ELECTRIC VEHICLE

EMERGENCY OPERATING **BEST PRACTICES**

DELAWARE VALLEY
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REGIONAL
PLANNING COMMISSION

Electric Vehicle Emergency Operating Best Practices

Disclaimer:** This document was prepared and reviewed by the DVRPC Electric Vehicle Task Force and is not an official guidance or training source. DVRPC serves strictly as an advisory agency. Actual authority for carrying out recommendations rest solely with the governing bodies that have the responsibility to implement transportation policy. The following recommendations are based on Junk Yard Dog Extrication Training's "Lithium-ion Battery Standard Operation Procedure" and local industry best practices. Recommendations should be taken in conjunction with hands-on training and individual vehicle manual instructions. **All personnel should be properly trained before operating at an electric vehicle incident.

Objective

This guideline identifies best recommended practices for emergency personnel to provide safe and effective mitigation of electric vehicles (EVs) with lithium-ion batteries (hybrid, plug-in hybrid, electric plug-in vehicle, or extended-range electric plug-in vehicle) through a coordinated multi-agency response.

Overview

This guide organizes recommended best practices for EV emergency operations into four sections: Incident Operations, Arrival to Scene, Tactics and Strategy, and Special Considerations. It is intended to prepare and educate first responders on how to approach and address electric vehicle roadway incidents. Because this is not an official guidance, recommendations can be adapted to meet the specific needs and capacity of each department. Definitions, links to emergency vehicle guides, towing protocols, medical management guidance, and an on-scene EV fire fighting action checklist can be found in the Appendices. For additional EV response resources, visit the Electric Vehicle Task Force website.

Incident Operations

This section provides a high-level overview of initial dispatch, response, and safety techniques that, when properly executed, can improve the outcome of EV incidents.

Dispatch

1. Inquire about the vehicle type during the call taking process. Determination of vehicle type, hybrid or electric should take place during the 911 call if possible. If it is determined that an electric vehicle or electric charging station is involved in fire, an electric vehicle response should be dispatched.

Response/Mitigation

1. A report of an electric vehicle fire or electric vehicle charging station fire should consist of the following multi-disciplinary notification/response:
    a. Fire
    b. Police/Traffic
    c. Roadway Authority (DOT, Tolling Authority)

d. EMS - BLS (Consider ALS for smoke exposure)
e. Hazmat Representative
f. Communications/Dispatch/PSAP Center
g. Tow/Recovery
h. OEM and/or Regulatory Agencies

General Safety Considerations

1. Utilize crew resource management (CRM) to improve coordination, cooperation and overall responder performance.
2. Increase situational awareness for all hazards (fire, smoke, traffic).
3. Prepare for extreme weather conditions.
4. Maintain awareness of smoke travel (speed, wind direction, etc.).
5. Wear proper personal protective equipment (PPE) for assigned task. Company officers and chief officers should ensure compliance with this.
6. Utilize proper traffic incident management procedures when operating on the roadway. Keeping in mind Safe, Quick Clearance, ensure that the apparatus is parked appropriately to provide a safe working area for all members operating on or near a roadway.
7. Don and wear a reflective vest.
8. Be aware of the potential high voltage components of electric vehicles and electric vehicle charging stations.
9. Be aware of the potential for hazardous and flammable vapors omitted during an electric vehicle fire.
    a. Require the use of self-contained breathing apparatus (SCBA) and all PPE for all responders engaging in fire suppression or operating in smoke.
    b. Be aware that EV fires can create harmful runoff during suppression efforts.

Arrival to Scene

This section provides step-by-step instructions for each agency responding to the scene of an EV incident in order of arrival.

