Federal Fire Department San Diego

Alternative Electric Drive Vehicles for the First Responder

Training resource information for all of the material in this outline came from the National Alternative Fuels Training Consortium (NAFTC) Online Education Center
http://naftc.wvu.edu

- Introduction to the Alternative Electric Drive Vehicle
  - The Alternative Electric Drive Vehicle (AED) is an Electric Vehicle or Hybrid Electric Vehicle
  - There are four types of AED Vehicles
    - Hybrid Electric Vehicle (HEV)
    - Battery Electric Vehicle (BEV)
    - Plug in Hybrid Electric Vehicle (PHEV)
    - Fuel Cell Electric Vehicle (FCEV)
  - Hybrid Electric Vehicle (HEV)
    - These are popular because they contain both an Internal Combustion Engine (ICE) and a battery Electric Vehicle (EV). This creates more economy to the ICE and eliminates the range anxiety that comes with the Battery Electric Vehicle (BEV).
    - The characteristics of an HEV are:
      - More than one power system
      - Combined ICE with battery pack
        - ICE may use fuel, but it may also use E85, CNG, LNG, LPG, or methanol for fuel
  - Battery Electric Vehicle (BEV)
    - There are a small amount of BEV's on the road today. They are becoming more popular though, this is because of better battery power storage, larger scale manufacturing, and more are being developed by large vehicle manufacturers.

- This vehicle has no Internal Combustion Engine (ICE) present. The electrical energy used to drive the vehicle is stored within batteries.
- There several characteristics of the BEV
  - Ready mode – vehicle does no idle when not in motion
  - Motor Generator (MG) – on board generator that produces energy such as through braking and supplies the motor with power
  - Regenerative braking – when decelerating energy is stored in the battering. When coasting downhill, or braking, MG is the generator that stores the power in the batteries.
  - Nearly silent – some may make noise or beeps to alert those present that the vehicle is running. Other than that the vehicle is nearly silent.
  - BEV's high and low voltage battery systems.
    - High voltage batteries can store up to 600v or more
    - Lights and accessories use 12v battery systems. There is an inverter on board to step down the power on these vehicles.
  - These vehicles may have multiples motors for each wheel

➢ Plug in Hybrid Electric Vehicle (PHEV)
- The PHEV is a hybrid with a battery, Internal Combustion Engine (ICE), and charger for additional energy.
- ICE on these vehicles may be powered by gasoline, but may also be powered by alternative fuels.

➢ Fuel Cell Electric Vehicle (FCEV)
- This type of vehicle uses hydrogen gas to power a fuel cell, which powers an electric motor.
- FCEV's are very rare, but they are on the road and you may encounter one.
- The way that this vehicle works is essentially as a Hybrid Electric Vehicle. FCEV's convert hydrogen (H_2) with oxygen (O_2) to electricity to power an electric motor.
- Regenerative braking is present in these vehicles, which includes when the vehicle is coasting.
- Generally speaking the H_2 in these vehicles is safe.
  - H_2 is one of the most abundant elements in nature. It is present in 75% of nature and is very safe.
- In the case of a H_2 spill, the H_2 would vaporize in the form of water vapor and cause no hazard. H_2 is stored on an FCEV under the pressure of 5psig. If there is a release of H_2 it will vaporize (it's liquefied at -423° F) and combine with O_2 to form water vapor, and as a result quickly disperse.
  - H_2 is non-toxic, non- poisonous, and non-corrosive.
- Although H_2 is very safe it does have one major risk factor as related to the first responder.
  - H_2 is extremely flammable; the flammable range is very wide. The flammable potential is 4% and the typical ignition range is 15-74%.
  - When H_2 is burning, it burns as a pale blue flame. It is almost invisible in day light, and is most easily located with a TIC or through the heat wave mirage effect that the heat

emits. Burning H_2, unless in the presence of an impurity, will not emit smoke. The H_2 flame also emits low to almost no radiant heat, although the direct flame is very hot.

