away from the vehicle to avoid exposure. However, the task lasted longer than anticipated and occurred in an area where hazardous contaminants remained present. Because disconnecting the hoseline did not involve an immediate life-safety objective, an ongoing risk assessment should have prompted reevaluation of the hazard before personnel continued operating without respiratory protection. This incident demonstrates the importance of continually reassessing changing conditions and matching the level of respiratory protection to the identified hazards.

The Fire Protection Research Foundation and NIOSH have recommended enforcing SCBA use during vehicle fire suppression, attacking fires from upwind positions, parking apparatus upwind of the incident, donning SCBA before initiating fire attack, and remaining on air until overhaul is complete [Long 2013]. Similarly, the United States Fire Administration (USFA) recommends SCBA use during all vehicle fires because of the potential for exposure to toxic combustion byproducts. Although this incident did not involve suppression of a flaming vehicle fire, it would be prudent to follow the same respiratory protection as outlined above due to the known exposure risks. Known contaminants associated with vehicle fires and EV/LIB incidents may include acid gases, such as HF, polycyclic aromatic hydrocarbons (PAHs), metals, volatile organic compounds (VOCs), and other toxic or carcinogenic substances. Exposure may occur through inhalation and other routes, reinforcing the importance of respiratory protection and other appropriate PPE.

Air purifying respirators (APRs) use filters, cartridges, or canisters to remove gases, vapors, aerosols, or a combination of contaminants from the air. Personnel must know the contaminants present and their concentrations in order to select an appropriate APR filter cartridge, and in an EV/LIB response these concentrations will be unknown. Additionally, APRs are not appropriate for use in environments that are potentially Immediately Dangerous to Life and Health. Therefore, an APR does not provide adequate protection in this environment.

Wearing SCBA and turnout gear may contribute to heat stress, especially during periods of physical activity. For prolonged incidents or operations conducted in high-temperature environments, incident commanders should monitor personnel for signs and symptoms of heat stress and implement rehabilitation measures consistent with NFPA 1580, *Standard for Emergency Responder Occupational Health and Wellness*. Crew rotation and rehabilitation can help reduce the risk of heat-related illness while maintaining respiratory protection and operational readiness [NFPA, 2025].

Recommendation #2: Fire departments should identify hazard control zones for each EV/LIB incident using a risk assessment method, such as HAZMAT incident modeling software, that incorporates environmental and structural factors

Discussion: Consider establishing EV/LIB incident hazard control zones based on incident-specific hazard assessments rather than fixed distances. The department’s current protocol of establishing a 75-foot exclusion zone perimeter for EV fire response may not be adequate for all responses, as demonstrated in this incident during which affected FFs were located 150 feet or more from the vehicle at the time of exposure. The Department of Transportation (DOT) Emergency Response Guidebook (ERG) is often used as a resource to establish initial hazard control zones at HAZMAT incidents. For incidents involving LIBs, the DOT ERG recommends an initial isolation distance of 75 feet in all directions [DOT 2024]. However, the guide also notes that LIB fires can produce toxic hydrogen fluoride gas, which has a recommended isolation distance of 330 feet in all directions [DOT 2024]. The hazard control zones established for an EV/LIB incident should account for factors such as battery involvement, thermal runaway conditions, fire behavior, weather, topography, structural exposures, and the potential for toxic gas release, projectiles, or other hazards. The hazard control zones may also evolve throughout the incident and may need to be expanded or contracted based on changes in conditions. OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) standard, 29 CFR 1910.120, requires that site control measures be implemented to control exposures and that control zones be established based on the hazards present. Similarly, NFPA 470 Hazardous Materials/Weapons of Mass Destruction (WMD) Standard for Responders emphasizes that hazard control zones should be determined through an assessment of incident-specific hazards rather than a predetermined distance. The established hazard control zones, and any subsequent changes to those zones, should be communicated to all personnel on scene. Physical markers of each zone in addition to briefings can be helpful to ensure the safety of everyone at the incident. This may also include designating an incident safety officer or special division to monitor and enforce hazard control zone interface or required PPE for each zone. Hazard assessment and modeling tools, such as the CAMEO software suite, may assist incident commanders in establishing and adjusting exclusion zones as conditions evolve, helping to reduce the risk of responder exposures.

