Hybrid and Electric Vehicle Emergency Response

336.1 SUMMARY

- This document is designed to provide Frisco Fire Department (FFD or the Department) members with procedures to interact with hybrid and electric vehicles and perform appropriate hazard mitigation strategies and tactics in a safe manner.

336.2 SCOPE

- This procedure should be followed by all Frisco Firefighters when interacting with hybrid and electric vehicles for any of the following conditions:
  - Stranded or disabled vehicle
  - Motor vehicle accident
  - Smoke or fire emanating from a vehicle
  - Flooded vehicle
  - Medical emergency involving vehicle occupants still in the vehicle
  - Structure fire with vehicle exposure
  - Structure fire with vehicle involvement
  - Proximity fire with vehicle exposure
  - Charging malfunction with vehicle plugged in

336.3 DEFINITIONS

- EV/BEV: Electric vehicle/battery electric vehicle - Any vehicle that uses electric motors, either in full or in part, as propulsion.
- HEV: Hybrid electric vehicle - A car that integrates a small battery and an electric motor to enhance the efficiency of the engine. The internal combustion engine (ICE) maintains the battery's charge. It cannot be charged by plugging into an electrical source. Hybrids can travel short distances on electric power only.
- PHEV: Plug-in hybrid electric vehicle - A vehicle configured like a traditional hybrid but with a bigger battery pack that can be charged by plugging into an electrical source. This vehicle can start a trip on electric-only propulsion after being plugged in and can usually travel further on battery-only as HEV.
- Li-ion/LITHIUM-ION BATTERY: The current chemistry standard in electric vehicle batteries that offers the needed energy density, power, and fast charging capability.
- 1st RESPONDER CUT LOOP/CUT LOOP/FIREFIGHTER CUT LOOP: A low voltage harness loop that, when cut, is designed to isolate the high voltage power to just the battery pack.

- BATTERY CELL: The smallest unit of the battery pack. They are individual single cells designed as either a cylindrical, pouch or prismatic combination, depending on the manufacturer. If the cylindrical battery pack housing is damaged, these cells can become dislodged or even ejected in a severe collision.
- BATTERY MODULE: A module can contain several hundred battery cells. The module design allows for electronic battery management thermal control and allows for greater capacity by using space more efficiently.
- BATTERY PACK: All the components of energy storage for a vehicle. The pack contains all the modules (which include the individual cells) used to store energy. Depending on the vehicle manufacturer and vehicle type, the battery pack can be used as a structural member of the vehicle's body in many cars. Additionally, on most EVs, the battery pack is located on the bottom of the vehicle and will run the length of the car between the axles. On HEVs and PHEVs, the battery pack location varies but can mostly be found towards the vehicle's rear (under or behind the back seat or in the trunk).
- DC/DC Converter: Converts Voltage from one range to another.
- DRIVETRAIN: System of components used to transfer power from the engine/motor to the wheels.
- REGENERATIVE BRAKING: Process whereby energy is generated by the motor during deceleration and is used to charge the battery.
- BATTERY MANAGEMENT SYSTEM(BMS): A system of components used to monitor and control the charge, discharge, and temperature of the battery cells.
- Thermal Runaway: Thermal runaway is a chain reaction within a battery cell in which an increase in the temperature of a lithium-ion battery can cause a further increase in temperature, causing an exothermic reaction leading to the release of flammable gas and the potential for an explosion. It is caused by the pressure created from the build-up of heat in the battery, which can be due to mechanical, electrical, or thermal abuse. Common causes of abuse include excessive current, internal short circuits, external heat sources, puncturing, or flame impingement.
- CO (Carbon Monoxide): Is a colorless, poisonous, odorless, tasteless, flammable gas that is slightly less dense than air. CO is an incomplete product of combustion.
- H (Hydrogen): This is a colorless, odorless, tasteless, non-toxic, and highly combustible gas. H is a natural element found in water and air.
- DIRECT COOLING - apply water directly onto the burning materials. Ex. Directing a water stream directly into an opening in a battery pack to cool the individual cells inside it.
- INDIRECT COOLING – applying water in an area with the intention to cool the environment without direct contact with the intended target. Ex. Directing a water stream onto an exposure to prevent thermal damage or auto exposure.

