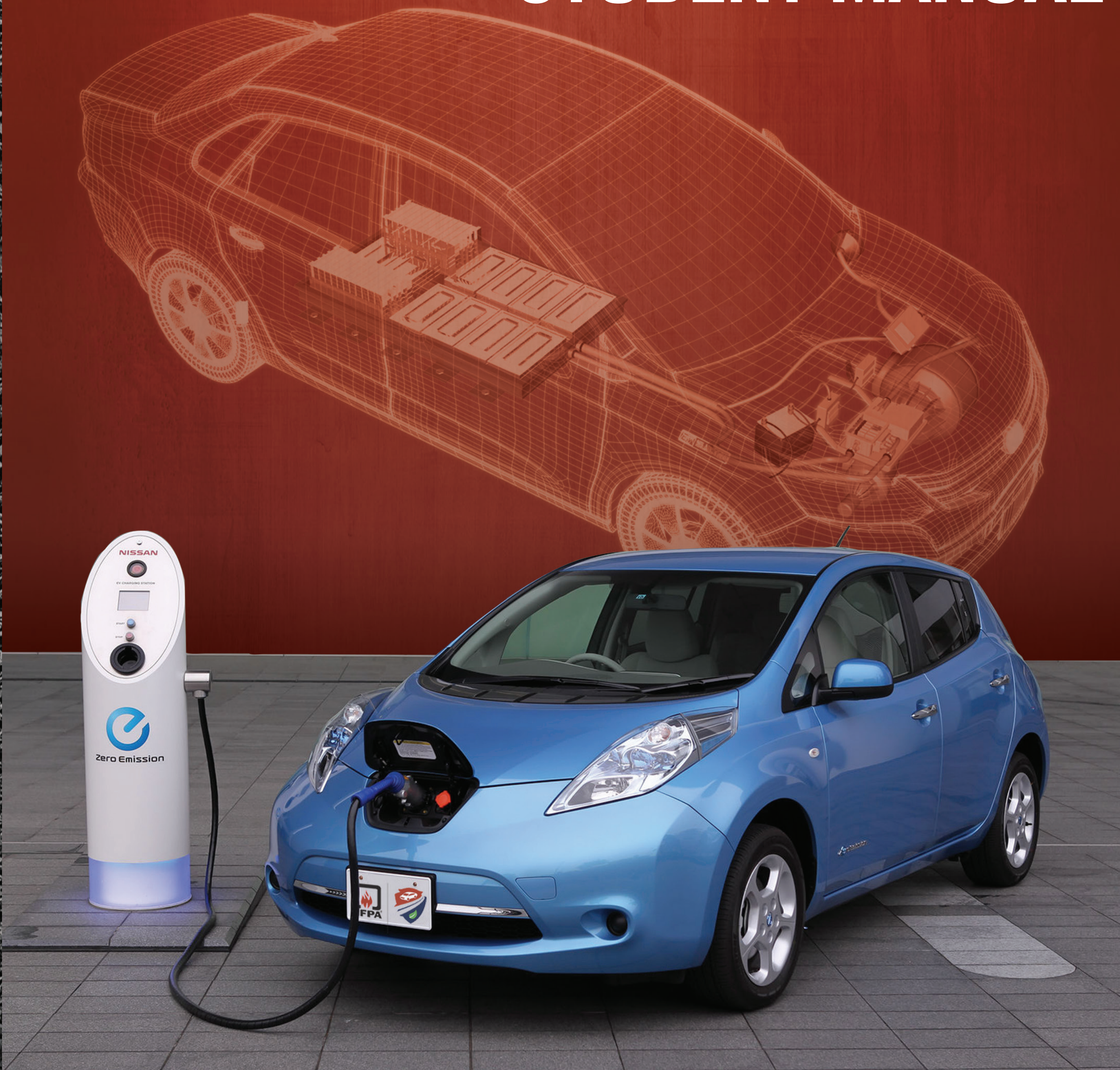
NFPA

ALTERNATIVE FUEL VEHICLES
SAFETY TRAINING PROGRAM

Alternative Fuel Vehicle Safety Training

Hybrid and Electric Vehicles Module

STUDENT MANUAL



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HYBRID AND ELECTRIC VEHICLE SAFETY TRAINING PROGRAM

STUDENT MANUAL

FOREWARD

Established in 1896, the National Fire Protection Association (NFPA) is the leading global advocate for the elimination of death, injury, property damage and economic loss due to fire, electrical and related hazards. Today the association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy

Since 2010, NFPA has developed a comprehensive training program which educates first responders across the country on alternative fuel vehicle safety. Through extensive research of both the fire service and current training methodologies, NFPA has produced a highly engaging multi-media training curriculum and delivery plan consisting of instructor-led classroom courses, train-the-trainer deliveries, self-paced e-learning modules, 3-D models, training videos, a quick-reference Emergency Field Guide, which includes on-scene procedures and safety precautions, and an app. Through this program, NFPA has demonstrated its deep commitment to developing and improving safety training and standards for first responders, with regard to alternatively fueled vehicles.

This manual represents the continued efforts of NFPA to ensure first responders are prepared for new technologies on our nation's roadways. This edition includes continued refinement of existing safety information, and the inclusion of gaseous fuel vehicles. These updates were made possible through a Department of Energy grant awarded to NFPA in 2015.

This course was developed using current fire-rescue service best practices and incorporates instructions and guidance from auto and battery manufacturers. However, due to the inherently dangerous and unpredictable nature of rescue operations, NFPA claims no responsibility for either the manufacturer instructions contained herein nor for unforeseen circumstances that may create rare exceptions to the general safety-related guidance provided.

This material is based upon work supported by the Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), under Award Number DE-EE0007020. This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CONTENTS

SECTION I: INTRODUCTION

SECTION OBJECTIVES

Following instruction, the student will be able to:

1. Define the following:
    a. Hybrid electric vehicle (HEV)
    b. Electric vehicle (EV)
2. List two (2) primary safety concerns for first responders

I. PROGRAM OVERVIEW

The use of electric and alternative fuel vehicles continues to increase. In fact, some auto industry analysts predict that one third of all cars purchased will be electric vehicles by 2020. This use of these new technologies brings new challenges for emergency responders. While the hazards of electric vehicle technology are not necessarily more serious than those of internal combustion engines, they are different and need to be understood by those who respond to emergencies involving electric and hybrid electric vehicles.

The purpose of this course is to introduce this new technology to emergency responders so that they will be able to perform operations safely and effectively.

A. Course Goal

The course goal is to prepare first responders to operate safely and effectively at emergency incidents involving hybrid electric, plug-in hybrid electric, and electric vehicles.

B. Course Sections

1. SECTION I: Introduction
2. SECTION II: Understanding Basic Electrical Concepts and Hazards
3. SECTION III: Vehicle Systems and Safety Features
4. SECTION IV: Charging Stations
5. SECTION V: Initial Response: Identify, Immobilize, and Disable (IID)
6. SECTION VI: Emergency Operations
7. SECTION VII: Course Review and Conclusion

II. DEFINITIONS AND TERMININOLOGY

A. Hybrid Electric Vehicle

A hybrid electric vehicle (HEV) utilizes two power sources: a conventional internal combustion engine (ICE) and an electric motor/battery combination.

B. Electric Vehicle

An electric vehicle (EV) uses only an electric motor(s) for propulsion and must connect to a charging station in order to recharge.

C. Commercial/Transit Vehicles

In addition to passenger vehicles, many commercial and transit model HEVs and EVs are being produced as well. In many cases, these vehicles can look very similar to traditionally-powered models.

III. HISTORY OF HEVS AND EVS

Electric vehicles have been around since the invention of the automobile. While they have not been significant in the market until recently, their value is not new. Between the late 1800s and early 1900s, the electric car was widespread.

In many cases, they were more popular than vehicles with internal combustion engines. Their popularity began to fade around 1912–1913, and by the 1930s they were pretty much obsolete.

- 1832–1839: The first crude electric vehicle was invented by Scottish inventor, Robert Anderson.
- 1898: Porsche built the first hybrid.
- 1900: 23% of all cars manufactured were electric, and 30% of all cars in New York City, Boston, and Chicago were electric vehicles.
- 1974: The prototype hybrid Buick Skylark was built.
- 1997: The Toyota Prius was introduced in the Japanese market.
- 1996–2003: GM built the EV-1 electric car for a lease-only pilot program. The controversial plan was eventually cancelled, and all vehicles were recalled.
- 1999: The Honda Insight became the first hybrid for large-scale production for the U.S. market.
- 2000-2003: Hybrid transit buses began to enter the market.
- 2006: The Tesla Roadster EV was released, creating renewed interest in EVs as a viable technology.
- 2007: Connecticut Transit began operating New England’s first fuel cell bus.

IV. HYBRID AND EV SALES FIGURES

A. The growth of HEV and EV sales has been dramatic in recent years.

1. According to vehicle sales statistics, approximately 5,000 HEVs were sold in 2000. In 2013, the combined sales of HEVs, PHEVs, and EVs was 592,232. This is a growth of 11,745% in 14 years.

2. In 2013, cumulative sales of hybrids and EVs since 1999 in the U.S. reached over 3 million.

3. In 2013, Toyota surpassed 1.5 million hybrids sold in the U.S.

V. TERMINOLOGY NOTE

From this point on in the course, we will refer to all types of hybrids and plug-in hybrids as P/HEVs. If referenced separately, they might be referred to as hybrid (HEV) or plug-in (PHEV). Electric vehicles will be referred to as EVs. High-voltage will often be abbreviated to HV.

VI. SECTION SUMMARY

HEVs and EVs are here to stay and will become more widely used each year. The key to safety and effectiveness is to understand the technology involved and how it affects operations involving P/HEVs and EVs.

SECTION II: BASIC ELECTRICAL CONCEPTS AND HAZARDS

SECTION OBJECTIVES

Following instruction, the student shall be able to:

1. Describe basic electrical concepts that pertain to P/HEVs and EVs
2. Define basic electrical terms
3. Understand the concepts of electrical circuits and the flow of electricity
4. Explain the difference between electrical systems in structures and those in P/HEVs and EVs
5. Describe how electricity affects the body and how to protect against electric shock.

I. INTRODUCTION

This section will give you a basic understanding of the types of electricity in hybrid and electric vehicles and how they affect emergency operations.

Many people are uneasy about dealing with electricity because it can be dangerous, they can't see it, and most don't completely understand it.

Emergency responders need to understand the dangers of high-voltage electricity in these vehicles and how those electrical systems differ from what responders are accustomed to seeing in residential or commercial applications.

II. DEFINING BASIC ELECTRICAL TERMS

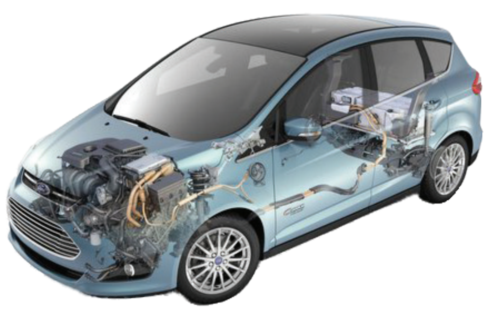
Voltage is the electrical potential of a circuit. It can be compared to the PSI of water in a hose stream, or the amount of force or power that is available to push the current. It is measured in *volts.*

Current is the measure of the quantity of electrons that move past a fixed point in one second; it is the rate of the flow of electricity. Comparing it to a hose stream, it is the number of gallons per minute flowing through a hose. Current is measured in *amperes* or *amps*.