First Arriving Company

1. Provide an incident size-up, and establish command as per incident management system.
2. Determine if the scene is a rescue situation.
3. Identify the vehicle type, and determine if the vehicle is a hybrid-electric vehicle (HEV) or an all-electric vehicle.
    a. Request the electric vehicle response if not already done.
4. Access Vehicle Emergency Guide for the vehicle (see Appendix B).
5. Identify any exposures to which fire may communicate. Exposure protection may require diversion of resources from the original fire, re-assignment of resources and request for additional resources.
6. Identify smoke travel.
    a. Initiate evacuations as needed. Evacuations may require diversion of resources from original fire, re-assignment of resources and request for additional resources.
    b. Shut down adjacent roadways as needed.
7. Attempt to determine whether there is battery pack involvement.
    a. Hissing sounds, vapors escaping, popping sounds are indicators of battery pack involvement.
    b. When the cab of the vehicle is on fire, the battery pack may not be involved.
    c. When the battery pack is involved in fire, the cab will almost certainly be involved.
8. If needed, assign unit(s) to shut down traffic and provide upstream blockers in order to protect responders.

First Arriving Engine

1. Secure a water source.
    a. Electric vehicles can take 10 times (10x) the amount of water to cool or extinguish when compared to an internal combustion vehicle.
2. Immobilize the vehicle by chocking the wheels.
3. Initiate evacuations if required.
4. Approach the vehicle from a 45-degree angle ensuring that all individuals stay out of the path of the vehicle and the potential silent movement of the vehicle.
5. Deploy the appropriate sized hose line/extinguishing device.
    a. Use 2 ½ hand line or multiple 1 ¾ hand lines.
    b. Utilize the reach of the stream to begin to extinguish the body of fire.
    c. As you approach, take note of the reaction the vehicle has with the water. Initial water application may cause a flare up of fire.
6. Upon extinguishment of the main body of fire, locate and identify the location of the battery.
7. Begin to monitor the battery for signs of thermal runaway using a thermal imaging camera (TIC), including:
    a. Heat signature present
    b. Vapors escaping from the battery back
    c. Popping sound from the battery pack
    d. Visible fire around the battery pack
9. Begin to cool the battery pack.
    a. The stream should be directed to one area on the battery pack and applied for 3-5 minutes.
    b. After application of water the battery should be checked again for heat.
    c. If the initial spot remains at an elevated temperature or a new area is found, the stream should again be applied to that area for an additional 3-5 minutes, followed by a second heat check.
    d. This process should be repeated until the battery pack no longer shows any elevated temperatures.
10. Monitor the battery.
    a. After the battery is cooled and it has been determined that there are no longer any spots on the battery of elevated temperatures, monitor for at least 30 minutes before moving the vehicle.

Second Arriving Company

1. Establish delineated Hot Zone and exclude all personnel not in full PPE, SCBA, and on air.
2. If safe, ventilate the vehicle.
    a. Due to the potential for toxic, flammable, and explosive vapors to accumulate in the vehicle cab, a minimum of two doors should be opened to allow/prevent the buildup of these vapors.
    b. Attempt to shut down the high voltage system of the electric vehicle [NOTE: if it's on fire, it's too late].
3. Tilt/open the vehicle.
    a. Upon identification of the battery location the next arriving apparatus should provide access for the engine company to apply water directly to the battery pack.
    b. Location of the battery pack will determine the tactic.
4. Remove the doors and rear seat top.
5. Open and remove the trunk lid.
6. Tilt the vehicle for access to the floor batteries. Consider utilizing the following tools:
    a. High-lift jacks
    b. Spreader and cribbing
    c. Grip hoist, comealong, or winch

Third Arriving Company

1. Ensure the first engine has a positive water supply.
2. Assist the first engine with the deployment of the appropriate sized hand line.
3. Be ready to relieve the first engine company of suppression and cooling activities.
    a. Fires involving electric vehicles can require extended scene times. These fires often require the application of 3-10x the amount of water of an internal combustion engine vehicle.

Fourth Arriving Company

1. Assist other companies in suppression, battery access, and thermal monitoring.

Police/Traffic Control

1. Establish traffic control (follow traffic incident management procedures).
2. Consider evacuation.

EMS

1. Prepare for hydrofluoric acid (HF) and other smoke exposure considerations.
2. Consider rehab and medical monitoring for long duration Incidents.
3. Consider Advanced Life Support (ALS) for HF and smoke exposure.

