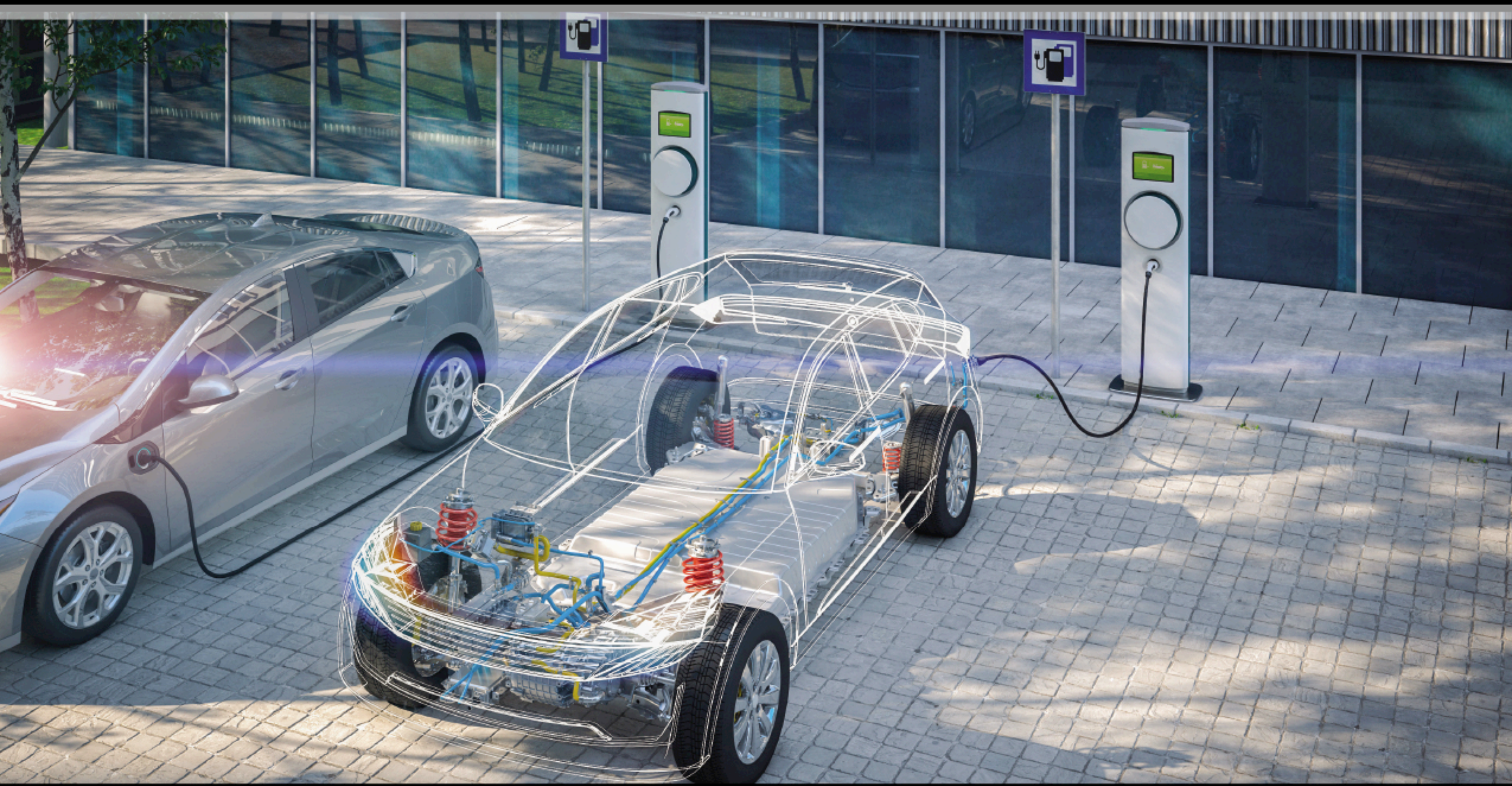
Electric & Hybrid Electric Vehicles



JAMES HALDERMAN CURT WARD

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ELECTRIC AND HYBRID ELECTRIC VEHICLES

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PREFACE

Introducing an innovative first edition in electric and hybrid electric vehicles! Designed to meet the needs of a third or fourth semester course in electrical systems, *Electric and Hybrid Electric Vehicles* is also designed for a special topic or certificate course in electric and hybrid electric vehicles or for an introductory course in connected and autonomous vehicles. It features all of the advanced technology of on-board diagnosis and up-to-date electrified vehicles technology, plus the same organization, flow, and features of the renowned Professional Technician series by Pearson!