Resistance is a material's opposition to the flow of electrons. Using the fire hose analogy, resistance can be compared to friction loss in the hose, valves, or nozzle. Resistance is measured in *ohms*.

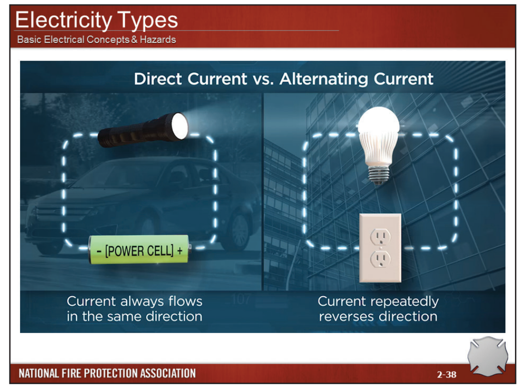
III. DIRECT CURRENT VS. ALTERNATING CURRENT

Both direct current (DC) and alternating current (AC) can be found in hybrid and electric vehicles.



In a DC circuit, the current moves in one direction. Direct current is primarily found in devices powered by batteries and in some industrial applications.

In an AC circuit, the current switches directions, or alternates back and forth, many times per second. The number of times per second the current reverses direction is measured in *hertz*. Alternating current is provided by utility companies to residential and commercial buildings.

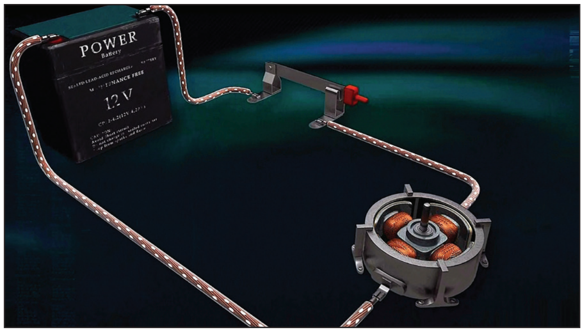


IV. UNDERSTANDING ELECTRICAL CIRCUITS

To better gauge potential dangers of high-voltage electricity in hybrid and electric vehicles, it is important to understand the concept of an electrical circuit — the path that electrical current will follow.

Both direct current and alternating current share the need for a *completed* path or circuit for the current to flow.

Using the hose line analogy again, if the bale on the nozzle is closed, no current is flowing. Once it is opened, the current flows. A switch creates a break in the circuit when it's turned off. Turning the switch on completes the circuit and allows current to flow.



Injury from electricity occurs when a person's body becomes part of a circuit by completing a path for current.

Responders must be aware of their surroundings and possible *secondary* points of contact that would allow their bodies to become part of a circuit. These could be body parts besides hands, or they could be metallic tools coming into contact with electrified components.

DC Circuits

DC power sources have positive and negative terminals. Current flows from the negative side of a battery through the circuit to the positive side.

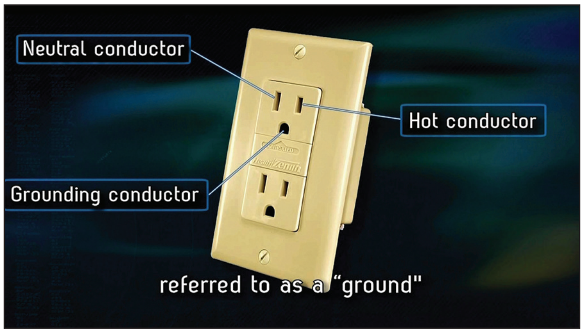
Contact with one side of the circuit will not result in an electric shock because the circuit is not completed. Contact with both sides, however, will complete the circuit and can result in shock.

AC Circuits

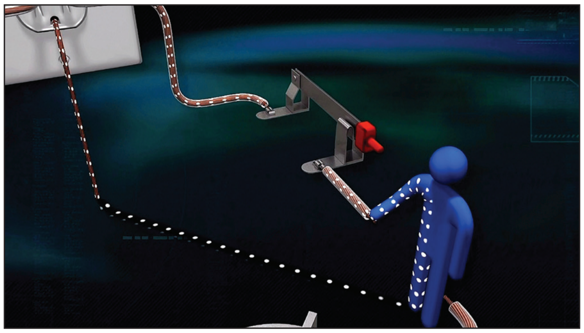
Since the current in an AC circuit flows in both directions, there is no positive and negative sides like what is found in DC circuits.

Instead they have a live, or hot, or energized conductor, a neutral conductor, and a grounding conductor, sometimes simply referred to as a “ground.”

Typically, when a circuit is completed, current flows back and forth between the hot and neutral conductors. The ground serves as a safety measure, allowing current to flow into the earth, helping fuses or circuit breakers to function and clear an electrical hazard.



You might think that in order to receive a shock from an AC circuit, you need to touch both the hot and neutral. This is not the case. Because typical AC circuits in the U.S., like those found in buildings, have an earth ground, touching just the hot side of the circuit will cause electricity to flow through you and back to the earth, completing the circuit and causing a shock.



HV Circuits in P/HEVs and EVs

All P/HEVs and EVs use DC circuit systems. Many also use AC-powered motors that require AC systems as well. High-voltage AC circuits in vehicles are isolated from the chassis and are not grounded the way AC circuits are grounded in a building. The current does not seek an earth ground. To get a shock, you must come into contact with TWO points in the circuit. Coming into contact with one will not create a circuit because it does not offer a complete circuit path for the electricity.

V. UNDERSTANDING HOW ELECTRICITY AFFECTS THE BODY

The human body and personal protective equipment (PPE) do provide some resistance to the flow of electricity. Voltage must be high enough to overcome resistance before it can enter a person's body. Environmental conditions, such as being wet, can greatly reduce resistance. Once resistance is overcome, the rate of amperage usually determines the degree of damage.

Circuits in HEV/PHEV/EVs have both the voltage and amperage in sufficient measure to be considered highly dangerous.

Hybrid and electric vehicle systems can operate in excess of 100 amps, or 100,000 milliamps, which is well beyond the human danger range —

especially in wet conditions. This is why it is important to be aware of potential dangers and to take appropriate safety measures at all times.

Analogy: A low-pressure garden hose flowing at three gallons per minute (GPM) of water is not dangerous. But the same three GPM pushed through a pressure washer at 1,000 PSI can be very dangerous. This illustrates how voltage (pressure) can affect whether a given level of current ever gets a chance to affect your body.

Examples:

9v Battery: If you touch a 9v battery with your finger, you don't feel anything — your dry skin offers too much resistance for the low-voltage level to overcome. If you touch it with your wet, thin-skinned tongue, however, you receive a shock because the resistance is much lower.

Stun Gun: Some models of stun guns can generate up to 25,000 volts — enough to overcome the resistance of thick clothing. However, they emit only a few milliamps of current so the potential for serious injury is low.

VI. SECTION SUMMARY

In order to work around P/HEVs and EVs safely at emergency scenes, it is important to understand basic electrical principles that will impact your response.

Voltage, amperage, and resistance are important concepts when looking at electrical circuits. Additionally, emergency responders need to understand how a circuit is created, how electricity flows through it, and when it poses potential harm. This will allow for better decision-making when determining what actions are safe to take at a scene and which are not.

SECTION III: P/HEV AND EV SYSTEMS AND SAFETY FEATURES

SECTION OBJECTIVES

Following instruction, the student shall be able to:

1. Compare and contrast the different P/HEV and EV models
2. List the major components of P/HEV and EV systems and describe their function
3. Describe the operation of the high-voltage system
4. Define terms related to P/HEV and EV systems
5. Identify the differences between passenger cars and truck/buses

I. INTRODUCTION

At the scene of an incident, it is important for emergency responders to not only follow the correct procedures, but to also understand why they are doing something a certain way. This allows for more knowledgeable decision making as scene conditions change unexpectedly.

This section will cover the various vehicle types, in both passenger and commercial/transit applications, that first responders will encounter. Several high-voltage system components and their operations will be addressed so responders have a better idea as to how they impact emergency response.

II. VEHICLE TYPES – PASSENGER

A. Hybrid Electric Vehicles (HEVs)

Hybrids use batteries and electric motors to reduce demand on the internal combustion engine (ICE). They allow better fuel economy. The ICE can shut down when not needed. Full hybrids can drive short distances on electric power only (which presents a silent movement hazard). The HV battery is charged automatically in two ways: during the normal course of driving by the ICE, and through regenerative braking (discussed later in this section). For response purposes, treat all hybrids the same. Examples: the Toyota Prius, Honda Civic and Hyundai are hybrid vehicles

B. Plug-in Hybrids

Plug-in hybrid vehicles have larger HV batteries that, in addition to being charged by the ICE and regenerative braking, can also connect to a charging station. Plugging it in increases the level of battery charge, boosts the range of the vehicle, and reduces dependence on the gasoline engine.

Plug-ins have the same basic system and components as full hybrids, with the addition of a charging system.

Examples: The Ford C-MAX and Toyota Prius are available as PHEVs and HEVs.

C. Electric Vehicle

In these vehicles, electric motors are the only means of propulsion. The vehicle must be charged by an external power source.

Examples: The Nissan Leaf, Telsa Model S and the Mitsubishi i-MiEV are electric vehicles.

D. Extended Range Electric Vehicle (EREV)

Electric motors provide the propulsion for this type of vehicle. When the battery power is low, a gasoline generator supplies electricity for the motor to allow for continuous driving. However, in order to fully recharge the battery, it must be connected to a charging station. During an emergency response, these vehicles should be treated the same as PHEVs — vehicles with a gasoline engine, a high-voltage battery and electric propulsion.

Examples: The Chevrolet Volt is an EREV. The BMW i3 also has an option to have a generator installed.

III. VEHICLE TYPES – COMMERCIAL/TRANSIT

A. Hybrid Electric Trucks and Buses

Hybrid electric trucks and buses share the same basic principles as their passenger vehicle counterparts. The major differences include a diesel internal combustion engine and larger hybrid electric components. It is important to note that the diesel engine may or may not shut down when the vehicle is stationary.

B. Electric Trucks and Buses

Electric trucks and buses have similar operating principles as passenger EV's. Due to their size and the fact that the battery is the sole power source, the batteries in electric trucks and buses are typically much larger than those found in hybrid versions. These vehicles usually operate out of a hub, or within a defined area, due to their limited operating distances.

C. Supplemental Hybrid Systems

These vehicles use a high- or medium-voltage system to power critical vehicle components, eliminating engine idling. Typically these systems do not assist in the propulsion of the vehicle. These systems can operate heating/air conditioning equipment, pumps, drilling attachments, and manlifts.