Hazmat

1. Monitor smoke, especially HF, hydrogen cyanide (HCN), and heavy metals.
2. Monitor runoff.
3. Decontaminate: have safety collect all running gear.

Tow

1. Communication should occur between the incident commander and tower before accessing the scene.
2. Utilize incident staging.
3. Check with fire to make sure the battery has been cool for at least 30 minutes.
4. See Appendix C for more information about EV emergency towing protocols.

Tactics and Strategy

This section provides special tactics and strategy best practices tailored to each response discipline that may be involved at the scene of an EV incident.

Traffic Control

1. Maintain in accordance with regional/applicable traffic guidelines, including MUTCD Chapter 6-O.

Fire

1. Employ offensive tactics when:
    a. A life safety threat occurs (someone trapped in the vehicle etc.).
    b. There is an exposure threat with the likelihood of fire extension without the ability to remove the vehicle from the exposure.
        i. Removal of the vehicle from the exposure needs to be a minimum of 50 feet.
2. Employ defensive tactics when:
    a. There is not a life safety threat
    b. There is not the risk of fire spread to an exposure
    c. Limited resources are present
    d. A sustained large volume of water is not present or practical
3. For Overhaul/Battery Cooling:
    a. Raise vehicle at least 24”
    b. Cool battery pack wide area pattern
    c. Monitor Battery with TIC for temperature of no higher than 120℉ for at least 30 minutes

EMS

1. Provide for evaluation of potential smoke exposure, including HF, as well as provide rehab - See Hydrofluoric Acid Emergency Medical Management in Appendix D.
2. Set up EMS treatment area in cold zone. Prepare to treat patients and emergency responders for smoke exposure, including HF, as well as exposure to fire. Lithium-ion battery fires can exceed 1800℉.
3. Determine need for ALS.
4. Determine need for rehab.

Hazmat

1. Monitor for hazardous materials released in smoke and runoff.
    a. Monitor for HF/HCN/heavy metals.

2. Monitor firefighters' exposure with fluoride paper or another similar method.
    a. Monitor PPE for contamination.
    b. Determine need for decontamination of personnel and PPE.
3. Consider the need for evacuation or shelter-in-place.

Tow

1. Determine the status of the vehicle face to face with the fire department.
    a. Determine the probability of ignition or reignition.
2. EVs should only tow on a flatbed.
3. Stow vehicle outdoors (50 feet from any other structure) or inside a containment barrier system.

Communications

1. Gather information on vehicle to determine if:
    a. Vehicle is hybrid or electric - access EV Emergency Response Guide (See Appendix B)
    b. If there is damage or fire from the vehicle
    c. Injuries are present
2. Use traffic cameras to provide pre-arrival information.

OEM - Resources Needed on a Situational Basis

1. Notify the OEM and/or regulatory agency with local protocol.
2. Provide support resources.
3. Notify the community.
4. Work with law enforcement for traffic diversion.
5. Work with hazmat for potential evacuation or shelter in place - potential for hazardous material clean up.

Special Considerations

This section outlines special considerations for handling EVs involved in an incident, highlighting the differences from the procedures used for internal combustion engine vehicles.

1. Vehicle battery packs that are found intact should remain that way. At no time should any department members attempt to breach, cut, or pierce an intact electric vehicle battery pack.
2. Vehicle battery packs that have been damaged/opened due to crash or fire should be directly doused with water due to mechanical or thermal injury.
3. Defensive tactics are the preferred method when dealing with electric vehicle fires. When possible defensive tactics should be used.
4. Due to the high temperature associated with electric vehicle fires, company officers and chief officers should consider escalating the alarm to meet the needs of the incident.
5. For fires involving electric vehicle charging stations, power must be isolated to the charging station before suppression of the vehicle can take place.
6. Vehicles involved in crashes and/or batteries subjected to damage are susceptible to delayed ignition up to weeks following the incident.
7. Police should store impounded vehicles in isolated bay areas, and not inside a building. See Appendix C for an example of safe EV storage.
8. If the vehicle fire cannot be controlled/extinguished, it should be placed in a container (e.g. roll-off) with the bottom of the container lined with sand and vehicle covered with sand so the container can be transported to an alternative location for monitoring/storage/salvage.
9. Electric commercial and bus vehicles have larger batteries with higher operating DC voltage that may be located in non-traditional locations (roof, undercarriage, rear compartments, etc.) and may increase extinguishing time.
10. Be aware of conversion vehicles.