In this incident, leadership exercised reasonable judgment in establishing a perimeter they believed would provide adequate protection based on the information available at the time. However, as EV and LIB technologies continue to evolve, the scientific understanding of the associated hazards and exposure risks is still developing. As demonstrated in this incident, the established perimeter may not have been sufficient to protect personnel from all hazards present. Therefore, when developing standard operating procedures, agencies should consider using a risk-based approach to perimeter establishment that accounts for incident-specific conditions rather than relying on a fixed distance exclusion zone.

Recommendation #3: Train firefighters on the signs and indicators of a thermal runaway event in EVs/LIBs and the associated physical and chemical hazards.

Discussion: Thermal runaway can happen at any time and without warning. According to the USFA, EVs exposed to physical damage are likely at higher risk than undamaged vehicles for thermal runaway for hours or days following an incident [USFA 2025]. *NFPA 1700 Guide for Structural Firefighting* also addresses the topic of thermal runaway [NFPA 2026]. Although this standard is designed for structural operations, much of the information remains relevant for any EV/LIB incident, such as LIB remaining a consideration for any incident size-up. It is important for firefighters to have a comprehensive understanding of how thermal runaway works: it is a self-heating, escalating failure process in LIBs that can lead to fire, explosion, release of flammable gases, and toxic off-gassing [NFPA 2026]. It is also important for FFs to know that portable gas meters are not currently reliable for detecting thermal runaway effluent gases from batteries. For this reason, FFs should remain outside of the hazard zone if there is a suspicion or chance for thermal runaway and there are no indicators of an active fire [NFPA 2026]. It may also be beneficial to establish a Lookouts, Communications, Escape Routes, and Safety Zones (LCES) protocol, with a FF assigned to watch for and alert personnel of any signs of thermal runaway at EV/LIB incidents. LCES protocols are most commonly used in wildland firefighting, but may also be utilized in other fire scenarios, such as structural, vehicle, or HAZMAT incidents. As all firefighters may be called upon to respond to an EV or LIB incident, training should be disseminated throughout the department and not limited to HAZMAT team members or those in other specialized roles.

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Prudent education on thermal runaway may also include the sounds and smells indicative of LIBs in thermal runaway. Teach FFs that popping, clapping, banging, or hissing sounds and white smoke (often low to the ground) are often indicators of imminent or ongoing thermal runaway [USFA 2025]. Smells of thermal runaway have been described as electrical and plastic [NFPA 2026]. Recognition of these signs can be useful at incidents to assess initial and ongoing risk assessments. This information can be particularly important for ICs or safety officers.

Recommendation #4: Firefighters should be familiar with symptoms of EV/LIB exposure and should seek medical care immediately if experiencing symptoms after a response. FDs should develop procedures for reporting, documenting, and medically evaluating firefighters who experience symptoms following potential exposure during EV/LIB incidents consistent with NFPA 470 and OSHA 1910.

Discussion: EV/LIB incidents represent an emerging occupational hazard. There is currently limited information describing the acute health effects experienced by firefighters following potential exposure to thermal runaway emissions, battery off-gassing, or combustion products. Although the specific agent or agents responsible for the illnesses observed in this incident could not be identified, several affected firefighters reported a similar pattern of symptoms occurring within minutes to days following the response. Reported symptoms included metallic taste; irritation of the eyes, nose, or throat; headache; nausea; vomiting; cough; shortness of breath; and flu-like symptoms. Because the health effects associated with EV/LIB exposures are not yet fully characterized, firefighters should promptly report symptoms that develop during or after an EV/LIB response and seek medical evaluation when symptoms are persistent, worsening, or otherwise concerning. FFs seeking medical care should inform healthcare providers of their occupation and the potential for exposure to emissions from an EV or LIB incident. There is currently no established testing or treatment protocol for exposures after EV/LIB incidents, and this is an evolving area of medical knowledge. Early recognition, documentation, and evaluation of symptoms may help guide medical treatment and contribute to a better understanding of the health effects associated with these emerging hazards. FDs may wish to build a means for reporting symptoms into their SOPs for EV/LIB responses.