DEPTH OF CONTENT AND FORMAT

Scope: Based on input and suggestions from automotive instructors, this title is aligned with ASE standards and includes comprehensive coverage as follows:

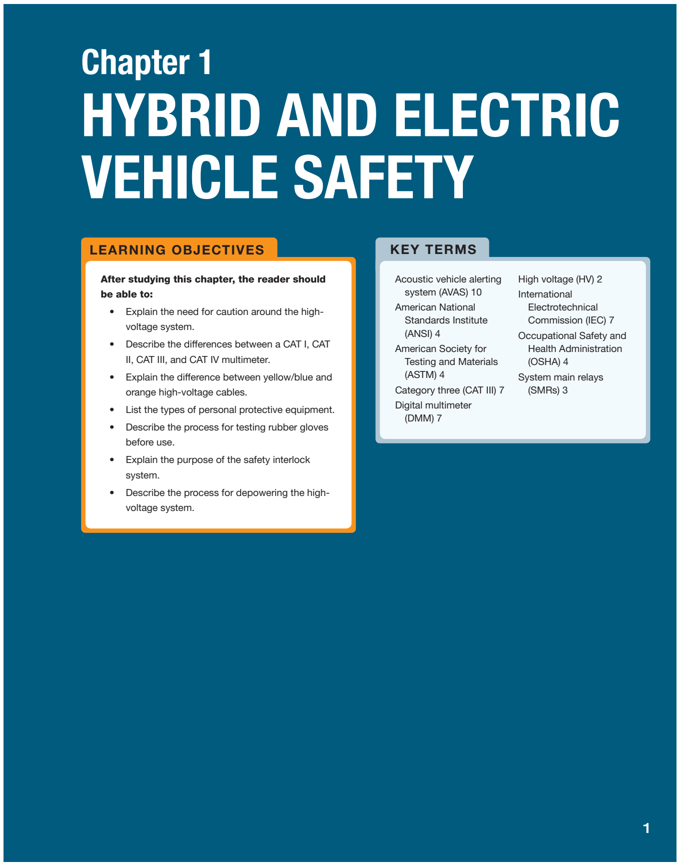
- The first four chapters are designed to introduce electric and hybrid electric vehicles including safety (chapter 1), introduction (chapter 2) and background information on the importance of the need for electrified vehicles (chapter 3), and hybrid ICE information (chapter 4).
- Chapter 5 (Hybrid and Electric Vehicle Preventative Maintenance) covers the routine maintenance required to be performed on electric and hybrid electric vehicles.
- Chapters 6 (Digital Storage Oscilloscope Testing) covers the uses of digital storage oscilloscopes (DSOs) with the emphasis on detailed analysis to locate the root cause of a customer concern.
- Chapter 7 (Energy and Power) includes the terms and definitions used throughout the rest of the text regarding energy and power including electrical units of measure commonly used when discussing electric and hybrid electric vehicles.
- Chapter 8 (Advanced AC and DC Electricity) is designed to prepare the reader for the circuits and testing of electric and hybrid electric vehicles.
- Chapter 9 (Low-Voltage Batteries and Stop-Start Micro Hybrids) includes useful information for the technician when dealing with currently available electric and hybrid electric vehicles.
- Chapter 10 (High-Voltage Batteries) includes the types and designs of high-voltage batteries used in both electric and hybrid electric vehicles.
- Chapter 11 (EV and HEV Motors, Converters, and Inverters) introduces the reader to the electronics involved in the electrified vehicle propulsion system.
- Chapters 12 (EV and PHEV Charging) and 13 (Electric Vehicle Charging Equipment) include all the details that are needed to know about levels 1, 2, and 3 charging.
- Chapters 14 (Regenerative Brakes), 15 (Electric Power Steering), 16 (EV and HEV HVAC System), 17 (EV and HEV Transmissions), and 18 (EV and HEV Driver Assist Systems) each round out the details that service technicians need to know to understand and service electric and hybrid electric vehicles.
- Chapter 19 (Fuel Cells and Advanced Technologies) covers advanced systems that are currently on the market and likely to be expanded in the future.
- Chapter 20 (First Responder Procedures) includes important procedures for identifying and mitigating potentially dangerous situations when working with electric and hybrid electric vehicles.
- The appendix provides a Sample ASE-type L3 Certification Test.