Appendix A:
Definitions

Electric Vehicle
An electric vehicle (EV) is one that operates on an electric motor, instead of an internal combustion engine (ICE) that generates power by burning a mix of fuel and gases.

Hybrid Vehicle
A hybrid vehicle (HEV) uses more than one means of energy, combining a gas engine with an electric motor. The two systems work with each other to move the vehicle. This allows the car to burn less gasoline, achieving better fuel efficiency than a traditional engine that solely uses fuel.

Plug-in Hybrid Vehicle
Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor and another fuel, such as gasoline, to power an ICE. The vehicle typically runs on electric power until the battery is nearly depleted, and then the car automatically switches over to use the ICE.

Nickel Metal Hydride Battery
A nickel metal hydride battery (NiMH or Ni-MH) is a type of rechargeable battery commonly found in older hybrid vehicles.

Lithium-ion Battery
A lithium-ion (Li-ion) battery is an advanced battery technology that uses lithium ions as a key component of its electrochemistry. During a discharge cycle, lithium atoms in the anode are ionized and separated from their electrons. The lithium-ions move from the anode and pass through the electrolyte until they reach the cathode, where they recombine with their electrons and electrically neutralize.

High Voltage
For automotive applications, any voltage greater than 30 volts alternating current, or AC, or 60 volts direct current, or DC, is considered to be a high or hazardous voltage due to the potential to produce serious injury or death due to electric shock. Electric drive systems on commercial vehicles can operate at voltages as high as 800 volts, both AC and DC, and can produce peak currents as high as 100 amps, which make contact with high voltage components even more dangerous.

High Voltage Cables
Visible orange cables are another indication that a vehicle has a high voltage system. That is because there is a voluntary Society of Automotive Engineers, or SAE, recommended practice that specifies that all high voltage cables have an orange outer covering. While voluntary, this practice has been adopted by virtually all manufacturers.

Level 1 Charging System

Level 1 represents 120-volt charging using the common household outlet. It's known as trickle charging because it typically provides 3-5 miles of range for every hour it's connected to an EV, HEV or PHEV.

Level 2 Charging System

A Level 2 EV charging station delivers an electrical current from an outlet or hardwired unit to the vehicle via the connector, similar to a standard-issue charger. However, Level 2 car chargers need a 208-240 Volt, 40 Amp circuit.

Level 3 Charging System

More commonly known as DC Fast Charging, DC Fast Charging utilizes over 480V. Due to the high power, DC Fast Charging is only found at commercial charging stations.

Thermal Runaway

Thermal runaway occurs when a lithium-ion battery becomes overheated and is often triggered by overcharging, a short circuit or other cell stress.
A chain reaction in the cell that generates gas is triggered by excess heat. This can spread to the rest of the battery pack if not mitigated, which can cause other cells to overheat and then decompose. The runaway causes the release of flammable gasses as it takes hold and the battery cells break down.

Appendix B:
Vehicle Emergency Guides

EV Rescue

autorescueapp.com

autorescueapp.com/index.html

NFPA

bit.ly/3G0nD7e

www.nfpa.org/education-and-research/emergency-response/emergency-response-guides#aq=%40culture%3D%22en%22&cq=%40taglistingpage%3D%3D(%22EV%20Guides%22)%20%20&numberOfResults=12&sortCriteria=%40title%20ascending

ESA

bit.ly/3DQUysh

energysecurityagency.com/erg

Appendix C:
EV Emergency Towing Protocols

Equipment

1. All tows should be flatbeds.
    a. Decks of beds should be steel.
    b. Most EVs are over capacity for dollies.
    c. Many manufacturers do not recommend dollies.
    d. Truck GVW minimum is 26,000lbs. Any truck that exceeds 26,000lbs requires CDL only drivers.
    e. Possible option: Flatbed trailer, able to release from truck in case of fire.