Consistent with NFPA 470, *Hazardous Materials/Weapons of Mass Destruction (WMD) Standard for Responders*, fire departments should also incorporate post-incident debriefings following EV/LIB responses [NFPA 2022]. The debriefing should include a discussion of potential hazardous exposures encountered during the incident, the known or suspected health effects associated with those exposures, and the signs and symptoms for which personnel should monitor themselves after the response. Responders should receive clear instructions on when and how to report delayed symptoms and when to seek medical evaluation. Reinforcing these topics during the post-incident debriefing supports responder health, improves early recognition of potential exposure-related illness, and complements pre-incident training on EV/LIB hazards.

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Recommendation #5: Firefighters should conduct on-scene preliminary exposure reduction (PER), isolate PPE, and store contaminated gear outside of the passenger compartments of vehicles according to NFPA 1850.

Discussion: As with any fire response, PER (on-scene decontamination) is essential due to the wide range of toxic byproducts firefighters may be exposed to during operations. Until further guidance is available, firefighters are recommended to perform PER following an EV response in the same manner they would following other types of fire incidents.

Although the specific contaminants associated with EV/LIB incidents continue to be studied, thermal runaway events can generate a complex mixture of gases, vapors, particulates, and combustion byproducts. Depending on battery chemistry, incident conditions, and fire involvement, these emissions may include substances that can contaminate PPE, tools, apparatus, and other equipment. Contaminated PPE can serve as a source of secondary exposure through dermal contact, off-gassing, or transfer of contaminants to apparatus cabs, stations, and personal vehicles. Given the evolving nature of the hazard and the limited data regarding contamination persistence following EV/LIB incidents, a precautionary approach to contamination control is warranted.

FDs should ensure that personnel understand the importance of contamination control measures following EV/LIB incidents, even when visible soot or fire damage is minimal. Thermal runaway and battery venting events may occur without significant visible smoke or flame yet still have the potential to release hazardous substances. Conducting PER, isolating potentially contaminated PPE, and minimizing the transport of contaminated equipment within occupied spaces may help reduce the potential for secondary exposures to firefighters and others.

NFPA 1850, Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural and Proximity Firefighting and Open-Circuit Self-Contained Breathing Apparatus (SCBA), establishes the guidelines for selection, care, cleaning, inspection, and maintenance of FF PPE to reduce health and safety risks [NFPA 2026]. This standard suggests that FDs create a standard operating procedure for field use to 1) determine when PPE contamination has occurred, 2) outline specific procedures for PER, advanced cleaning, sanitization, disinfection, and specialized cleaning as necessary, and 3) provision for providing spare, loaner, or back-up PPE when PPE needs to be removed from service. The standard further states that PPE used in a HAZMAT incident should undergo PER and then be assessed by the HAZMAT team; the standard contains a decision flow chart with questions to help guide decision making.

PER is a critical step following any incident and ideally occurs immediately after exiting the scene where the PPE may have been contaminated. FFs should remain on SCBA air while completing PER. Dry, wet, or a combination of PER methods are acceptable [NFPA 2026]. According to NFPA 1850, section 7.2.2, it is recommended that dry mitigation precedes wet mitigation if they are used in combination [NFPA 2026]. The potential re-aerosolization of contaminants from gear during dry mitigation highlights the importance of wearing respiratory protection during PER for both the person conducting the PER and the person undergoing PER. Following PER, PPE elements should be isolated, bagged, and whenever possible transported away from passenger areas of a vehicle. Current FF best practices developed by The International Association of Fire Chiefs and the National Volunteer Fire Council outline 11 best practices for decontamination that include wiping off exposed areas of the body to remove as much soot as possible and showering as soon as possible after being exposed to products of combustion or other contaminants [IAFC, NVFC, 2018].

In this incident, the PPE was bagged following the event; however, it does not appear that PER was conducted. This was likely influenced by the operational circumstances at the time. Much of the PPE had already been doffed before the thermal runaway event occurred, and several firefighters were experiencing medical symptoms that required immediate evaluation and transport. As a result, responder medical care appropriately became the primary operational priority. Nonetheless, this incident highlights the importance of conducting PER and implementing contamination control measures as soon as practical following a suspected EV/LIB exposure event.