- The H_2 fire speed is 10^1/sec or 4,600mph.
- As a result of the low radiant heat, and mostly pure burning of H_2 there is little risk of secondary fire and/or personal injury.

- FCEV's have the following components:
  - Batteries, fuel tank, fuel cell stack (several fuel cells stacked to provide electricity), inverter, motor generator, and an electric motor(s) which may combine more than one power system to drive the wheels
- Most FCEV's on the road are test models and will be clearly marked as such.

➢ Standard Internal Combustion Engine (ICE) vehicles can be retrofitted with aftermarket kits to make them any one of the AED types.

❖ Hybrid Electric Vehicle (HEV) for the First Responder

➢ Battery Types

- Lead acid battery also known as a conventional battery
  - These are 12 volt battery type, low voltage batteries.
  - Conventional batteries on these vehicles are used for lighting and accessory controls
  - The lead acid battery is a standard vehicle battery the same as found on an ICE
  - In an emergency situation the following should be noted:
    - ♦ Acid can cause burns to the skin/eyes
    - ♦ If ruptured the battery can emit a mist that can cause difficulty breathing
      - ➢ Use of water spray can disperse this mist if there is no fire present
    - ♦ Absorbent should be used to prevent seepage
    - ♦ When overheated from fire these batteries can vent explosively because of the hydrogen gas that is emitted
- NiMH (Nickel Metal Hydride)
  - These are the most common batteries found in the current production HEV vehicles to power the high voltage system. The NiMH battery has a high tolerance for abuse. They can be compromised in emergency situations.
  - Upon rapid discharge, such as in a major vehicle collision or vehicle fire, the battery can overheat and short circuit. This causes overpressure of the battery and a flammable electrolyte gas can vent out.
    - ♦ Federal Motor Safety Standard 571.305 states that the battery should not overheat in a crash and that no electrolyte should spill into the passenger compartment upon collision.
  - A ruptured NiMH battery can cause several adverse health effects such as burns, ulcers, nausea/vomiting, and can cause death.
- Li-Ion (Lithium Ion)
  - This is the newest technology for high voltage batteries in electric vehicles. They are mostly found in PHEV and FCEV, but they are also found in HEV vehicles and there will be significant increase in Li-Ion batteries in future year models.

- There is no risk of electrolyte spill in these vehicles under most conditions because of a safety vent.
- A safety vent is in place to keep these batteries from overheating. In a catastrophic failure this vent can fail and cause overheating of the battery.
  - If the battery overheats because of failure of the safety vent there is a chance for explosion and fire.
- Use water or an ABC extinguisher to put out fire in the Li-Ion battery.
- In a fire there can be an electrolyte gas leaked.
  - Do no inhale the gas, if electrolyte is on the skin wash skin for 15 minutes.

- Safety Systems
  - All Alternative Electric Drive (AED) vehicles have both active and passive safety systems in the event of a collision or fire. These systems are both active and passive systems.
    - Active
      - Inertia impact switch can cut off fuel and high voltage in a collision.
      - These impact switches are located in the front, rear, and side impact zones. Although effective these switches should not be counted on to work every time, and all high voltage systems should be treated as live regardless of the damage to the vehicle in a collision.
    - Passive
      - Air bags are part of the passive safety systems in these vehicles. They present a measurable hazard even if they have deployed. There are secondary systems which can cause re-deployment of the airbag. There are also capacitors which give power to air bags, and these capacitors can hold energy for several minutes.
      - Service disconnects are found on all HEV vehicles. These are manual disconnects for the high voltage system.
        - Using the service disconnect should be a last resort and only used if you are unable to shut down the ignition or the 12 volt battery.
- High-voltage and Low-voltage Systems
  - Inverter and battery packs contain high voltage at all times. All high voltage systems should be labeled as so. Never tamper or open inverter and batteries. These systems can store high voltage for several minutes even when power has been severed.
  - There are typically two different colors that indicate either a high-voltage or medium-to-low-voltage.
    - Orange is high voltage. This is a standard and will be found on all AED vehicle types.
      - Orange cables are generally found along the drive train.
    - Blue is medium-to-low voltage. This is not found on all AED vehicles.
      - Blue cables can go to components such as A/C, or power storage.
      - Medium-to-low voltage does have the potential to electrocute, shock, and/or burn.
    - Orange cables should never be cut in extrication. If performing extrication and cutting is necessary peel and peek. Some vehicles such as the Tesla will provide marked cut points to indicate where it is safe to cut.