336.4 EQUIPMENT AND RESOURCES REQUIRED

- The following is a list of required items for safely interacting with hybrid and electric vehicles:
    - Four-gas meter, CO meter at a minimum
    - Full structural PPE with SCBA when signs of thermal runaway (any kind of smoke or fire), electrical damage, submersion, vehicle rollover or heavy physical damage are present
    - Thermal imaging camera

336.5 PROCEDURE

336.5.1 VEHICLE IDENTIFICATION

- INITIAL CALL: Dispatch shall make every effort to identify the vehicle as a hybrid or electric vehicle while processing the initial call and inform responding units. If vehicle make, model, and manufacturing year can be ascertained it shall also be communicated to responding companies.
- UPON ARRIVAL: Establish a safe work zone through apparatus positioning and proper traffic management tools.
    - Identify or confirm EV/HEV/PHEV through formal and/or informal assessment. Perform initial size up and adjust safe work zone if needed based on vehicle presentation. Any indications of heavy physical damage, smoke/gas/fire, submersion, or exposure to heat or fire should require a safe work zone of 75' minimum, if possible, and full PPE with SCBA.
    - Perform 360 at a minimum distance of 20' from the vehicle with a four-gas meter and thermal imaging camera to detect the presence of CO/LEL or the visual indication of off-gassing. Heavily damaged vehicles may produce displaced batteries or other high-voltage equipment that should be identified and avoided initially.
    - If occupants are still in the vehicle and gas/smoke/fire are present, perform rapid extrication sequences.
    - For advanced guidance, contact the Energy Security Agency to initiate on-scene support: 855-372-7233 (855 ESA SAFE).

336.5.2 IMPLEMENT ACTION PLAN (HAZARD MANAGEMENT)

- Position appropriate wheel chocks to prevent vehicle movement. EV/HEV/PHEV may present without audible indications of being energized or in drive mode and have the potential to accelerate at rapid rates. Firefighters should use extreme caution when approaching the vehicle until it is fully secured.
- Attempt to gain entry to the passenger cockpit through door handle access. If electromechanical door handles do not present and do not operate the door, use appropriate glass removal techniques to gain access through either of the front windows.

- If the doors cannot be opened, visually assess the cockpit dash display for illumination and signs of vehicle status. If the vehicle appears to be on, attempt to locate a power button or ignition key and turn the vehicle off, resulting in INITIAL SHUTDOWN. If key fobs, vehicle cards, or cell phones are present, remove those items and isolate them in Faraday bags or a minimum of 30' from the involved vehicle. If the passenger cockpit cannot be accessed and the vehicle cannot be turned off due to obstruction or other scenarios, progress to the following step.
- Locate, access, and perform the vehicle energy isolation procedure as needed. Minor to moderately damaged vehicles may not require any actions other than vehicle shutdown. SECONDARY SHUTDOWN procedures may be required and will be specific to the vehicle involved. If specific vehicle guidance is not being utilized, access the low voltage battery and the vehicle first responder cut loop if present and disconnect or cut the negative battery cable or plug and cut or disconnect the fireman's loop.
- Some vehicles and special circumstances may require the removal of fuses, relays, or manual service disconnects. High voltage service disconnects should not be accessed or manipulated. Arc flash potential is always present when interacting with high-voltage components.
- DO NOT CUT, INADVERTENTLY COMPRESS, OR CONTACT ORANGE HIGH-VOLTAGE CABLES OR VEHICLE COMPONENTS WITH ELECTRICAL HAZARD WARNING LABELS. DO NOT CUT FIRST RESPONDER LOOPS OR BATTERY CABLES WHEN VEHICLE PRESENTATION DOES NOT MERIT ENERGY ISOLATION.

336.5.3 IMPLEMENT ACTION PLAN (VEHICLE STABILIZATION)

- Apply four points of contact under the A and C pillars of the vehicle if the vehicle is on all four wheels. Avoid deep contact points that would apply point load pressure to the floor pan of the vehicle. This could result in physical abuse of the battery pack.
- Rollover or collision resulting in an unnatural resting position of the vehicle will require advanced stabilization. Avoid contact with the floor pan of the vehicle that could result in point load pressure and physical abuse of the battery pack. Back tie techniques and less reliable contact points such as control arms, wheels, and suspensions may be required as anchor points to avoid battery pack abuse.
- Focal points for undercarriage contact should be the original equipment manufacturer (OEM) engineered lifting points located near the frame rails and rockers under the A pillars and posterior B or C pillars.