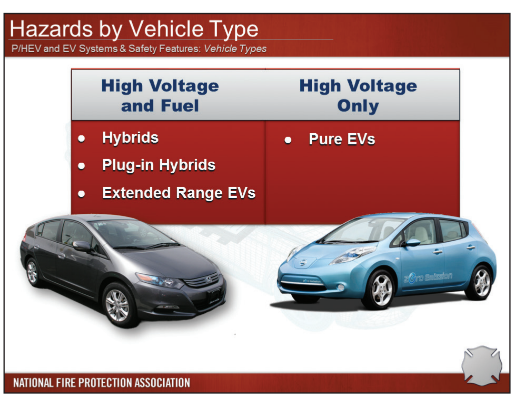
D. Hybrid and Electric Conversions

Conversion vehicles have aftermarket hybrid components installed to supplement the traditional drivetrain. These are primarily used in fleet applications and may look like conventionally-powered vehicles.

E. Response Hazards by Vehicle Type

For response considerations, HEV/PHEV/EVs fall under two categories based on the hazards they present:

- High voltage *and* fuel (P/HEVs and EREVs)
- High voltage only (EVs)



IV. P/HEV AND EV COMPONENTS

A. Internal Combustion Engine

An ICE similar to the one in a conventional vehicle is found in HEVs, PHEVs, and EREVs. The hazards associated with it remain similar to a conventional vehicle.

B. Low Voltage Battery

12V System

A 12v battery is used in all P/HEVs and EVs. Common locations for the 12v battery in passenger vehicles are the trunk, cargo area, and under the hood. Less common locations are the front wheel well and under the second row seats.

24V System

It is common in trucks and buses to encounter a 24v system. These systems are simply two 12v batteries wired in series to produce the increased voltage. On trucks, they will often be mounted along the frame, behind the cab. On buses, they may be found in the rear engine compartment, or in the front on the driver's side in a small compartment.

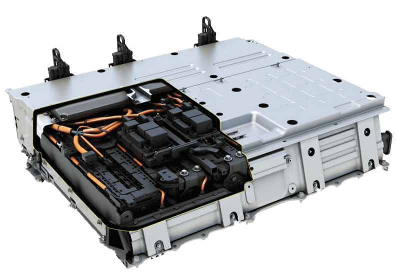
C. High-Voltage Battery

NiMH

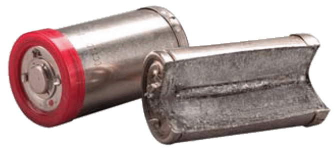
The nickel-metal hydride (NiMH) battery is most common in existing hybrids, but less so in newer vehicles. The electrolyte is a caustic alkaline material consisting of sodium and potassium hydroxide, which can give off harmful fumes if heated or exposed to air.

Lithium-Ion

The lithium-ion (Li-ion) battery is most common in electric vehicles and will be used more often in future hybrids. It has many chemical variations. Those in electric and hybrid vehicles are different from the Li-ion batteries used in home electronics. The electrolyte can give off harmful, flammable fumes if exposed.



High-voltage batteries are made of multiple small, low-voltage cells that are wired together as a series to multiply the voltage. Example: six 1.5v DC batteries in a series produces 9v.



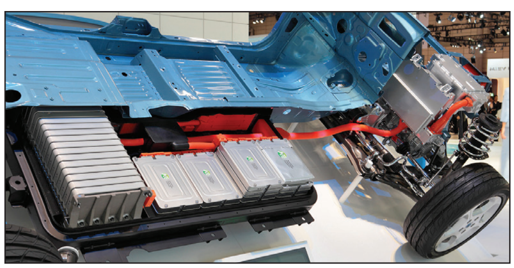
D. Locations of HV Batteries in Passenger Vehicles

HEVs and PHEVs

Generally, batteries in HEVs and PHEVs are in the rear of the vehicle. In SUVs and trucks, they can be found under the second row seating. In sedans, they are in the trunk or cargo area.

E. EV's

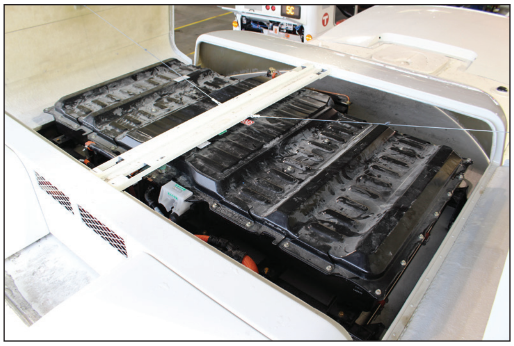
EV batteries are larger and of higher voltage than HEV and PHEV batteries. Usually they are located on the underside of the vehicle due to the amount of space they occupy. Newer models could have more than one, wired together for greater storage capacity, and could be in more than one location.



F. Locations of HV Batteries in Commercial/Transit Vehicles

Transit Bus HV Battery Locations

High-voltage batteries are commonly located on the roof of transit buses. These battery tubs can weigh approximately 700 pounds or more.



Truck and Passenger Van HV Battery Locations

In trucks and smaller passenger buses, high-voltage batteries are usually found along or within the frame rails. A side impact from a smaller vehicle may damage an exterior mounted battery section.

V. THREE WAYS P/HEVS AND EVS RECHARGE THE HV BATTERY

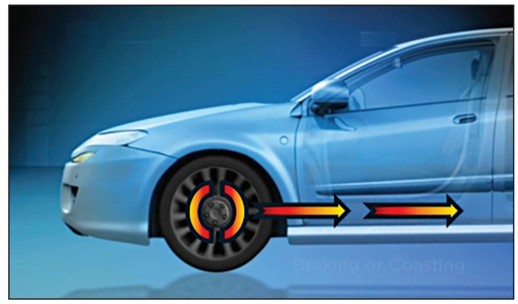
A. Internal Combustion Engine

The ICE generates energy via the electric motor, which acts as a generator when the ICE is powering the vehicle and charges the HV battery. This process is used in P/HEVs.

B. Regenerative Braking

This is the process used to capture energy from braking to help recharge the high-voltage battery. During braking, the electric motor provides resistance and absorbs some of the kinetic energy that slows the vehicle. As the motor turns, it acts like a generator and produces electricity. This technology is used in P/HEVs and EVs.

There is danger of a fire hazard or damage to the electrical system if the vehicle is towed with the drive wheels on the road.



C. External Power

Plugging in to an external power source recharges the batteries in PHEVs, EVs, and extended range EVs. This process will be covered in greater detail in the next session.

D. P/HEV and EV Cabling

Cabling is color-coded to voltage:

Low-voltage is less than 30v and is often red (+) or black (-). Intermediate- or medium-voltage is 30v to 60v and is usually yellow or blue, depending on the manufacturer. High-voltage is greater than 60v and is orange, per the Society for Automotive Engineers (SAE) standards.

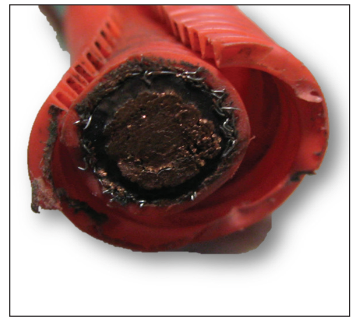
Medium- and high-voltage cables should both be considered dangerous. For the purposes of this program, treat blue/yellow cables the same way you would treat high-voltage orange cables.

HV cables are located between the high-voltage battery, high-voltage components, and the electric motor. In passenger vehicles and trucks, they are typically routed along the underside of the vehicle and under the hood.

On transit buses, they typically run on the roof in the area of the roof perimeter and through either the rear roof supports or directly into the rear engine compartment.

If a cable is compromised or damaged, the system is designed to detect that damage and shut down.

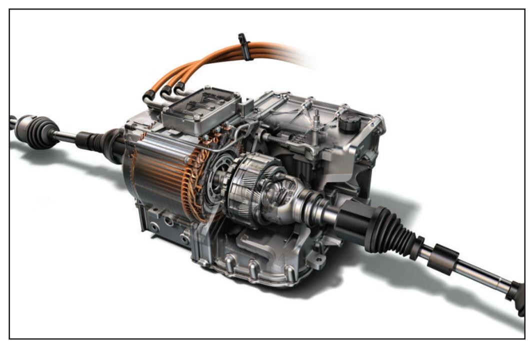
For maximum safety, ALL high-voltage cable must be considered energized during response operations.



E. Electric Motors

Electric motors provide propulsion in EVs and most P/HEVs. They start and stop the ICE as needed. The HV battery is recharged through regenerative braking and ICE (P/HEVs).

In EVs, electric motors also provide propulsion and recharge HV batteries through regenerative braking. They are sometimes called drive or traction motors.

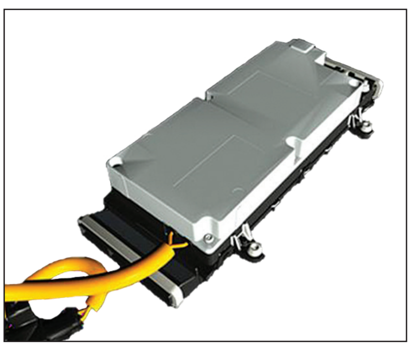


F. Inverter/Converter

Inverter/converters are found in vehicles using AC drive motors. In passenger vehicles and trucks, they are generally located in the engine compartment. In buses, they will be found on the roof or in the rear engine compartment. They convert DC from high-voltage batteries to AC to power the drive motor. They also convert AC from regenerative braking back to DC to charge the HV battery. It is dangerous to penetrate the cover with tools. Capacitors inside can store voltage for a period of time, typically up to 10 minutes after the HV system is shut down. If damaged, it is capable of rapid energy discharge that can cause severe injury.

G. DC/DC Converter

A DC/DC converter takes the place of the alternator in conventional vehicles and serves the same purpose: charge the 12v battery and run the low-voltage systems. It converts DC electricity from the high-voltage battery to 12v DC to power the low-voltage systems. In some models, the DC/DC converter is housed in the inverter/converter section.



H. Charging Ports

Charging ports connect a charging cord to the vehicle. The charging components reside on the vehicle itself. The charging unit is an interface between the power supply and the vehicle.

On passenger vehicles, the locations of these ports vary from the nose of the vehicle to the front or rear fenders.

On commercial trucks, it can be located anywhere on the side of the vehicle, including to the side of the rear door (up high in relation to the ground) for charging while at a loading dock.

Buses may utilize a traditional charging port or may have a roof-mounted charger which allows for a "pit stop" type of charging while temporarily parked at transit hubs.

I. Passenger vs. Commercial/Transit Vehicles

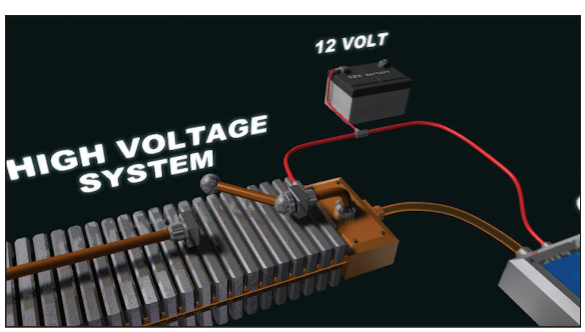
For the most part, both passenger and commercial/transit vehicles employ similar technologies and equipment in the production of their vehicles, with the primary difference being the size or scope of the design.