Recommendation #6: Ensure SOPs for handling damaged EVs/LIBs are in compliance with NFPA Standards, and manufacturers' recommendations.

Discussion: When developing standard operating procedures, it is important to consider the full spectrum of response activities. This includes specifying appropriate PPE to be worn while preparing a vehicle for towing and providing tow truck drivers with information on warning signs of thermal runaway and instructions if reignition occurs. Firefighters wearing full PPE may move LIBs, when appropriate, using non-conductive tools (e.g., shovel with a wooden or fiberglass handle); avoid using hands (even gloved) to move LIBs [NFPA 2026]. Current guidance from USFA for towing and removal of an EV following an emergency incident is to transport EVs with rollbacks and to keep the vehicle at least a 50-foot space from other vehicles or structures. If space is limited, consider a fire-resistant bunker to protect surrounding structures should the vehicle reignite [USFA 2025]. Further guidance for towing includes keeping the drive wheels under 1 mile per hour, not rolling on drive wheels for long distances or high speeds, and if this does occur, checking for heat and fire [USFA, 2025].

In this case, the tow truck driver was aware of the risk of thermal runaway and had been instructed to stop driving and leave the vehicle on the roadside if reignition occurred while en route to the storage yard. It is unknown whether the driver used any PPE. As fire departments update their SOPs, it may be beneficial to incorporate outreach or educational sessions with local tow truck operators to familiarize them with departmental procedures for managing EV/LIB incidents, as well as recommended best practices in the event of potential exposure.

Recommendation #7: Firefighters should undergo an annual physical examination to assess fitness for duty. Existing policy regarding annual examination for HAZMAT team members should be enforced.

Discussion: NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*, states that "All members shall receive a baseline medical evaluation after hiring and prior to performing firefighter emergency functions and at least annually thereafter.” Section 9.1.2 of this standard states that “the occupational medical evaluation shall include a medical history, examination, and any medical tests required to assess medical conditions that can affect an individual's ability to safely and effectively perform the essential job tasks” [NFPA 2022]. Components of the annual medical evaluation are outlined in Section 11.4.2 as “Each medical evaluation shall include a medical history, including exposure and behavioral health histories; physical examination; blood tests; urinalysis; vision tests; audiograms; spirometry; chest x-ray, as indicated; ECG; cancer screening, as indicated; and immunizations and infectious disease screening, as indicated” [NFPA 2025]. Section 5.2 addresses specialized teams like HAZMAT teams. While the NFPA standard does not prescribe specific additional testing for specialized teams, it notes that the physician performing the exam should take the additional demands and hazards of these roles into account. Finally, while HAZMAT team members might have specialized on-scene roles or increased potential for work-related hazardous exposures, any firefighter may be involved in a response to an EV or LIB incident. Therefore, it is not only HAZMAT team members who might encounter EV/LIB-associated exposures; all firefighters are potentially at risk.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program's Medical Team based in the Division of Field Studies and Engineering in Cincinnati, Ohio. This investigation was conducted and this report co-authored by Alexandra Barger, MD, MPH, Micah Niemeier-Walsh, PhD, and Andrea Wilkinson, MS, ATC/LAT. Dr. Barger is a board-certified internal medicine physician. Dr. Niemeier-Walsh is a research industrial hygienist. Ms. Wilkinson is a fire service researcher and exercise physiologist. She is also an honorary Lieutenant for the Hanover Park Fire Department in Illinois. Jasmine Nelson, MSPH, contributed to the data visualization for this report.

Disclaimer

The information in this report is based upon dispatch records, audio recordings, witness statements, and other information that was made available to the National Institute for Occupational Safety and Health (NIOSH). Information gathered from witnesses may be affected by recall bias. The facts, contributing factors, and recommendations contained in this report are based on the totality of the information gathered during the investigation process. This report was prepared after the event occurred, includes information from appropriate subject matter experts, and is not intended to place blame on those involved in the incident. Mention of any company or product does not constitute endorsement by NIOSH, Centers for Disease Control and Prevention (CDC). In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