        - ♦ Although not a standard, if the HEV has blue cables do not cut through these cables.
    - Low voltage systems found on these vehicles control the lights, controls, and accessories. The low-voltage system is a 12 volts system.
    - High voltage systems found on these vehicles power at minimum the electric motor, motor controllers, cooling fans, and pumps, have voltages ≥400 – 650 volts present.
- HEV identification
    - It is the First Responder's responsibility on any scene to do a proper scene-size-up and identify the vehicles type if possible.
        - Some owners use aftermarket devices to retrofit their standard vehicles.
    - The identification of the HEV vehicle is through the following:
        - Badging, markings, decals
            - ♦ Hybrid emblem on side or trunk
            - ♦ Lexus will use an h on the model number
        - On the dash of the vehicle
            - ♦ Look for charge indicators. On large or heavy duty vehicles there will be a dashboard label.
        - Under the hood or chasse
            - ♦ Orange cables.
            - ♦ Blue cables (<60v).
            - ♦ Emblems – high voltage stickers
        - Charge indicators
        - Visible battery vents
            - ♦ This may not be on newer HEV's but on older models such as the old Prius this can be found on the C post. The vent may be in a different location than the C post on non-Prius models.
- Internal Combustion Engine (ICE)
    - The HEV also has a fuel tank and an ICE. All standard vehicle hazards may be present in the HEV.

❖ Battery Electric Vehicle (BEV) for the First Responder

- Current BEV's use 12 volt lead acid batteries for accessories and controls such as ignition systems and lights. The standard 12 volt battery is used in conjunction with either a NiMH or Li-Ion battery system.
- The NiMH and Li-Ion battery systems on the BEV have the same hazards as on the HEV
- The Safety Systems on the BEV are the same as the Active and Passive safety systems on the HEV
- If any part is removed from the high voltage system such as during maintenance or collision, i.e. a high voltage cable is disconnected or broken; the high voltage interlock loop will disconnect the high voltage system.
    - Even with the high voltage system disconnected power will still remain in several components such as the inverter for several minutes

- Orange cables on the BEV indicate high voltage with voltages ranging between 144 to 650v DC on most BEV
- To identify the BEV look for same items as on the HEV but also look for charging ports, this can indicate that the vehicle is a BEV.

❖ Plug in Hybrid Electric Vehicle (PHEV) for the First Responder

- These are becoming more popular because they contain both an Internal Combustion Engine (ICE) and a battery Electric Vehicle (EV) with a charging port. This creates more economy to the ICE and eliminates the range anxiety that comes with the Battery Electric Vehicle (BEV).
- The battery types, safety systems, voltage systems, and identification is the same as on the PHEV.