Liability

1. Towers take on the greatest liability with the least amount of protection and support. Liabilities include:
    a. Hazardous threat to employees
    b. Toxic smoke/fumes from fire
    c. Toxic chemicals from battery exposure
    d. Risks associated with High Voltage
    e. Least amount of resources/funding for training and PPE
2. Threat to equipment includes:
    a. Damage or total loss if fire occurs while loaded
        i. Due to the nature of thermal runaway, total loss is imminent.
3. Threat to property/environment includes:
    a. Requirement of substantial amount of storage space or a specialized containment
    b. Risk of property damage without space or protection of vehicle
    c. Toxic water used for extinguishing EV fires
        i. Tower is liable for clean up and disposal of water.
        ii. Insurance will not cover clean up costs.
    d. Major threat to communities surrounding towing storage facilities
4. Increased costs/financial responsibilities includes:
    a. Increased insurance cost for towers that tow and store EVs
        i. Insurance companies recognize greater risks.
    b. Absorbing costs for environmental clean up of EV fire on tower's property
    c. Absorbing costs to tow, store and dispose uninsured vehicles
    d. Lack of method or location to dispose of an EV if left abandoned with the tower

Additional Concerns

1. Dispatch centers/municipalities/law enforcement agencies should contact the towers on their rotation to verify if they are willing and able to tow and store EVs.
2. Towers who do not wish to tow EV should not be punished/disciplined for refusing the tow considering the risks, liability, and storage requirements.
3. Most regulatory agencies including New Jersey State Police, New Jersey Turnpike Authority and most municipalities have regulated rates for towing, recovery, storage, etc. Due to increased risks, liability, PPE, training and storage requirements, these rates need to be adjusted as applied to EVs.

Resources for Towers

1. Energy Security Agency (ESA): www.enersgysecurityagency.com
    a. Towers should engage with ESA prior to towing damaged EVs
    b. CALL 855-ESA-SAFE
    c. 24HR technical and safety support
    d. Online support including procedures, safety checklists and storage requirements
    e. Best practices and recommendation for towing procedures
    f. Storage/containment specifications and recommendations
    g. Risk analysis, compliance and liability mitigation
    h. Safety monitoring for stored vehicles
    i. Offer on-site training courses
2. WreckMaster (www.wreckmaster.com) offers online and in-person training courses.

Example: Electric Vehicle Storage (As Recommended by ESA)

1. Storage is designed to accommodate commercial and passenger EVs.
2. Interior dimensions:
    a. Each 16ft wide X 32ft deep
    b. 2 bay capacity
    c. Each block 8ft X 2ft X 2ft

Appendix D:
Hydrofluoric Acid Emergency Medical Management

Hydrofluoric Acid (HF) is a colorless, corrosive that can be found in the fire smoke of a Lithium-ion battery fires/chemical release. It is also a liquid used in etching, the manufacturing of fluorinated chemicals, electro-polishing of metals, and in the semiconductor industry. The toxic effects of HF are due to the fluoride ion, which is able to penetrate the tissues and bind to the intracellular calcium and magnesium.

The following are general guidelines for medical treatment and are not a substitute for an agency's policies and protocols.

Signs & Symptoms

1. Systemic Effects – Decreased levels of calcium and magnesium and increased levels of potassium in the blood with any route of exposure.
2. Routes of exposure include inhalation, absorption, ingestion, and ocular contamination.
3. Patient presentation
    a. Patient may present with signs of hypoxia, stupor, lethargy, or coma. Respiratory burns are common with airway obstruction, non-cardiogenic pulmonary edema, and pneumonitis.
    b. The skin may appear normal with no outwards signs of burns except severe pain due to demineralization of the bone.
4. Monitor for:
    a. hyperkalemia
    b. hypocalcemia (prolonged QT)