Organization: The content includes the basics needed by all service technicians and covers the following organization for most systems:

- Purpose and function of the system
- Parts involved and operational description
- Diagnosis and service

HALLMARK IN-TEXT FEATURES

The following highlights the unique core features that set the Professional Technician Series book apart from other automotive textbooks.


Chapter 1

HYBRID AND ELECTRIC VEHICLE SAFETY

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

- Explain the need for caution around the high-voltage system.
- Describe the differences between a CAT I, CAT II, CAT III, and CAT IV multimeter.
- Explain the difference between yellow/blue and orange high-voltage cables.
- List the types of personal protective equipment.
- Describe the process for testing rubber gloves before use.
- Explain the purpose of the safety interlock system.
- Describe the process for depowering the high-voltage system.

KEY TERMS

Acoustic vehicle alerting system (AVAS) 10
American National Standards Institute (ANSI) 4
American Society for Testing and Materials (ASTM) 4
Category three (CAT III) 7
Digital multimeter (DMM) 7
High voltage (HV) 2
International Electrotechnical Commission (IEC) 7
Occupational Safety and Health Administration (OSHA) 4
System main relays (SMRs) 3

1

OBJECTIVES AND KEY TERMS appear at the beginning of each chapter to help students and instructors focus on the most important material in each chapter. The chapter objectives are based on specific ASE tasks.

TECH TIP

Test Motor Before Replacing the Inverter

Before replacing a failed inverter, test the electric motor for any defects. It is relatively common for shorted electric motor windings to cause a failure of the inverter. The new inverter is likely to fail upon installation if the electric motor failure is not resolved first.

TECH TIPS feature real-world advice and “tricks of the trade” from ASE-certified master technicians.


PHOTO SEQUENCE

1 A Mustang Mach E electric SUV is showing 66 miles (27%) of charge remaining.

2 Using a smartphone app, Plug Share in this case, the driver located a Level 3 charging station.

3 After using a credit card to gain access, the driver removed the SAE CCS charge plug from the charging station.

4 The charge post on the Mustang Mach E is located on the left front fender.

5 During charging, the Mach E lights a series of lights around the charge receptible to let the driver know the level of charge. When all lights are on, the vehicle has been fully charged.

6 The charging station also shows the state-of-change on the display. Most experts recommend only charging to 80% unless traveling when the extra range is required to help protect the HV battery.

EV AND PHEV CHARGING 175

STEP-BY-STEP PHOTO SEQUENCES show in detail the steps involved in performing a specific task or service procedure.

Case Study

The Case of the Vibrating Tesla

An owner of a Tesla Model Y visited a tire shop complaining of a vibration in the steering wheel at highway speeds. A local tire shop balanced both front tires. The right front only needed a quarter ounce whereas the left front required over four ounces to balance. After leaving the shop, the owner immediately noticed that the vibration was much worse. The owner returned to the shop and this time the tire was removed from the rim. It became apparent that the vibration issue was caused by the foam inside the tire. This foam that generally played the role of reducing noise had separated and was loose inside the tire. The shop removed the foam and did not try to reinstall it. The wheel was balanced, which solved the vibration concern. The driver did not notice any increase in noise. ● **SEE FIGURE 2-6.**

Summary:

- **Complaint**—A Tesla owner complained of a vibration in the steering wheel at highway speeds.
- **Cause**—The acoustical foam inside a tire that is supposed to reduce noise had separated from the inner liner of the left front tire.
- **Correction**—The foam was removed from the tire and the tire/wheel assembly was balanced which corrected the vibration concern.

CASE STUDIES present students with actual automotive scenarios and shows how these common (and sometimes uncommon) problems were diagnosed and repaired. Uses the Three Cs approach (Complaint, Cause, Correction).

NOTE: These numbers originally referred to the metric dimensions of the graticule in centimeters. Therefore, an 8 × 10 display would be 8 centimeters (80 millimeters or 3.14 inches) high and 10 centimeters (100 millimeters or 3.90 inches) wide.

NOTES provide students with additional technical information to give them a greater understanding of a specific task or procedure.

? FREQUENTLY ASKED QUESTION

How Do You Reboot the Digital Display?

For most electric vehicles, pull the first responder loop under the hood, then disconnect the negative battery terminal by the fuse box. Wait 5 minutes, reconnect the battery terminal and then the first responder loop.