❖ Fuel Cell Electric Vehicle (FCEV) for the First Responder

- Battery Types
  - The FCEV contains the same standard 12v lead acid battery for the low voltage systems
  - To propel this vehicle a high voltage battery pack is used, mostly NiMh.
- Fuel Type
  - The FCEV uses hydrogen as its fuel type.
  - The fuel cell powers the motor by converting hydrogen and O_2 into electricity.
  - Hydrogen storage in the rear of the vehicle is the storage tank for the hydrogen gas.
  - FCEV hydrogen sensing devices monitor the air for hydrogen, initiate shut down, and isolate hydrogen and electrical storage systems.
  - If a hydrogen leak is detected, such as in a collision, a hydrogen flow monitor will shut off excess flow through an automatic shutoff valve. This allows some hydrogen, but not a hazardous amount, to vent.
  - Fuel pressure relief device senses increased pressure buildup such as from heat and protects hydrogen cylinder by opening one of two relieve valves. A hissing sound will be heard as excess hydrogen is released.
- Safety Systems
  - Active
    - Inertia impact sensors are located on the front, rear, and side impact zones and will isolate hydrogen, cut off high voltage component, and cut of fuel. They should trip automatically but cannot be relied upon.
  - Passive
    - Air bags are part of the passive safety systems in these vehicles. They present a measurable hazard even if they have deployed. There are secondary systems which can cause re-deployment of the airbag. There are also capacitors which give power to air bags, and these capacitors can hold energy for several minutes.
    - Service disconnects are found on all HEV vehicles. These are manual disconnects for the high voltage system.
      - Using the service disconnect should be a last report and only used if you are unable to shut down the ignition or the 12 volt battery.
- High-voltage Systems

- All OEM FCEV have warning placards under the hood and near any high voltage components.
- FCEV have the same electric orange high voltage wires.
- Most FCEV have between 144 and 650 volts DC in the high voltage system at any given time.
- High voltage components on the FCEV include the following:
  - Power control unit – controls flow of electricity
  - Electric motor
  - Fuel cell stack
  - High voltage battery
  - Inverter
  - DC-DC converter
  - Power cables

➢ FCEV Identification
- To identify the FCEV many vehicles have colorful logos or graphics on the body panels. They may have an emblem on the trunk or panels.
- A special hydrogen fuel fill port will be present on all FCEV vehicles and clearly marked.
- Look for a blue diamond that says compressed gas which indicates hydrogen.
- The FCEV should look different and more modern than most vehicles on the road and emblems should be present.
- The dash board on FCEV will not have a standard tachometer; instead it will have a Kw tachometer and should look different than a standard tachometer.
- Under the hood of the FCEV should indicate that the vehicle is an FCEV by wording and/or emblems.
- You may not be able to identify all of the FCEV indicators in the event of a significant collision.

❖ Emergency Response to the Alternative Electric Drive (AED) Vehicle

➢ Proper PPE and tool selection is the first important consideration in the AED emergency response.
- When responding to fire and/or collision respond in full PPE according to NFPA 1971 standards which will include helmet, jacket, hood, boots, pants, goggles, and gloves at minimum.
- Major incidents with fire and or large spills will require SCBA.
- Use non static tools if at all possible.
- Jewelry including rings, necklace, and watches under PPE is discouraged in the AED emergency because they can conduct electricity.
- Use a TIC for FCEV incidents to locate the hydrogen flame and use insulted hand tools to reduce igniting hydrogen gas.
- A corn broom can be useful to clean up debris.
- In the event of an AED collision/fire emergency hazardous chemicals can damage firefighter's PPE. If large spills are present contact HazMat. A quick in-and-out operation can be performed if needed to mitigate a significant life hazard.