336.5.4 IMPLEMENT ACTION PLAN (VEHICLE EXTRICATION)

- Charging ports, low and high-voltage batteries, high-voltage cables, and high-voltage components with capacitors should be located, identified, and avoided at all costs. Any direct contact may result in arc flash or arc weld with tool contact. Inadvertent displacement of any high-voltage components may also result in energy hazards, which may lead to arcing events, short circuits, and thermal runaway.

- Ultra-high strength vehicle structures produce highly hazardous reactions in hydraulic extrication tools that may result in violent shifting or relocation of the tools. Firefighters should exercise added caution and safe physical positioning when performing extrication techniques with hydraulic tools to avoid injury from tool shifting and high resistance cutting responses.

336.5.5 IMPLEMENT ACTION PLAN (FIRE OPERATIONS)

- If the vehicle is off-gassing, smoking, or actively burning, identify the source of the event. Battery-based fires will produce products of combustion through the engineered vent points of the battery pack or the paths of least resistance. This will typically originate from the vehicle undercarriage.
- The incomplete combustion of Li-Ion battery gas contains toxins that may result in serious injury or death if inhaled. Full PPE and SCBA shall always be worn in these conditions.
- Water shall be the primary suppression application. Multi-class extinguishing agents designed to encapsulate or emulsify shall only be deployed in the absence of water. Traditional foam should be avoided.
- DO NOT APPLY WATER to early off-gassing that is not combusting.
- ALLOW THE VEHICLE TO BURN if the following conditions exist:
    - Fully involved fire will not create an imminent life safety hazard.
    - Exposures can be adequately protected.
- IF VEHICLE IS LOCATED INSIDE A STRUCTURE, consider the following:
    - Deploy fire blanket to minimize exposures
    - Move the vehicle to an area that provides a safe area to burn.
    - If unable to move the vehicle, remove exposures and utilize appropriate ventilation techniques.
- Consider suppression efforts if the above conditions are not met.
- Ensure adequate water supply is available to support fire suppression operations. Continuous flow may be required for up to eight hours.
- Rapid attack lines should be deployed initially for rapid extrication attempts or aggressive, offensive attacks designed to knock the initial fire down.
- Extended suppression efforts will require an appropriate water supply, primary and secondary lines, backup lines, and remote water monitors.
- Effective suppression efforts require direct cooling of the Li-ion batteries. This is only accomplished with water penetration to the interior of the battery pack enclosure. Controlled streams should be directed into the vent points or breaches in the battery pack.
- Reposition the vehicle for lifting and stabilization to optimize access to the vent or breach points of the battery pack.

- Adequate suppression and extinguishment will be confirmed by a continuous decline in the thermal condition of the battery pack and the decline of CO in the off-gas. This is not an indication of absolute containment. Stranded energy may still be present in the vehicle with unvented battery cells, and secondary thermal runaway is highly probable.
- Vehicles should not be transferred down the chain of custody or relocated until stable conditions are present for a minimum of one hour.

336.5.6 IMPLEMENT ACTION PLAN (SUBMERGED OR FLOOD-DAMAGED VEHICLES)

- Consult EV manuals and resources for dive-based access, rigging, and removal of the submerged vehicle.
- Electric vehicles may experience thermal events while submerged. This will be identified through the presence of gas emanating from the surface of the water and active fire bursts under the surface of the water. Firefighters should avoid entering the water if the vehicle is experiencing an active event while submerged unless rescue operations are required.
- There is a high probability that the vehicle will experience a thermal event upon removal from the water. Firefighters should establish fire operations action plans upon vehicle removal.

336.5.7 POST-INCIDENT MANAGEMENT

- Battery components or debris shall only be managed by firefighting personnel. Thermal imaging cameras, four gas meters, full PPE, and SCBA shall be utilized when handling separated high-voltage materials.
- Damaged batteries may be unvented and fully energized and pose significant risk potential to firefighters, personnel, and bystanders. If displaced batteries appear unvented, thermal imagery should be used to detect cell temperature. Any isolated cells exceeding 200 degrees Fahrenheit should be cooled immediately with water through suppression operations.

336.6 SPECIAL CONSIDERATIONS

336.6.1 VEHICLE CONFINEMENT (PARKING GARAGES, PARKING LOTS, VEHICLE ENCLOSURES)

- These environments may require rapid isolation of combustible gasses and fire to prevent fire spread to exposures and accumulation of combustible and toxic gas. Gas clouds (smoke) emanating from EVs should always be perceived as highly toxic and highly combustible until determined otherwise through atmospheric monitoring.
- Firefighters should consider the deployment of EV fire blankets on the involved vehicle in accordance with the manufacturer's recommendations. Fire blankets should be deployed as temporary containment tools that are not designed to stop thermal runaway. Firefighters should be prepared to manage fuel-rich gas products that have developed under the blanket when the blanket is removed. This removal process may result in the combustion of the released gasses and should be addressed with water

stream application.