There is, however, a notable difference to consider. Passenger vehicles are generally mass produced and there are limited variations of the vehicle from the manufacturer. This makes production of a standardized Emergency Response Guide (ERG) simple and makes recognition easier for first responders. In commercial/transit applications, many of the vehicles are custom produced and may have numerous variations. This makes it more difficult for first responders to become familiar with any particular model or procedures associated with it.

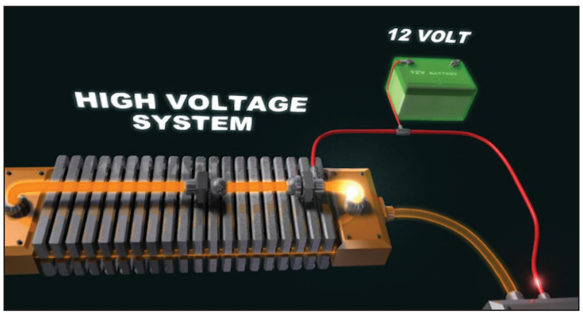
VI. HEV AND EV SYSTEM OPERATION

A. High-Voltage Battery Relay

This relay functions like a switch. When closed, it completes a circuit, allowing current to flow from the HV battery to the rest of the HV systems. When open, the circuit is broken, and no current flows from the HV battery.



Depending on the vehicle type, either 12v current in passenger vehicles or 24v in larger commercial/transit vehicles will be used to control the HV system. The 12v/24v battery closes the relay initially on startup, allowing power to flow from the HV battery. When the relay is closed and the DC-DC converter comes online, 12v/24v power (from either the 12v battery or the DC-DC converter) keeps the relay closed. When all 12v/24v power is removed, the relay opens and isolates the HV battery, which shuts down all HV systems.



IMPORTANT: When a vehicle is running, simply disconnecting the 12v battery will not open the HV relay in many passenger cars.

The DC-DC converter will still supply 12v power to keep the HV relay closed. In trucks and buses, you may encounter a 24v system with similar operating parameters.

Disabling the DC-DC converter will be explained in Section IV.

B. Safety Systems

P/HEVs and EVs are equipped with safety systems that are designed to shut down the high-voltage system in the event of a crash impact, airbag deployment, or damage to the high voltage cabling or components. This is accomplished through opening the relays in the HV battery. A current interrupt device, such as a fuse, is also present in the HV circuit and activates in the event a short circuit occurs.

Many of these same safety features are utilized in commercial trucks and transit buses. Crash sensors and air bag deployment detection features, however, are not as common as they are in passenger vehicles.

Some trucks and buses are equipped with an emergency shutdown switch or knob that may be the best to isolate the HV system. This switch cuts 12v/24v current to the HV relays and isolates the HV circuit. In other instances this can be accomplished by disconnecting a low voltage wiring assembly under the hood.

Responders must always treat HV systems as energized for maximum safety.

VII. SECTION SUMMARY

HEVs, PHEVs, EVs and ER-EVs make up the various vehicle types using high-voltage current to provide propulsion. These vehicles can be used in both passenger and commercial/transit applications.

These vehicles share many of the same systems and components; understanding their location and function will aid emergency responders in maintaining a safe scene and making educated decisions. Understanding how the systems operate is critical to ensure all the appropriate shutdown procedures are followed.

SECTION IV: CHARGING STATIONS

SECTION OBJECTIVES

Following instruction, the student shall be able to:

1. Identify and describe the different types of charging systems.
2. Describe the effect voltage has on the charging times as it relates to the different charging station types (EVSE)

I. INTRODUCTION

This section covers the various types of charging stations and methods used to recharge passenger and commercial plugin hybrid and electric vehicles. Understanding how these devices function, as well as their associated voltages, is important to emergency responder safety. Within the industry these systems are commonly referred to as electric vehicle supply equipment or EVSE.

II. CHARGING PROCESS

The charging unit is an interface between the available power supply and the vehicle. The component that converts AC to DC for battery recharging is on the vehicle. Current flowing from the charging unit into the vehicle is AC current as supplied by the electrical grid (except in DC quick charging applications).

III. CHARGING STATIONS

Charging Stations (Electric Vehicle Supply Equipment)

In the automotive industry, charging equipment is referred to as Electric Vehicle Supply Equipment or EVSE. For the purposes of this training, the more common term "charging station" will be used.

Level I Charging Station

A Level I charging station utilizes 120v AC power and uses a standard household plug. It is the slowest rate of charging of the three levels (8 to 16 hours). This device can accompany the vehicle and be used anywhere there is access to an outlet. These systems are generally not used in commercial or transit vehicles due to charge times that could exceed one day because of the battery size and capacity.

Level II Charging Station

Level II utilizes 240v AC power. It can be a fixed installation or portable. It typically takes three to eight hours, depending on the size of the battery. This type of charging station can be found in both residential and commercial applications.

DC Quick-Charge Charging Station

This station provides 480v DC directly to the battery. This is the fastest charging station (typically 20-30 minutes for a passenger vehicle), but not all vehicles are equipped to connect to it. Due to wiring requirements, availability, and expense, it will likely only be in commercial sites such as service stations, dealerships or rest stops.

A. J1772 Plug and Receptacle

The SAE J1772 plug is the standardized connection for Level I and Level II charging. It is a multipin communication link between the charger and the vehicle that conducts current and relays charge status. It communicates the shutdown command when the battery is fully charged. It also prevents the vehicle from moving when plugged in.

Recent updates to the standard include an additional option for DC quick chargers. The design allows a single charging port to be placed on vehicles that can accept all three levels. Vehicles equipped to handle only level I or II charges would not be able to accept a DC quick charger-type connection.



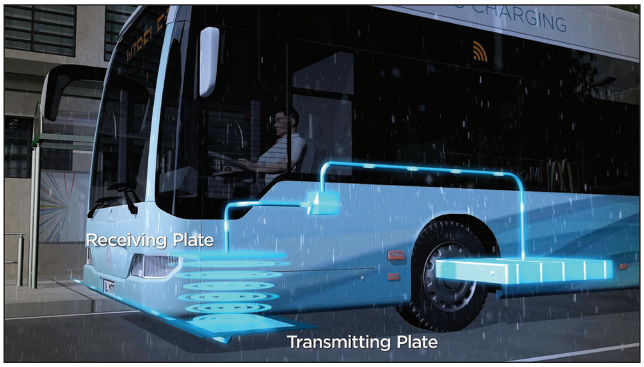
B. Roof Mounted Charging Port

These are found on some electric transit buses. It is a version of a DC quick charging station that allows the bus to recharge for short periods when returning to a central hub to pick up more passengers. The driver aligns the bus with the charging arm and it automatically engages and initiates the charging process. This type of charging only takes a few minutes per stop.

C. Inductive Charging

Charging “plates” or “mats” are installed in the ground along a pre-determined route. These allow the vehicle to use smaller batteries because it can recharge more frequently. The plate is not energized until the vehicle is aligned on top of it, so there is no chance of electrocution by simply walking over it. The driver aligns the vehicle with the mat and the battery charges while loading/unloading. Charging occurs through the airspace between the plates and no physical contact takes place.

This type of system is best suited for transit buses based on their numerous predetermined stops. It does, however, have potential in the delivery market as well.



IV. SECTION SUMMARY

A charging station or EVSE is a key system component for many of these vehicles, and response personnel will likely encounter them in a variety of emergency situations. It is important that personnel understand the types of systems that are utilized and their operating voltages.

SECTION V:
INITIAL RESPONSE
"IDENTIFY, IMMOBILIZE, AND DISABLE"

SECTION OBJECTIVES

Following instruction, the student shall be able to:

1. Describe size-up procedures and scene hazards of an incident involving a P/HEV or EV
2. Positively identify P/HEVs and EVs using visual clues and the NFPA *Alternative Fuel Vehicle Emergency Field Guide (EFG)*
3. Identify and describe proper immobilization techniques
4. Identify vehicle disabling methods and techniques

I. INTRODUCTION

Proper techniques, standard protocols, and the use of proper PPE are crucial to staying safe during emergency operations involving any vehicle.

Many of the shutdown procedures for HEV/PHEV/EVs are similar to the shutdown procedures for a conventional vehicle.

Since HEV/PHEV/EVs can move with little or no noise, traditional methods of determining whether a vehicle can move under its own power are not effective. Assumptions about the power status of these vehicles can be dangerous.

By understanding the proper procedures for disabling and immobilizing HEV/PHEV/EVs, emergency responders can operate safely at emergencies involving these vehicles.

II. INTRODUCTION TO INITIAL RESPONSE ACTIONS

A. Scene Safety

Always ensure a safe working environment for response personnel by using proper PPE, high-visibility clothing, proper apparatus placement, and traffic devices.

B. Scene Size-up

Upon arrival, conduct your size-up as you would at any other incident.

1. Survey the scene for hazards
2. Identify types of vehicles involved, their hazards, and the presence and location of occupant protection systems (airbags, pretensioners, etc.)
3. Determine a course of action

Common hazards at any incident scene:

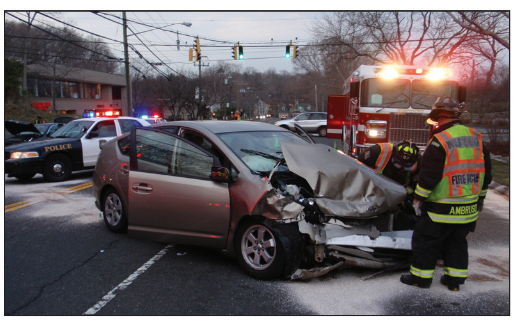
- Traffic
- Downed power lines
- Fuel spills or other hazmat
- Environmental hazards (ice, flooding, etc.)
- Fire

- Unstable vehicles

Do not become so focused on the EV that you forget the basics!

Potential hazards at P/HEV and EV Incidents

- Electric shock
- Silent powered movement
- Toxic/flammable gasses
- Electrolyte contact
- Battery fires and re-ignition
- Improper towing risks



C. Initial Response Actions

For an incident involving a P/HEV or EV:

1. Identify
2. Immobilize
3. Disable

This process is referred to as *IID*.

P/HEV and EV models on the road include passenger cars, pickup trucks, sport utility vehicles, and commercial trucks and buses. Current P/HEVs and EVs are primarily based on conventional vehicle designs and models. This increases the difficulty of identifying them during an emergency such as a crash.

The IID steps, especially *identify*, can and often will begin during the initial size-up process.

III. IDENTIFICATION

It is often difficult to identify P/HEVs and EVs from a distance. Responders must assume all vehicles are P/HEVs and EVs until positive identification is made, and approach them from the side when possible.

Identification methods include:

1. Badging/Labeling
2. Design features
3. Telematics
4. NFPA's A*lternative Fuel Vehicle Emergency Field Guide*

Badging/Labeling

This process involves the recognition of badging or labels that visibly indicate that a vehicle is a HEV, PHEV, or EV.