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Appendix

Appendix Table 1. Incident Timeline

Time	Activity	Timelapse from Initial Dispatch Hr:Min
2204	Crews dispatched for MVA	0:00
2209	IC1 and M1 arrive on scene	0:05
2214	E1 arrives on scene	0:10
2218	M1 departed to transport patient	0:14
2233	M1 arrival at hospital	0:29
2238	Incident upgraded to HAZMAT Level II	0:34
2241	HM1 en-route, IC2 self-dispatched to call	0:37
2255	IC2 arrival on scene to assist IC1, takes over as IC, IC1 moves to engine work. Hot zone created.	0:51
2305	HM1 arrival on scene	01:01
0120*	Truck requested to escort EV to storage yard	03:16
0129	E3 and M2 were asked to assist with EV escort, but not involved in actual response	03:25
~0130	FF3 is transported to ED by EMS, FF2 and C3 follow in engine	~03:26
0150	HM1 (4 people) returned to station and went to available status	03:46
0220	EV delivered to storage yard	04:16
~1000	FF1 and C2 self-transported to ED	~12:00

*Please refer to the main body of the report for details of the timeline between 2305 and 0120.

Appendix Table 2. Number of firefighters reporting experiencing each sign or symptom at any time* from the electric vehicle exposure incident to administration of the medical questionnaire for this investigation (N = 5)

Experienced by ≥ 3 firefighters

- Chest pain
- Cough
- Cognitive impairment/brain fog
- Dizziness
- Fatigue
- Headache
- High blood pressure
- High heart rate
- Irritability or other mood changes
- Metallic taste in mouth
- Muscle stiffness
- Nasal irritation
- Nausea
- Palpitations
- Shortness of breath

Experienced by 1-2 firefighters

- Contact burns
- Coughing up blood
- Eye irritation
- Joint pain
- Loss of appetite
- Loss of coordination or balance
- Muscle aches
- Skin itching
- Vomiting

*Only symptoms that the firefighter attributed to this exposure, or to side effects of their post-exposure treatment, are included.

Appendix Table 3. Description of on-scene activities and acute symptoms of affected personnel who did not seek medical care

Personnel	On-Scene Activity Summary	Acute Symptom Summary
IC1	- Served as first-due IC and then transitioned to Engine as the incident progressed - Was approximately 150–200 feet from the vehicle at the time of thermal runaway. He reported a metallic taste in his mouth during the incident.	- Experienced metallic taste in mouth during the incident. - After the incident, experienced mild nausea, disorientation, headache, and fatigue that persisted for approximately 3 days -Day 4, he was feeling mild fatigue and shortness of breath. -Experienced unusual persistent fatigue for months after the incident.
C1	- Arrived on-scene approximately 90 minutes into the incident. - Was overseeing HAZMAT operations. Was in a vehicle approximately 150 feet downwind at time of thermal runaway	- Experienced metallic taste in mouth during the incident.

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Appendix Table 4. Acute poisoning metal blood panel results for four firefighters

Metal	**Normal result (per laboratory report)**	**FF1** (Sample collected 103 hours after exposure)	**FF2** (Sample collected 95 hours after exposure)	**C2** (Sample collected 106 hours after exposure)	**C3** (Sample collected 16 days after exposure)
Cadmium	<5 mcg/L	None detected	None detected	None detected	None detected
Chromium	<1 mcg/L	None detected	None detected	None detected	None detected
Cobalt	<1 mcg/L	None detected	None detected	None detected	None detected
Molybdenum	<10 mcg/L	None detected	None detected	None detected	None detected
Nickel	<5 mcg/L	None detected	None detected	None detected	None detected
Selenium	60-230 mcg/L	200mcg/L	200mcg/L	200mcg/L	180mcg/L
Arsenic	<10 mcg/L	None detected	None detected	None detected	None detected
Antimony	<5 mcg/L	2.9mcg/L	3.2mcg/L	3.1mcg/L	4.9mcg/L
Bismuth	<1 mcg/L	None detected	None detected	None detected	None detected
Tellurium	<1 mcg/L	None detected	None detected	None detected	None detected
Zinc	440-860 mcg/dL	710mcg/dL	690mcg/dL	540mcg/dL	590mcg/dL
Copper	80-180 mcg/dL	85mcg/dL	79mcg/dL	82mcg/dL	80mcg/dL
Mercury	<10 mcg/L	2.1mcg/L	6.4mcg/L	3.5mcg/L	1.0mcg/L