Possible BLS/EMT Treatment Parameters

1. Begin BLS initial management procedures.
2. For **DERMAL EXPOSURE:**
    a. **Rapid decontamination is critical!**
    b. Apply premixed Calcium Gluconate gel to topically burned skin and leave in place. Vigorously massage burned areas with gel until pain is relieved.
        i. Reapply if pain reoccurs.
        ii. For bum to the hand(s) place hand in a glove filled with gel.
3. For **OCULAR CONTAMINATION:**
    a. Instill Tetracaine according to Initial Management and irrigate the affected

eye(s) with 1% Calcium Gluconate solution (Do Not Use Calcium Chloride). Prepare this solution *by* mixing 50 mt of 10% Calcium Gluconate In 500 ml or Normal Saline. Repeat as necessary.

Possible ALS/Paramedic Treatment Parameters

1. Begina Advanced Life Support (ALS) initial management protocols. Consider contacting medical command.
2. For **RESPIRATORY EXPOSURE** (Paramedic Only):
    a. Administer Calcium Gluconate 1 gram via breath actuated nebulizer, administered as 5 ml or a 10% solution followed *by* a repeat of 5 ml of a 10% solution. Maximum total dose is 5 gm.
3. For **CARDIOVASCULAR EXPOSURE**:
    a. Patient must be exhibiting signs of hypocalcemia and/or hyperkalemia on 12 lead ECG, such as peaked T waves and/or prolonged QT segment.
    b. Calcium Gluconate 1 gm of 10% solution slowly IV/10 over 5 minutes Pediatric: 0.5 gm of 10% solution slowly IV/10/ over 5 minutes.

Key Points/Considerations

1. Acute effects may progress for several days before symptoms appear.
2. Specific treatment depends on the body system affected.

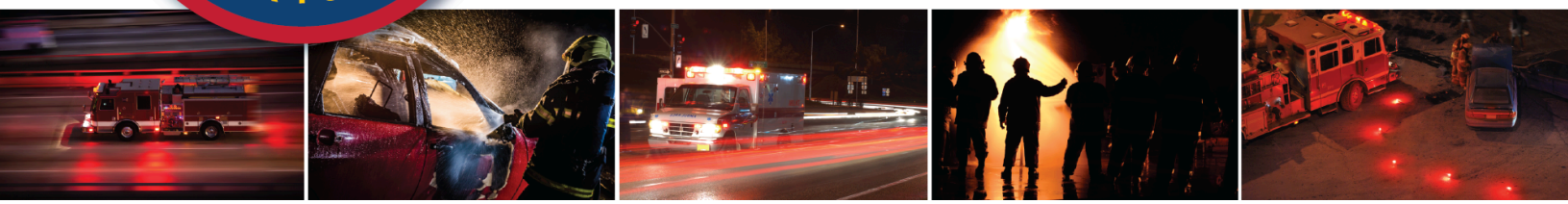
National Institute for Occupational Safety and Health. (2018, August 22). Mercury (elemental). Centers for Disease Control and Prevention. Retrieved June 3, 2024, from https://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750030.html

Regional Emergency Medical Services Council of New York City. (2021, January). 2022 HazTac protocols. Retrieved June 3, 2024, from https://nycremsco.org/wp-content/uploads/2021/01/2022-HazTac-Protocols.pdf

Appendix E:
EV Fire Fighting & Scene Management Action Checklist

ELECTRIC VEHICLE FIRE FIGHTING
& SCENE MANAGEMENT

ACTION CHECKLIST



Updated: March, 2024

Dispatch

Include on initial dispatch in addition to fire department:

1. Traffic Incident Management resources - probable long-term incident (over 4 hours)
2. Hazmat (Initially can just be a team representative)
3. EMS, add ALS if any exposure to smoke or runoff. Persons exposed to smoke should get additional evaluation for inhalation of hazards associated with toxic byproducts in smoke (e.g. hydrogen fluoride, H2S, toxic metals, etc.).