External Badging: One method for identifying an HEV/PHEV/EV is by exterior emblems and badging. The most common places for badging are on the front fenders or doors and at the rear of the vehicle on the truck or lift gate. Badging often involves manufacturer trade names; it may become hidden or dislodged in a crash or fire.

Some EVs have badging that indicates they are "Electric" or "Zero Emission" vehicles. Some model names are specific and are created solely for P/HEVs and EVs.

Some new models are being made without any external badging — on the assumption that in the near future all cars will be hybrid or electric. The SAE J2990 standard, however, has since recommended badging in at least two locations on the outside of the vehicle.

Commercial trucks and buses may have subtle references to "green" or "eco-friendly" technology. Advertising wraps added on transit buses will obscure labeling. Other commercial vehicles may use high-profile markings to advertise the fact that the company is using electric or hybrid vehicles in their fleet. There are no standards for identification at this time for these types of vehicles.

Engine Compartment Badging/Emblems: Manufacturers use different terms stamped on components under the hood to label their vehicles, including:

1. Hybrid
2. Hybrid Synergy Drive (Toyota/Lexus)
3. Integrated Motor Assist (IMA) by Honda

High Voltage Warning Labels: High-voltage warning labels can be found in a variety of locations, including under the hood area and on high-voltage components and cabling elsewhere. Some labels may also show the location of the 12v and HV battery within the vehicle.

Instrument Cluster Badging: These emblems include a hybrid or IMA logo. In the case of digital dashboards, the icons will not be visible when the vehicle is shut down. On commercial trucks and buses, there may be emergency shutdowns located at the operator's position.

Design Features

This method of identification includes nonspecific visual clues that don't spell out the words *hybrid* or *electric* but indicate that it is such a vehicle; clues include battery vents, instrument panels, and electric cables. Modifications in or on the vehicle can also indicate it is a P/HEV or EV.

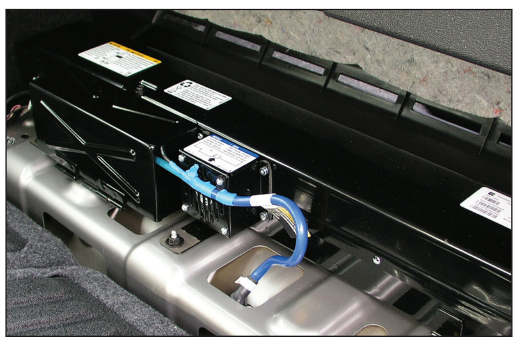
Charge/assist indicators: On HEVs, charge/assist indicators on a dashboard indicate to the driver when the battery is being charged and when the battery power is assisting with propelling the vehicle. These can be in either an analog or digital format.

Hybrid/electric drive status screen: Some vehicles have a battery/system status screen on the instrument panel in the center of the dash. On some commercial trucks, there may be a computer display that monitors its high-voltage electrical system.

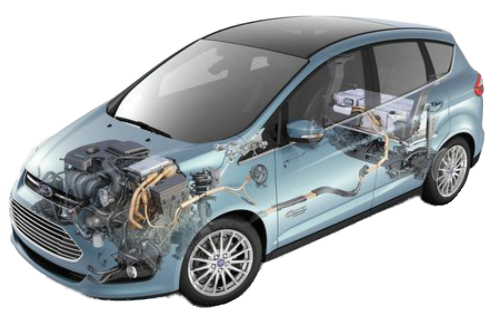
Ready or **Auto Stop** lights indicate to the driver that the vehicle is on and that, when placed in gear, the vehicle will move. They can indicate to responders that the vehicle has not been shut down. The feature is used on most HEVs and EVs.

Emergency shutdowns: Some trucks and buses are equipped with an emergency shutdown switch. This provides responders with an obvious indicator that they are dealing with some type of alternatively-powered vehicle.

Medium-voltage electrical cables are typically blue or yellow and can be found in the same general locations as high-voltage cables (see below).



High-voltage electrical cables: When visible, electrical cables are also an indicator of a P/HEV or EV. These cables are orange in color, per SAE standards. They can be found under the hood, on the underside of the vehicle, and near the high voltage battery. They are generally **not** placed in areas typically considered cut points.



There is no requirement that the orange cable be visible. In fact, some new models have covered up a portion of the orange cables with a black protective shrouding. For example, the Nissan Altima HEV has cabling that is completely covered by a black casing under the vehicle.

Some models have plastic paneling under the vehicle to decrease wind resistance, and that also obscures the cables. In earlier models, orange cables on the underside of the vehicle are more commonly visible.

Battery vents: The purpose of these vents is to keep the high-voltage battery from overheating during the normal charge and discharge process by keeping air flow around the case. To ensure proper air flow, the vents are in close proximity to the battery. They can look like HVAC vents or speakers. Not all vehicles have visible vents.

Charging ports: On PHEVs and EVs, the charging ports will have a cover that can look like the cover of a gas filling port, but they are usually located either in the front of the vehicle or on the front or rear fenders. They are most likely found on the rear of commercial trucks.

High Roof Lines: These are a prominent feature on alternatively-powered transit buses. This extended-height roof line can conceal HV batteries and compressed gas cylinders. Responders should keep in mind that on some buses they only conceal air conditioning equipment, so they are not always a definitive indicator.

External HV Battery Tubs: On commercial trucks and some school bus applications, they will typically be located along the frame rails just behind the cab. They can either be on the inside or outside of the frame rail, depending on the design and available space.

Scanning the Vehicle: Use the same systematic approach every time to ensure that nothing is overlooked.

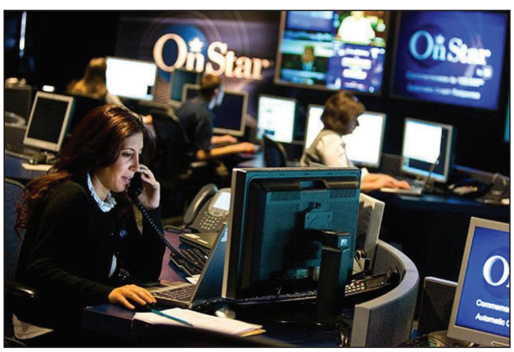
1. Exterior – badges and labels, orange wiring, HV battery vents
2. Interior – dashboard markings, under the hood badging and labels, and wiring
3. HV battery and battery vents

Even if indicators are not immediately noticeable, use all information available to verify whether the vehicle is a P/HEV or EV.

In the absence of visible badging due to extensive vehicle damage, continue to look for additional clues.

Telematic Systems

Telematic systems monitor a vehicle’s status. In the event of a crash, these electronic safety and security systems notify a dispatch center of the location and nature of the call and can relay information to responding personnel about the type of vehicle involved.



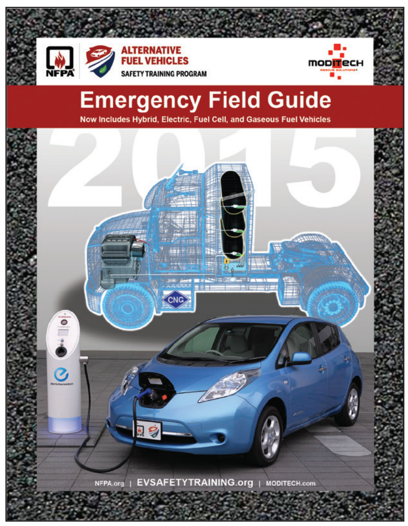
The use of telematics is increasing and multiple vendors are now marketing vehicle systems such as the following:

- OnStar (GM)
- Blue Link (Hyundai)
- BMW Assist (BMW)

Alternative Fuel Vehicle Emergency Field Guide (EFG)

This consolidated quick reference guide is in a simple, easy-to-use format and covers the following topics:

- Identification
- Shutdown procedures
- Danger areas
- System diagrams
- Suppression
- Submersion procedures



E. Identification summary

To determine whether a vehicle is a P/HEV or EV, use all possible information available. Even if indicators are not immediately noticeable, take time to verify whether the vehicle is a P/HEV or EV. In the absence of a visible badge, such as extensive damage to the vehicle where the badging would normally be found, continue to look for additional indicators as covered in this section.

IV. IMMOBILIZE

The second step in the IID process is to immobilize the vehicle. This procedure needs to occur at every incident, regardless of whether or not the vehicle is a P/HEV or EV.

Approaching the vehicle(s)

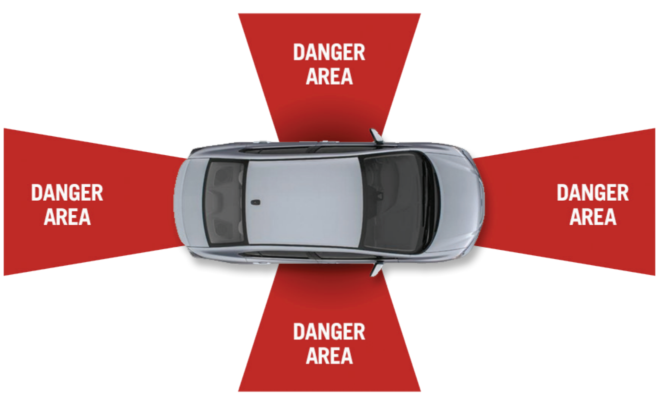
When approaching a vehicle involved in an incident, be sure to do so from a 45 degree angle. Never approach a vehicle directly from the front or rear, because there is always the potential for it to move unexpectedly until it is immobilized and positively shut down.

WARNING:

Physical damage to the HV battery may result in immediate or delayed release of harmful or flammable gases.

If the HV battery is damaged, or if emergency responders detect fluid leakage, sparks, smoke, increasing temperature, or gurgling/bubbling sounds coming from the HV battery, they must attempt to ventilate the passenger compartment (open doors, roll down windows, or break glass) and the trunk/cargo compartment to prevent gas buildup.

THESE ARE WARNING SIGNS THAT COULD POTENTIALLY LEAD TO IGNITION OF THE HIGH-VOLTAGE BATTERY!



As soon as you get to the vehicle, immediately do the following:

- Deploy wheel chocks
- Engage the parking brake
- Place the vehicle in park

A. Unique design features

Joystick shifters that always return to the same position regardless of gear selection are standard on some models such as the Toyota Prius.

Putting the vehicle into the parking gear might require pushing a button or switch on the dashboard that actuates an electrical parking pawl mechanism on some models. Electronically operated parking brakes will not engage after battery power has been cut from the vehicle.

It is important to engage the parking brake at this stage, because in some models, the parking brake is electronic and cannot be engaged once you disable the vehicle's low voltage electrical system.

B. Truck and bus considerations

When dealing with trucks or buses, be sure to use wheel chocks appropriately sized for the vehicle, such as those from the fire apparatus. The use of air brakes is still common in HEV and EV trucks and buses. Also, many of these vehicles do not have a "park" selection on their transmission. In this case, ensure the wheels are chocked, the parking brake is set, and the transmission is in neutral.

V. DISABLING PROCEDURES

The third step in the IID process is to disable the vehicle.