- When approaching the scene of the AED emergency always consider the following.
  - Do not rush in.
  - Position up ill-up wind and away from all possible hazards, spills, leaks, or vapors.
  - Do a 360. If no fire present secure the vehicle and identify by under the hood, on the dash, or through body markings and emblems.
  - When approaching the AED follow standard operations including:
    - Immobilize
    - Stabilize
    - Disable
  - Once the vehicle is identified as an AED disable the high voltage system.
  - If the AED is on fire do not approach the vehicle, put out cones or non-sparking markers to secure the scene first. Do not approach an AED vehicle closely when it is on fire.
  - If you approach the vehicle and it sounds like it is off and no engine sound is heard the vehicle still may move. The vehicle has potential to move as long as the high voltage system is energized.
- When approaching an FCEV the unique properties of the hydrogen need to be taken into consideration.
  - Follow standard vehicle emergency response guidelines.
  - Locate the Pressure Release Device (PRD) vent which is usually in the rear. Try to locate this vent before beginning any operation in the FCEV and avoid direct exposure to it in case there is a PRD release.
    - The PRD vents only under high pressure or high temperature situation in the trunk.
    - Do not approach the PRD vent directly.
    - Look for thermal waves indicating heat and possible hydrogen fire.
  - If the vehicle is on fire do not approach. Set up cones and secure the scene.
  - Hydrogen flame may be nearly invisible during daylight. Detect the flame with a TIC.
    - The hydrogen flame may appear yellow if dust is in the air.
    - Look for thermal waves which may indicate heat and possible hydrogen flame which may not be visible.
    - The hydrogen flame will not give off smoke.
  - Listen for venting hydrogen.
- Active and Passive safety systems
  - Be aware of airbags and seatbelt tensioners.
  - Do not count on the vehicles built in auto-disable systems to disarm the high voltage system.
    - An example is in a fire. This can cause the electrical contacts to weld together causing a short. This in turn can cause the auto-disable not to function.
- Disabling the high voltage system.
  - Turn off ignition, if smart key is present move it a minimum of 25’ away from the vehicle and proceed to cut the 12volt battery cables.
  - Do not cut the orange cables.

- On the Lead Acid 12volt battery cut a 3-4" section of the negative (-) black first, next do the same to the positive (+) red.
- This will disrupt the flow of electricity and shut down the high voltage and low voltage systems. Without the 12 volt signal from the controller no voltage can flow to the high voltage system
- It may take more than 5 minutes for the high voltage system to fully discharge.
- Some vehicles have a manual service disconnect on the high voltage battery pack. As a last resort disconnect this, taking precaution because it has at the high voltage source.
- FCEV Special Consideration
  - If the ignition key is off hydrogen flow is shut down. About two tables spoons of hydrogen still remains in the fuel lines though.
  - Because hydrogen has a wide flammable range, DO NOT cut the 12-volt cables. Try the manual service disconnect.

➢ AED Vehicle Fire
- Always wear SCBA. Dangerous gases can be released from the battery vents. These gases may remain present even when the fire is out.
- If the vehicle is plugged in, and it is safe to do so, unplug it.
- Use copious amounts of water or an ABC fire extinguisher.
- You can let the battery burn out. If you choose to let the fire burn out continue use of SCBA and use a light mist to avoid fumes.
- Do not cut into the battery to put out the fire, this can cause significant burns.
- FCEV Fire Considerations
  - Burns can result from unknown hydrogen flame
  - It is best to let the hydrogen burn itself out.
    - ♦ This will keep the hydrogen burning, which will not allow it to leak and pool, causing excess hydrogen with the potential for ignition.
  - Keep fire from spreading to exposures while you are letting it burn.
  - Do not attempt to extinguish the flame.
  - If you can isolate the hydrogen source do so, stop it, then you can put out the flame, otherwise let it burn.
  - Never stand near the Pressure/Temperature Release Device (PRD/TRD) vent.
  - Never spray water near a vent stack.
  - DO NOT ATTEMPT TO EXTINUISH

➢ AED Extrication
- Be aware of airbags. Even if they have been deployed, because two-stage systems can cause secondary deployment.
- Be sure to disable the high voltage system.
- In the CEV shut down fuel and locate PRD release.
- Do not cut below the floor line.
- Avoid contact with high-voltage sources such as electronic controller, power inverters, and capacitors.

- Batteries cannot be de-energized, take proper precautions.
- Crib vehicles under the vehicle along the frame “pinch weld” avoiding high-voltage power cables, related components, hydrogen lines, and hydrogen storage tanks.
- Avoid cutting orange cables, blue cables, the high voltage battery pack, the inverter/converter, and fuel lines.

❖ For additional training, including current and future vehicles visit. naftc.wvu.edu