Arrival to Scene

1. Secure the scene and move all bystanders to a safe distance.
2. Evaluate smoke travel and consider down-wind, down-hill evacuation due to toxic smoke and runoff.
3. Maintain heightened situational awareness at all times due to dynamic environment and hazards.

Initial Attack

Remember:

- Traffic Incident Management for these incidents could be prolonged with a working period in excess of 4 hours based on current reports.
- Fire departments should brief their police departments on this issue prior to an incident.
- Always wear full PPE.
- **Access Emergency Response Guides ASAP.**

EV Rescue	**NFPA**	**ESA**
autorescueapp.com	*bit.ly/3G0nD7e*	*bit.ly/3DQUysh*

Recommended Order of Operations & Considerations

1. Perform initial traffic incident management principles of creating a safe work area with temporary traffic control, advanced warning, blocking, tapers, etc. to protect responders working in the area.

2. Rescue injured persons. Consider treating HF exposure/poisoning (see attached *Supplemental Information* section).

3. Isolate vehicle power as soon as reasonably possible.
    a. **Unless otherwise advised by an ERG or vehicle manufacturer**, find the battery, cut 12 volt negative cable or first responder loop (look for cut diagram). **DO NOT CUT ORANGE CABLE(S).**
    b. Remove the electronic key fob from the vehicle and move at least 50' from the vehicle or isolate it in a RFID, EMF, EMI, or signal blocking/isolation type bag (Faraday bag).
    c. Obtain vehicle state of charge from vehicle operator.

4. Treat as HazMat response level (HazMat Lite), as needed.

5. Fight fire from a distance, protect exposures, and avoid smoke whenever possible. Limit persons in the Hot Zone.
    a. Smoke contains high concentrations of Hydrogen Fluoride (HF) / Hydrofluoric Acid. HF permeates turnouts and is very difficult to remove. Smoke also contains heavy metals.

6. **Cool battery to ambient temperature or no hotter than 120F.**
    a. Battery temperature monitoring should be a continuous process. Vehicles should not be released until battery compartment temperature is stabilized for at least 30 minutes post-suppression.
    b. Air should be continually monitored. Increasing carbon monoxide and other gas levels could be an indication that batteries are still in thermal runaway.

7. Extinguish small fires that do not involve the high voltage battery using typical vehicle fire fighting procedures, monitoring the underneath battery compartment with the TIC to ensure it is not heating up.

8. Consider defensive operations if there are no life safety or exposure concerns. It is exceedingly difficult to put water directly on the cells to effectively cool them and prevent further runaway.

9. If an open area and no hazards or exposures consider letting the vehicle burn. The battery can take up to 1.5 hours to burn out.

10. Do not try to open/pierce the battery for water application, damage to the battery could result in electrocution.

11. Monitor throughout the incident for HF (gas monitor with HF sensor & F paper) and consider fog streams to knock down or reduce vapors if indicated. HF compounds are extremely toxic and can be inhaled, as well as absorbed through the skin.

a. See link for more details on health hazards: www.emergency.cdc.gov/agent/hydrofluoricacid/basics/facts.asp.

12. Use a thermal imager (TIC) to monitor the battery compartment during the fire. Temperatures can reach >1400F (Lack of flames is not a sufficient indication that thermal runaway is not taking place).

13. When safe, chock the wheels. EVs move silently, so never assume it is powered off. Never assume that an EV will not move.

14. Use of foam (Class A or Class B) is not recommended.

15. Consider applying "specialized" agents, surfactants and encapsulating agents (F-500, Fire-Ice, Pryo-Cool, etc.).

16. Batteries should always be treated as energized. During overhaul do not make contact with any high voltage components (see above for battery isolation).

17. Note that runoff can be hazardous.

18. Plan for multiple hours of operation, traffic control (TTC safety), light and air unit, water tenders, and coverage/move-up issues.

19. Fire hoses can become easily contaminated, and must be bagged and properly cleaned.

20. When fire is suppressed sufficiently, lift the car on one side so the battery can be exposed to continue to cool and monitor (lift at least 24"). Have access to the full profile of the battery compartment. Consider other continuous cooling methods such as tanks and pools. Gear and personnel can become contaminated. Gross decontamination to be done on anyone in the Hot Zone at the scene. Bag gear for commercial cleaning due to heavy metals in addition to HF in smoke.