- Adjacent exposures, such as other vehicles or mobile objects, can then be relocated away from the fire source.
- Structural elements such as pre- and post-tensioned concrete decks, walls, or ceilings made of combustible materials should be aggressively protected with fire streams to reduce the risk of collapse and fire spread.
- Ventilation and gas monitoring may be necessary to safely manage atmospheric conditions.
- Consider hydraulic ventilation tactics through hand line applications to produce venturi effects and add water weight (power cone) to the gas in highly pressurized environments with unfavorable natural ventilation.

336.6.2 COMMERCIAL VEHICLES (BUSSES, SEMI TRACTORS, COMMERCIAL VANS, BOX TRUCKS)

- Consult EV manuals and resources when mitigating emergencies involving commercial vehicles. Commercial vehicle systems have more complexities related to integrated suppression and detection systems, braking, and energy isolation. Additionally, battery packs may be located on the roofs of the vehicle and highly reinforced compartments. Rooftop packs may require elevated streams for proper suppression applications.
- USE CAUTION when accessing or opening compartments that contain Li-ion batteries. Combustible and toxic gas may be contained in a fuel-rich state within these compartments and produce highly combustible/explosive conditions when accessed. All compartment spaces that may potentially be compromised should be monitored with a 4-gas meter probe in FULL PPE and SCBA prior to opening.
- Commercial vehicle electric parking brakes may be compromised due to damage, and firefighters should apply appropriate wheel chocks and potential anchoring to prevent undesired vehicle movement.

336.6.3 CHARGING STATIONS (LEVEL I, II RESIDENTIAL AND LEVEL II, III COMMERCIAL)

- Electric vehicles that are plugged into a charging station and require firefighter interaction should be unplugged or disconnected from the charging station.
- In the case of fire, off gas, smoke, audible signs of electrical damage, submersion, or collision while plugged in, charging stations should be isolated remotely through charging station electric panels, E Stops, or identified island breakers. Lock-out/tag-out procedures should be followed.

336.6.4 STRUCTURE FIRE (HYBRID AND ELECTRIC VEHICLES AS AN EXPOSURE AND FIRE SOURCE)

- Tactical priorities should include life safety and then the mitigation of fire spread to the garage or area where the electric vehicle is located. This may include defensive fire stream positioning or vehicle removal/relocation.
- Firefighters should exercise extreme caution when making an entry on residential structure fires where a hybrid or electric vehicle is involved. The presentation of dense, white smoke (gas) should be an immediate indicator to consider the presence of li-ion battery gas. This gas has high concentrations of CO and H, which may result in a

flashover or gas explosion. This can produce intense fire, shrapnel, and flying debris up to and including complete overhead door displacement.

336.7 HAZARDOUS CONSIDERATIONS

- Signs of Thermal Runaway:
  - Sight: White smoke or gas, fire, arcing
  - Sound: Arcing, hissing, or popping of battery vent due to pressurized release of gas within the battery cells
  - Smell: Electrical burning odor with a "sweet" undertone
- Firefighters exposed to Li-Ion battery gas should be evaluated for potential toxic inhalation exposure.
- Firefighter PPE ensembles do not provide adequate protection against prolonged direct flame exposure to battery-based fire production. Battery flames may extend 6 – 10 feet from the battery pack and will have a blowtorch presentation. Direct exposure may result in significant burns.
- Environmental conditions may be significantly impacted by incomplete combustion of Li-ion battery gas, and careful risk/benefit analysis should be conducted before initiating suppression efforts. Indirect cooling or inadequate water supply and improper stream direction will likely extend the event significantly and produce a much larger impact environmentally and atmospherically.
- Direct contact with high-voltage components may result in arcing events and electrocution.
- Li-ion batteries may produce off-gassing that cannot initially be seen with the naked eye. Thermal imaging cameras are essential to early visual detection of off-gassing, and four gas meters indicate CO production and LEL.
- Li-ion batteries may ignite with little warning through rapid, pressurized releases of combustible gas. Firefighters should always wear FULL PPE with SCBA and exercise extreme caution when interacting with heavily compromised hybrid and electric vehicles with hazardous presentations.