On the Tesla Model 3, hold down both scroll wheels on the steering wheel until the display reboots. Press and hold both scroll wheels on either side of the steering wheel for up to 10 seconds and the main/central screen will reboot. A soft reboot is performed by holding in both scroll wheels until the touchscreen turns off. A hard reboot is allegedly doing the same thing, but pressing and holding the brake pedal until the Tesla logo appears on the touchscreen. Another variation of a "reboot" is to power off the car from the touchscreen and leave it off for a few minutes (you have to stay in the car).

On a Mustang Mach E, to reboot the SYNC 4 system, push Volume Down button and Forward seek button. Hold them both down at the same time until the screen reboots.

FREQUENTLY ASKED QUESTIONS are based on the author's own experience and provide answers to many of the most common questions asked by students and beginning service technicians.

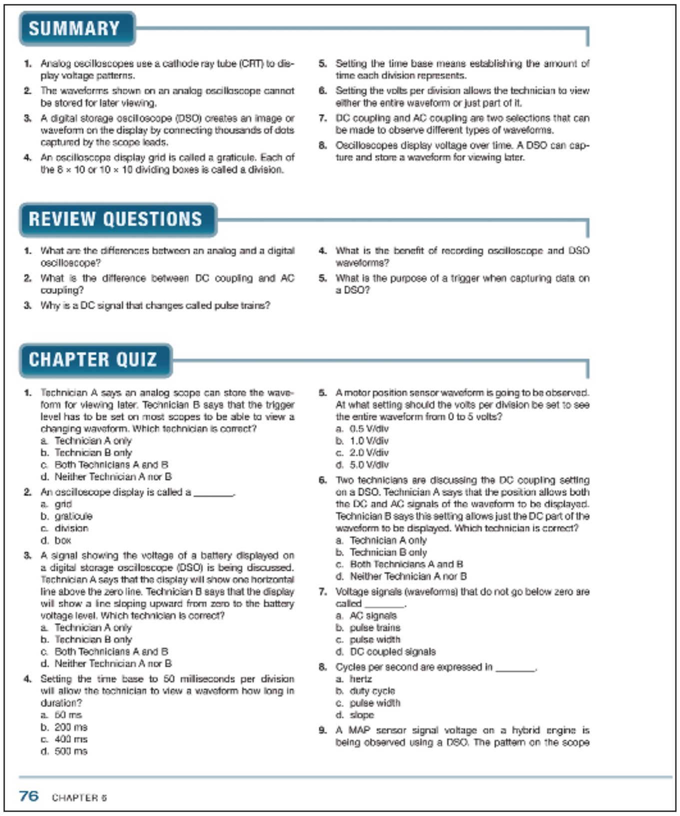
CAUTION: Check the instructions for the scope being used before attempting to scope household AC circuits. Some scopes are not designed to measure high-voltage AC circuits.

CAUTIONS alert students about potential damage to personal property that can occur during a specific task or service procedure.

WARNING

To avoid an electrical shock, any capacitor should be treated as if it were charged until it is proven to be discharged.

WARNINGS alert students to the potential dangers of personal injury during a specific task or service procedure.



SUMMARY

1. Analog oscilloscopes use a cathode ray tube (CRT) to display voltage patterns.
2. The waveforms shown on an analog oscilloscope cannot be stored for later viewing.
3. A digital storage oscilloscope (DSO) creates an image or waveform on the display by connecting thousands of dots captured by the scope leads.
4. An oscilloscope display grid is called a graticule. Each of the 8 × 10 or 10 × 10 dividing boxes is called a division.
5. Setting the time base means establishing the amount of time each division represents.
6. Setting the volts per division allows the technician to view either the entire waveform or just part of it.
7. DC coupling and AC coupling are two selections that can be made to observe different types of waveforms.
8. Oscilloscopes display voltage over time. A DSO can capture and store a waveform for viewing later.

REVIEW QUESTIONS

1. What are the differences between an analog and a digital oscilloscope?
2. What is the difference between DC coupling and AC coupling?
3. Why is a DC signal that changes called pulse trains?
4. What is the benefit of recording oscilloscope and DSO waveforms?
5. What is the purpose of a trigger when capturing data on a DSO?