NOTE:

If needed, move seats, roll down windows, unlock doors, and open trunk before disabling the vehicle, as these systems will not function once 12v power is removed (and in many cases will not function once ignition is turned off).

Disabling passenger vehicles

There can be more than one method for disabling the vehicle.

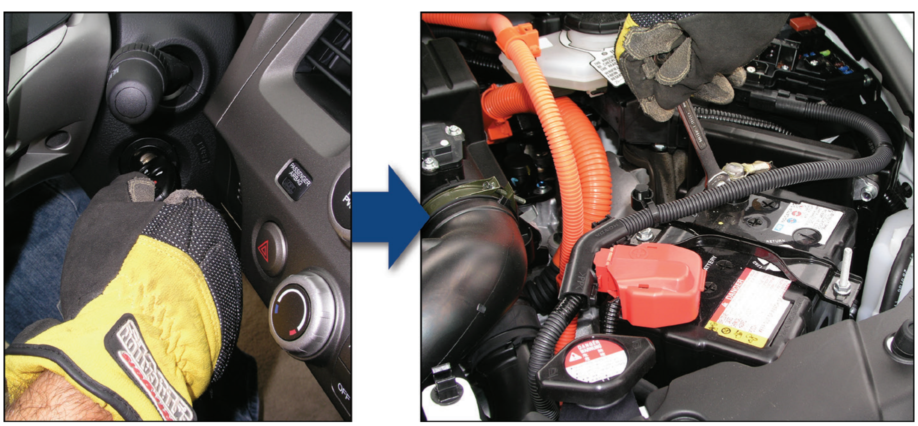
A. The primary method — when ignition is accessible:

A standard protocol is followed for both conventionally-powered vehicles and for P/HEVs and EVs, when the ignition can be accessed.

STEP 1: Shut off the vehicle ignition.

This could either be a traditional key ignition or a push button ignition with a proximity key.

STEP 2: Disconnect the 12v DC battery (cut cables or disconnect at terminal).



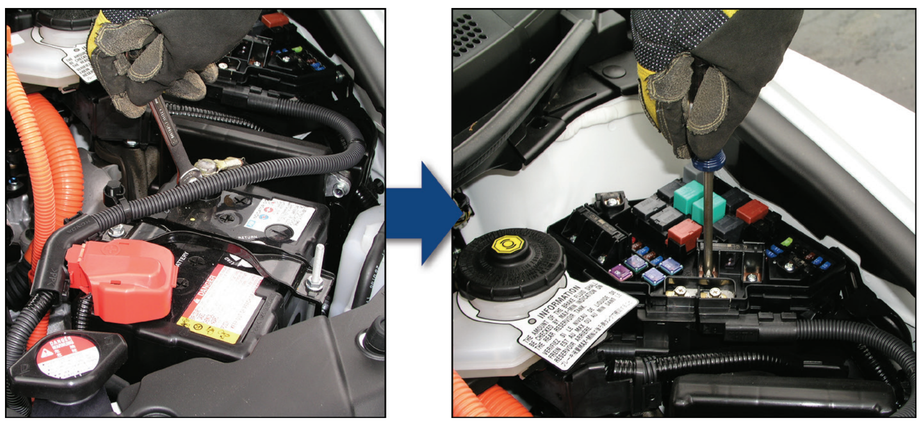
B. Possible secondary method — when ignition is not accessible:

Secondary methods vary by vehicle model. The responder should refer to the manufacturer's ERG or NFPA's *EFG* for model-specific instructions. The most popular secondary method applies to most Nissan, Toyota, Lexus and Honda models.

STEP 1: Disconnect 12v battery.

STEP 2: Pull HV system control fuse(s) or relay(s). This will prevent 12v current (from the DC-DC converter and 12v battery) from reaching the normally open relay in the HV battery. This opens up the HV circuit and stops the flow of electricity from the HV battery.

BOTH STEPS MUST BE COMPLETED TO ENSURE BOTH THE HV SYSTEM AND THE OCCUPANT PROTECTION SYSTEMS ARE DISABLED.



Important note about secondary shutdown methods:

- They vary by model. There is no one-size-fits-all solution.
- Treat disabling the HV system and supplemental restraint system (SRS airbags, etc.) as two separate steps.
- Shutting off ignition will disable the HV system, but not *necessarily* SRS.
- In most vehicles, disconnecting 12v DC battery will disable SRS, but *not* the HV system because the DC-DC converter is still supplying power to the HV relay.
- Pulling HV fuses or service disconnects will disable the HV system but *not* the SRS.

C. Proximity Key Systems

Many vehicles now offer smart or proximity key systems with push button ignition switches. These can be found in P/HEVs and EVs as well as conventional passenger vehicles. Proximity keys bi-directionally communicate with the vehicle. They allow the user to unlock the doors and start the vehicle as long as the key is nearby, such as in a pocket or purse.

Responders should attempt to secure the key from the driver as well as ask any other occupants if they have keys. Manufacturers generally recommend moving these keys a minimum of 16 feet from the vehicle. However, do not waste too much time if the keys cannot easily be located. If the driver is unconscious, it will likely be difficult to secure the key. It may be possible to find one key but not be able to determine if there is another in the vehicle. In that event, the responder should follow normal ignition shutdown procedures by pushing the button to turn the vehicle off and disconnecting the 12v battery. Once the 12v battery is disconnected, even if the power button is pushed again with the key in the car, it will not start.

Disabling Trucks and buses

This process is very similar to the primary procedure for passenger vehicles.

STEP 1: Turn off the vehicle ignition. It may be a key or simple switch.

The use of proximity keys is extremely limited in trucks and buses.

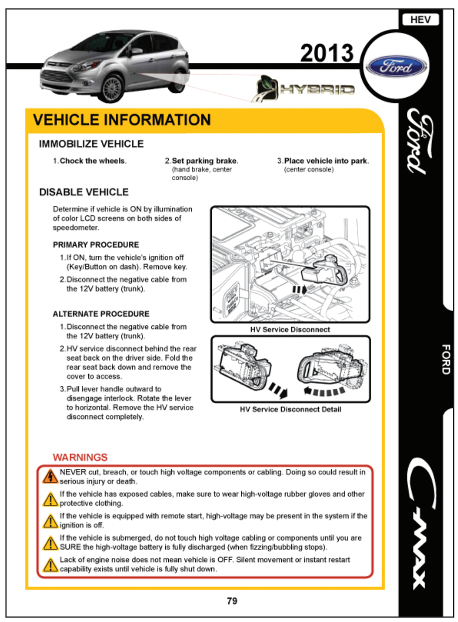
STEP 2: Cut or disconnect the 12v/24v batteries.

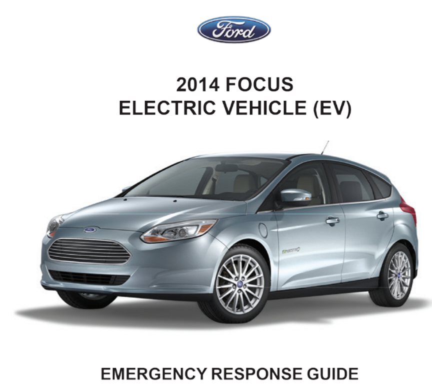
Many trucks and buses have a shutoff switch or manual disconnect located at or near the 12v or 24v batteries. Manipulating this switch serves the same function as cutting a battery cable. On a 24v system that does not have a disconnect switch, responders will have to cut the negative battery cable. With batteries wired in series, it is not always obvious which cable is the negative. Responders should look for the cable that terminates at a chassis ground.

Vehicle Operators: The operator of the vehicle can be the best resource for commercial vehicle identification. They are typically trained not only in the operation of the vehicle, but in how to shut down and disable it correctly.

D. Procedure reference sources

Reference NFPA's *EFG* or the manufacturer's ERG for the specific vehicle to determine the primary disabling procedures for that model, as well as any secondary options such as pulling fuses or relays.





E. System Drain Down

1. Even when properly disabled, some models have HV system capacitors that can keep the HV systems energized up to 10 minutes after disabling (varies by model).
2. SRS capacitors can keep airbags and other SRS systems active for up to five minutes, depending on the model.
3. Refer to manufacturer guides or NFPA *EFG* for specific drain-down times.

F. Manual Service Disconnects

Recommendations for use and required safety equipment can vary by manufacturer.

Consult appropriate ERG before using service disconnect.

Located on the HV battery, when removed it physically disconnects it from the high-voltage system unless an outside force has compromised the battery pack and created an alternative path for electricty to flow.

Service disconnects on trucks and buses are similar to the types found in passenger vehicles. The major difference is that there may be more than one disconnect that needs to be operated in the event there are multiple HV batteries onboard the vehicle.

G. Disabling Cautions

1. Regardless of shutdown method, the HV battery will **always** retain its charge.

2. Always assume the HV system and components are energized and treat them with caution.

VI. SECTION SUMMARY

When responding to an incident involving a P/HEV, EV or even a conventional vehicle, it is important to follow the Identify, Immobilize, and Disable process to ensure that the vehicles are safe to work around. On approach, always look for all the indicators that may identify it as a P/HEV. Always be sure to approach from the sides of the vehicle until you can immobilize and disable it to prevent being injured from unanticipated movement of the vehicle. Be sure to use the NFPA *EFG* or manufacturer ERG as a resource to properly complete the necessary steps for the particular model you are dealing with.

SECTION VI: EMERGENCY OPERATIONS

SECTION OBJECTIVES

Following instruction, the student shall be able to:

1. Identify unique extrication challenges presented in P/HEV and EV crashes.
2. Determine appropriate actions for extinguishing P/HEV and EV fires.
3. Determine the appropriate actions to handle a fire involving a P/HEV or EV HV battery.
4. Determine appropriate actions when responding to submerged P/HEVs or EVs.
5. Determine the appropriate actions to handle a damaged P/HEV or EV battery.
6. List procedures required when handling damaged P/HEVs or EVs post-incident.
7. Determine the appropriate actions for incidents involving charging stations.

I. INTRODUCTION

Many procedures for responding to an incident involving a P/HEV or EV are the same as those used in responses to a conventional vehicle incident. However, there are some differences that will be highlighted throughout this section.

Emergency responders must take several steps at every vehicle crash and extrication, including the following:

1. Perform a scene size-up
2. Use appropriate PPE for operations
3. Identify, immobilize, and disable the vehicle

II. EXTRICATION OPERATIONS

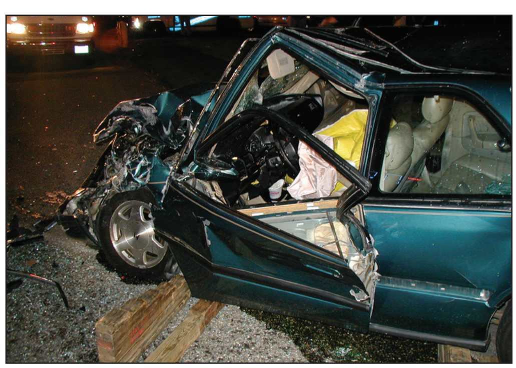
Extrications on P/HEVs and EVs can be accomplished with the same tools as with conventional vehicles; no special equipment is required. As always, responders must maintain situational awareness, especially with the high-voltage components present in the vehicle.