Incident Demobilization

First responders should brief the towing company and their personnel on associated EV hazards.

1. Provide 50' clear space around the vehicle once stored and never inside a building.
2. EVs must be towed "wheels up," either on a flatbed or dolly.
3. An engine company may need to escort the vehicle to the storage/salvage location.
4. Be aware of the stranded energy potential that could cause the battery to ignite again.
5. Fire personnel may need to follow the tow truck to the yard.

Other Considerations

- [ ] Use Fluoride Test Paper (F paper) to test the atmosphere (tape to SCBA mask and/or turnouts to test for contamination). Also use the F paper for testing turnouts, hose, and other equipment used at the incident.
- [ ] Be alert for signs of a lithium-ion battery fire (leaking fluids, increased temperature, gurgling sounds, popping or hissing noises from the battery compartment, smoke, flames, sparks). If a lithium-ion battery fire is suspected, vent the passenger area, and remain alert for reignition.
- [ ] Remove the electronic key fob from the vehicle and move at least 50' from the vehicle or isolate it in a RFID, EMF, EMI, or signal blocking/isolation type bag (Faraday bag).

Supplemental Information

Physical and Chemical Properties for Hydrofluoric Acid Vapors

Formula: HF Molecular Weight: 20
Flash Point: Non-Combustible Boiling Point: 151°F
Melting Point: -96°F
Rel Vapor Density 1.9 (Heavier than air)
Vapor Pressure @68°F: 0.16 atm (121.6 mm Hg) Liquid Specific Gravity: 1.26 (Heavier than water)
Ionization Energy/IP: 15.98 eV

Toxic Levels of Concern NIOSH (IDLH/STEL/TWA)

IDLH: 30 ppm (24.54 mg/m³)
STEL: 6 ppm (4.91 mg/m³)
TWA: 3 ppm (2.45 mg/m³)
Acute Exposure Guideline Levels (One Hour AEGL)
AEGL-1: 1 p

Recommended Equipment for EV Fire Incidents

- [ ] Thermal Imaging Camera/TIC
- [ ] Fluoride Paper
- [ ] Air/Gas monitor with Fluoride sensor
- [ ] Special Extinguishing Agent to control battery - Lithium fires
- [ ] Large plastic bags (drum liners) to contain contaminated turnouts, hose, etc.

Notes

1. The electrolyte (Polymer Gel that the charging nodes are encased in) includes a volatile hydrocarbon-based liquid (electrolyte will contain petroleum/organic solvent and fluoride compounds) and a dissolved lithium salt (which is a source of lithium ions) such as lithium hexafluorophosphate. Another toxic gas, hydrogen fluoride (HF) may be also generated from the decomposition of electrolytes.

2. With a higher state of charge, battery failure and cell propagation will be much more energetic. It also takes less physical or thermal insult to cause a failure and subsequent thermal runaway. With less charge, it can take more to get it to fail. Once battery failure occurs, the state of charge has little effect on involvement of the available fuels in the form of electrolyte and anything else surrounding the cells. It also doesn't affect the compounds produced and released as a part of the post fire debris, smoke or water run-off. Overall duration of an EV fire is influenced more by construction and things that either allow or don't allow for propagation, such as being able to apply water to cells or modules that have not yet failed.

Additional Resources

ESA: www.energysecurityagency.com/
Fire Research: www.tkolb.net/tra_sch/CarFires/HybridVehicles/FFTacticsElecVeh.pdf
NFPA: www.nfpa.org/EV
NHTSA: www.nhtsa.gov/battery-safety-initiative
NVFC: http://virtualclassroom.nvfc.org/products/electric-vehicle-safety-an-awareness-level-training
Industrial Emergency Council: www.iectraining.org/ (special thank you!)

Here you can access the digital version of this checklist:

For more information on DVRPC's EV Task Force contact Kayla Bancone.