A. Stabilization

Standard cribbing methods are acceptable to stabilize a P/HEV or EV.

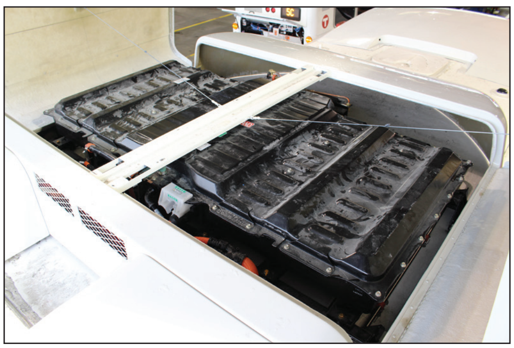
Always place cribbing at vehicle structural points.

Avoid fuel lines, HV cabling, and HV battery (for vehicles with a battery in the floor pan and trucks with batteries along the frame).



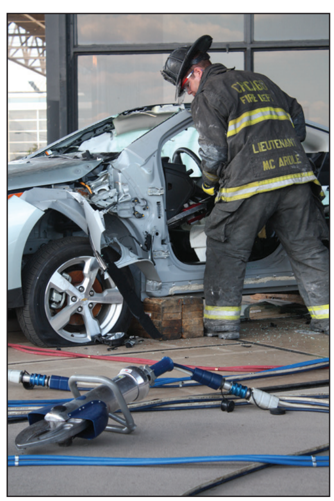
On trucks and buses, the same stabilization points can be used as those on conventional vehicles. Some additional considerations include:

- On transit buses, the additional weight of the HV batteries and/or gas storage on the roof could slightly alter the vehicle's center of gravity.
- Rearmost roof support on a transit bus could contain HV cables running up to the roof.
- Avoid placing cribbing under frame-mounted HV batteries or wiring.



B. Cutting operations

Car and truck manufacturers have designed these vehicles so that the high-voltage components and wiring are generally not located in typical vehicle cut points. In passenger vehicles this includes the roof posts. Before cutting into the vehicle, determine the location of the occupant protection systems and high-voltage components by peeling back any plastic panels in the cut area.

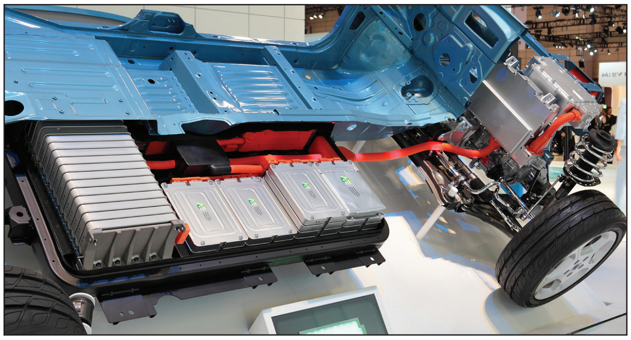


The need for cutting operations on transit buses will be extremely limited due to the large size and frequent spacing of the windows. In commercial trucks, HV cables are not typically located in standard cut points. As always, be sure to expose the area to be cut to ensure there are no HV components.

Certain advanced extrication techniques can be difficult or impossible depending on the location of the HV battery.

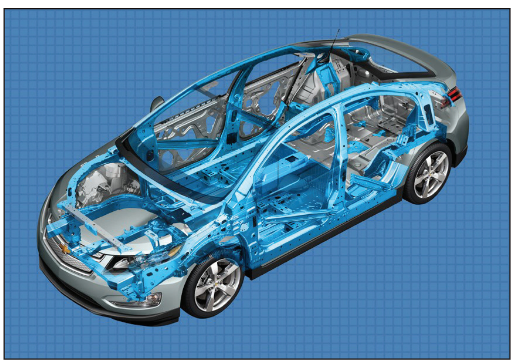
Trunk Tunneling: In some cases, trunk tunneling may not be possible as the high-voltage battery is located vertically behind the rear seat. Emergency responders should refer to NFPA's *EFG* for the location of the battery in current models.

Through the floor: If it is necessary to go through the floor, the high-voltage wiring and batteries could be a problem. Keep in mind that neither this method nor trunk tunneling is used on a regular basis.



High- and ultra-high-strength steels (HSS and UHSS)

Used in many conventional vehicles as well as P/HEVs and EVs, these materials are designed to decrease the vehicle's weight and increase the protection of the occupants. Tools specifically designed to cut these materials must be used.



III. HV BATTERY BREACHES

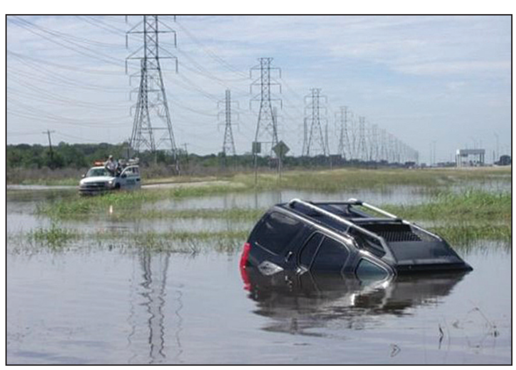
Although high-voltage batteries are generally well protected, the potential always exists for them to be damaged as a result of a crash. Keep the following in mind when dealing with a damaged high-voltage battery.

- Electrolytes can be caustic, toxic, and flammable.
- Batteries are considered to be dry-cell batteries. Even if crushed, electrolyte leakage should be minimal.
- When damaged, some models can leak liquid coolant, which is similar to coolant in conventional vehicles' radiators. It poses no greater hazard than conventional coolant.
- DO NOT TOUCH OR HANDLE a damaged HV battery. It poses a risk of high-voltage shock as well as potential contamination by electrolyte.
- Watch out for unusual odors and eye, nose, throat, or skin irritation. If detected, limit exposure and don SCBA. Follow local medical protocols in the event of exposure to electrolyte or fumes. Immediate first aid usually involves flushing the affected area with water or providing oxygen for inhalation injuries
- Monitor the HV battery for fluid leaks, sparks, smoke, flames, or gurgling/bubbling sounds. These are signs of a damaged battery and could lead to a thermal runaway event and possibly fire.

IV. VEHICLE SUBMERSION

Because of the design of the vehicle, coming into contact with the P/HEV or EV's shell should not be a shock hazard. However, DO NOT TOUCH damaged or submerged HV components!

AC and DC currents in HEV/PHEV/EVs do not "energize" the water as they are isolated from the chassis. Ground fault circuit interrupters (GFCIs) are on AC circuits for additional protection. Consult the NFPA *EFG* or manufacturer's ERG for procedures based on the specific vehicle.



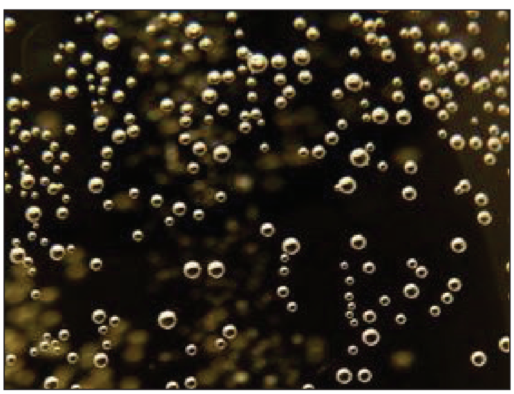
Typical procedures for handling vehicles in water are:

1. Follow standard shutdown procedures for the vehicle.
2. If access prevents these shutdown procedures, remove the vehicle from the water, allow excess water to drain, and then complete the procedures.

The surrounding water is not energized, but, again, there *is* a shock hazard if direct contact is made with unprotected HV cabling or HV components.

NEVER REMOVE A SUBMERGED SERVICE DISCONNECT!

When a P/HEV or EV is submerged in water, the potential exists for water to enter the HV battery. Impurities in the water allow for electrical *conduction* between the terminals internal to the HV battery, which results in micro-bubbling. Electrolysis occurs, producing micro-bubbles of oxygen and hydrogen when the water molecules are split. Open a window or door to allow any buildup of hydrogen and oxygen to be released.



V. VEHICLE FIRES

A. NFPA HV Battery Burn Study

Conducted in the spring of 2013 at the Maryland Fire and Rescue Institute, the burn study was designed to provide firefighters with a series of best practices and tactical guidelines in dealing with this kind of fire.

Specifically, the study looked at the amount of time and water it took to extinguish both a HEV and EV type HV battery fire. It also tested the potential of electrical current to travel down the hose stream from the HV battery.

The study showed that, in some instances, over 2,600 gallons of water was used and extinguishment took up to 60 minutes. It also showed that there were no adverse electrical currents that were transmitted to firefighters through the hose line.

The study also indicated that the larger and less accessible EV-type high-voltage batteries took more water and time to extinguish than the smaller and more accessible HEV-type.

B. Recommended Fire Suppression Practices

Based on standard firefighting practices and the data collected from the HV battery burn study, the following are a list of best practices for fire suppression activities.

All P/HEV and EV fires

- Use NFPA-compliant fire-fighting PPE and SCBA.
- Use standard equipment for extinguishment.
- DO NOT use equipment (such as a Halligan bar) to blindly to pierce the hood. You could penetrate HV components or capacitors by doing so.
- When it is safe to do so, follow normal shutdown procedures.
- As with all vehicle fires, avoid inhaling toxic byproducts that will be released.

- Keep bystanders and all nonessential personnel upwind and uphill from the danger area, if possible.

P/HEV or EV Fires with HV Battery Involvement

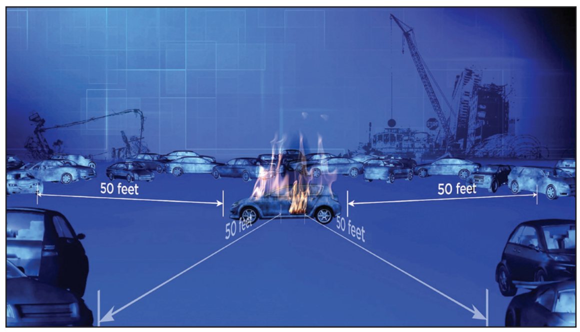
Additional factors should be considered when the high-voltage battery becomes involved in the fire.

- Thermal runaway is a heat driven process. In order to stop or slow the process the heat must be removed.
- Research has shown that fires involving a P/HEV or EV can require over 2,700 gallons of water to completely extinguish if the HV battery becomes involved. It is important to establish a secure water supply either with a hydrant or static water source to support the operation.
- Due to the extinguishment times involved, SCBA cylinder exchanges may be necessary.
- It might be preferable to allow a fire in the battery pack to burn itself out.
- After extinguishment, determine any HV battery involvement. Use thermal imaging equipment if available.
- HV battery fires are extremely difficult to extinguish and could reignite. Use thermal imaging to monitor the condition. During testing, one HV battery reignited several hours after it was believed to have been extinguished.
- Do not attempt to force access in to the high voltage battery compartment or pack to apply an extinguishing agent.
- Fires involving trucks and buses may require more water due to the increased size of their components.
- In the case of a transit bus, consider the use of an aerial master stream to access burning batteries on the roof.

Post Fire Overhaul and Vehicle Handling

During overhaul operations, avoid contact with HV components. The relays in the HV battery may have become damaged or welded in a closed position. Always treat the HV components as energized.

Due to the potential for an HV battery fire to reignite several hours or more after extinguishment, it is recommended by NHTSA that any P/HEV or EV with a burned HV battery or fire damage in the area of the HV battery should be stored at least 50 feet from other vehicles or combustibles. Greater distances should be considered for trucks and buses.



VI. INCIDENTS INVOLVING CHARGING STATIONS

Fires

Fires involving charging stations should be treated as class C fires. Use the same procedure as with any energized electrical fire and shutdown the source of the electricity prior to firefighting operations. In the event that a vehicle connected to the charging station is on fire, it should also be handled like an energized electrical fire. Proper lock out/tag out procedures should be followed.

Collisions

Charging stations could also be damaged from a collision. Again, shut down the charging station power source as soon as possible for scene safety. If a vehicle is struck while it is at a charging station, turn off the power source supplying the charging unit before attempting any operations.

VII. POST-INCIDENT VEHICLE HANDLING

Avoid all HV components, and during overhaul, storage, or investigation, treat them as though they are energized. Consider ventilating the passenger and cargo compartments to prevent possible buildup of toxic or flammable gases from undetected HV battery damage.

Notify the authorized service center or dealer as soon as possible if you have a potentially damaged HV battery. They might be able to assist by de-energizing the battery or otherwise rendering it safe.

Manufacturers generally recommend the use of flatbed trucks for transporting P/HEVs and EVs due to the risk of damage or fire from the regenerative braking system if the drive wheels are turning during towing.

Do not store a severely damaged vehicle with a Li-ion battery inside a structure or within 50 feet of any structure or vehicle due to the possibility of a delayed fire event. First responders should allow greater distances for trucks and buses.

NOTIFY THE TOW OPERATOR OF THIS AS WELL!

The vehicle should be monitored for leaking fluids, sparks, smoke, fire, or gurgling sounds coming from the HV battery. These could be signs of thermal runaway and fire.

ACTIVITY 6.2
EMERGENCY OPERATIONS

Directions to the Students:

1. You are going to be shown videos of emergency situations involving P/HEVs or EVs.
2. You will be given a few moments to do a scene size-up and determine the following:
   a. What are the hazards present?
   b. What are your initial response actions?
   c. What steps would you take to fully mitigate the situation?

Scenario 1:

HEV transit bus is struck by a passenger car at an intersection.

Scenario 1

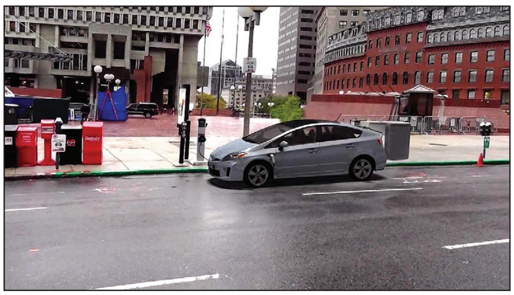
1. What are the hazards present?

2. What are your initial response actions?

3. What steps would you take to fully mitigate the situation?

Scenario 2:

Chevrolet Volt is connected to a charging station on a busy city street. The Volt is struck by another vehicle which results in a fire. There are no occupants in the Volt and the driver of the second vehicle exits on his own.



Scenario 2

1. What are the hazards present?

2. What are your initial response actions?

3. What steps would you take to fully mitigate the situation?

Scenario 3:

Nissan Leaf goes off the road and into a body of water and is partially submerged. The occupant of the vehicle is still inside.

Scenario 3

1. What are the hazards present?

2. What are your initial response actions?

3. What steps would you take to fully mitigate the situation?

VIII. SECTION SUMMARY

Many established procedures for responding to an incident involving P/HEVs and EVs are the same as those used for an incident involving a conventional vehicle.

Responders should take into account the following considerations when responding to incidents involving P/HEVs and EVs:

- Extrication operations largely remain the same, although responders should always look for high-voltage cables before beginning to cut.
- Submerged vehicles are safe to approach in the water to secure and shut down.
- Damaged HV batteries pose some additional concerns, including off-gassing and possible thermal runaway resulting in a fire.
- HV battery fires will take more time and water to extinguish than a conventional vehicle fire. Re-ignition is possible several hours after extinguishment.

SECTION VII:
PROGRAM REVIEW

I. PROGRAM IMPORTANCE

A. Educated Decisions

This program answers important questions that responders may have regarding hybrid and electric vehicles that they encounter on the roads today. This will allow responders to better handle emergencies involving these vehicles in a safe and effective manner. The training will dispell many of the myths surrounding this technology, and shed light on the vehcile safety features that protect both occupants and responders.

II. BASIC ELECTRICAL CONCEPTS AND HAZARDS

A. Voltage and Current

Voltage is the electrical potential of a circuit. It can be compared to the PSI of water in a hose stream, or the amount of force or power that is available to push the current. It is measured in *volts.*

Current is the measure of the quantity of electrons that move past a fixed point in one second; it is the rate of the flow of electricity. Comparing it to a hose stream, it is the number of gallons per minute flowing through a hose. Current is measured in *amperes*.

B. Direct Current and Alternating Current

Direct Current– In a DC circuit, the current moves in one direction. Direct current is primarily in devices powered by batteries and in some industrial applications.

Alternating Current– In an AC circuit, the current switches directions, or alternates back and forth, many times per second. The number of times per second the current reverses direction is measured in *hertz*. Alternating current is provided by utility companies to residential and commercial buildings.

It is important to understand that regardless of the type of electricity, in order for current to flow, there must be a completed circuit.

Responders must remember that high-voltage AC circuits in vehicles are isolated from the chassis and are not grounded the way AC circuits are grounded in a building. The current does not seek an earth ground. To get a shock, you must come into contact with TWO points in the circuit. Coming into contact with one will not create a circuit because it does not offer a complete circuit path for the electricity.

III. VEHICLE SYSTEMS AND SAFETY FEATURES

A. Vehicle Types

HEV– Hybrids use batteries and electric motors to reduce demand on the internal combustion engine (ICE). They allow better fuel economy. The ICE can shut down when not needed.

PHEV– Plug-in hybrid vehicles have larger HV batteries that, in addition to being charged by the ICE and regenerative braking, can also connect to a charging station.

EV– In Electric vehicles, electric motors are the only means of propulsion. The vehicle must be charged by an external power source.

EREV– Electric motors provide the propulsion for this type of vehicle. When the battery power is low, a gasoline generator supplies electricity for the motor to allow for continuous driving. However, in order to fully recharge the battery, it must be connected to a charging station.

B. HEV System / Components

Internal Combustion Engine– An ICE similar to the one in a conventional vehicle is found in HEVs, PHEVs, and EREVs. The hazards associated with it remain similar to a conventional vehicle.

High Voltage Battery– High-voltage batteries are made of multiple small, low-voltage cells that are wired together in series to multiply the voltage.

Inverter / Converter– Converts DC from high-voltage batteries to AC to power the drive motor. They also convert AC from regenerative braking back to DC to charge the HV battery.

12 Volt Battery– Supplies current to the vehicle's low voltage systems but also may control the relay in the high voltage battery.

Electric Drive Motor– Electric motors provide propulsion in EVs and most P/HEVs. They start and stop the internal combustion engine in a P/HEV as needed. They act as a generator to recharge the HV battery through regenerative braking, in both P/HEVs and EVs.

DC / DC Converter– Converts DC electricity from the high-voltage battery to 12v DC to power the low-voltage systems.

Charging Port– Connects a charging cord to the vehicle. The charging components reside on the vehicle itself. The charging unit is an interface between the power supply and the vehicle.

High Voltage Wiring– Cables are located between the high-voltage battery, high-voltage components, and the electric motor. In passenger vehicles and trucks, they are typically routed along the underside of the vehicle and under the hood. On transit buses, they typically run on the roof in the area of the roof perimeter and through either the rear roof supports or directly into the rear engine compartment.

C. HEV and EV System Operation

The 12/24 volt battery introduces electricity to the high voltage relay, closing it. This energizes the high voltage components on the vehicle. In many cases, the 12/24 volt battery is only needed to close the relay during the initial startup of the vehicle. Once started, the electricity needed to close the relay may come from the DC / DC converter.

IV. CHARGING STATIONS

Level I– Utilizes 120v AC power and uses a standard household plug. It is the slowest rate of charging of the three levels (8 to 16 hours). This device can accompany the vehicle and be used anywhere there is access to an outlet.

Level II– Utilizes 240v AC power. It can be a fixed installation or portable. It typically takes three to eight hours, depending on the size of the battery. This type of charging station can be found in both residential and commercial applications.

DC Quick Charging Station– Provides 480v DC directly to the battery. This is the fastest charging station (typically 20-30 minutes for a passenger vehicle) but not all vehicles are equipped to connect to it.

V. INITIAL RESPONSE

A. Scene Safety

Upon arrival, conduct your size-up as you would at any other incident.

1. Survey the scene for hazards
2. Identify types of vehicles involved, their hazards, and the presence and location of occupant protection systems (airbags, pretensioners, etc.)
3. Determine a course of action

B. Initial Response

Identify– Responders should look for badging, labeling, and design features that would indicate that the vehicle is a P/HEV or EV. Some telematics systems can notify responders upon dispatch that the vehicle may be alternatively powered.

Immobilize– Responders should approach from the sides and chock the wheels before attempting to access the interior of the vehicle. Then the parking brake can be applied and the vehicle can be placed in neutral.

Disable– Turn off the vehicle ignition and remove the key at least 1 vehicle length away. Responders should then access and disconnect the low voltage battery(ies). Secondary disabling procedures may be necessary as indicated in the ERG or EFG.

VI. EMERGENCY OPERATIONS

A. Extrications

Standard stabilization points and techniques still apply in most situations. Avoid areas where HV cabling may run. Be sure to expose areas where HV cabling may run before cutting. Trunk tunneling and through the floor techniques may not be viable options due to HV component locations.

B. HV Battery Breach

Responders should avoid contact with any leaking electrolyte. Do not handle the HV battery and use SCBA if any unusual odors are detected. Ventilate the passenger compartment as needed.

C. Vehicle Submersion

Although the water is safe to enter, responders should avoid contact with HV components. After securing the vehicle, it is safe to turn off the ignition. Futher disabling of any HV components must be delayed until the vehicle is removed from the water.

D. Vehicle Fires

Research has shown that hose streams are not energized by HV components. Due to the inaccessibility of many of the batteries, large quantities of water may be needed to extinguish them. Responders should never pierce the battery compartment to try to apply water and should use thermal imaging cameras to detect heat buildup and confirm extinguishment. Always wear full PPE and remember, allowing the fire to burn itself out is always an option.

E. Charging Stations

Treat a fire involving charging stations as a class "C" fire. Power must be shut off prior to extinguishment. If a vehicle is also involved, use the same Identify, Immobilize, and Disable procedure outlined earlier.