CHAPTER QUIZ

1. Technician A says an analog scope can store the waveform for viewing later. Technician B says that the trigger level has to be set on most scopes to be able to view a changing waveform. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
2. An oscilloscope display is called a ________.
   a. grid
   b. graticule
   c. division
   d. box
3. A signal showing the voltage of a battery displayed on a digital storage oscilloscope (DSO) is being discussed. Technician A says that the display will show one horizontal line above the zero line. Technician B says that the display will show a line sloping upward from zero to the battery voltage level. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
4. Setting the time base to 50 milliseconds per division will allow the technician to view a waveform how long in duration?
   a. 50 ms
   b. 200 ms
   c. 400 ms
   d. 500 ms
5. A motor position sensor waveform is going to be observed. At what setting should the volts per division be set to see the entire waveform from 0 to 5 volts?
   a. 0.5 V/div
   b. 1.0 V/div
   c. 2.0 V/div
   d. 5.0 V/div
6. Two technicians are discussing the DC coupling setting on a DSO. Technician A says that the position allows both the DC and AC signals of the waveform to be displayed. Technician B says this setting allows just the DC part of the waveform to be displayed. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
7. Voltage signals (waveforms) that do not go below zero are called ________.
   a. AC signals
   b. pulse trains
   c. pulse width
   d. DC coupled signals
8. Cycles per second are expressed in ________.
   a. hertz
   b. duty cycle
   c. pulse width
   d. slope
9. A MAP sensor signal voltage on a hybrid engine is being observed using a DSO. The pattern on the scope

76 CHAPTER 6

THE SUMMARY, REVIEW QUESTIONS, AND CHAPTER QUIZ at the end of each chapter help students review the material presented in the chapter and test themselves to see how much they have learned.

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Student Supplements (for purchase):
ASE Correlated Task Sheets for *Electric and Hybrid Electric Vehicles*, ISBN: 9780137532155

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Chapter 1

HYBRID AND ELECTRIC VEHICLE SAFETY

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

- Explain the need for caution around the high-voltage system.
- Describe the differences between a CAT I, CAT II, CAT III, and CAT IV multimeter.
- Explain the difference between yellow/blue and orange high-voltage cables.
- List the types of personal protective equipment.
- Describe the process for testing rubber gloves before use.
- Explain the purpose of the safety interlock system.
- Describe the process for depowering the high-voltage system.

KEY TERMS

Acoustic vehicle alerting system (AVAS) 10
American National Standards Institute (ANSI) 4
American Society for Testing and Materials (ASTM) 4
Category three (CAT III) 7
Digital multimeter (DMM) 7
High voltage (HV) 2
International Electrotechnical Commission (IEC) 7
Occupational Safety and Health Administration (OSHA) 4
System main relays (SMRs) 3

HIGH-VOLTAGE SAFETY

NEED FOR CAUTION Electrical systems have been used on vehicles for more than a century. Technicians have been repairing vehicle electrical systems without fear of serious injury or electrocution. However, when working with electric or hybrid electric vehicles, this is no longer true. It is now possible to be seriously injured or electrocuted (killed) if proper safety procedures are not followed.

Electric and hybrid electric vehicles use **high-voltage (HV)** circuits that if touched with an unprotected hand could cause serious burns or even death.

PRECAUTIONS FOR ELECTRONIC MEDICAL DEVICES

- Electronic medical devices include cardiac pacemakers and cardioverter defibrillators.
- Technicians who rely on cardiac pacemakers should not service or repair electric or hybrid electric vehicles because of strong magnetic fields.
- Technicians who rely on implanted cardiac pacemakers or implanted cardioverter defibrillators should check with the manufacturer of the device before being in or around a charging vehicle.

? FREQUENTLY ASKED QUESTION

How Much Current Is Too Much?

Low voltage, such as the 12–14 volts used in conventional vehicles, does not represent a shock hazard and it is safe to handle. The only concern would be a possible burn could occur if a 12-volt wire were to touch ground causing the wiring to overheat. Voltages between 14 and 60 volts do not present a shock hazard, but an arc can occur if a connector carrying current is opened. High voltage, over 60 volts, does create a shock hazard and all precautions must be adhered to prevent personal injury. Typical current and how it affects the body are given as follows:

- 1 milliamp—May be noticeable as a slight tingle.
- 2–5 milliamps—May be noticeable as a light shock forcing the technician to let go.
- 6–25 milliamps—Noticed by pain and the technician cannot let go of the wires or component.
- 26–150 milliamps—Severe pain and possibly fatal.
- 1,000 milliamps—One ampere across the heart can stop the heart (fatal).

Also, always wear HV gloves for protection whenever working on or near a potential HV circuit or component. To help prevent an electric current from flowing through the body, always place one hand in a pocket and use only one hand when measuring a potential HV circuit or disconnecting a potential HV circuit.

IDENTIFYING HIGH-VOLTAGE CIRCUITS HV components are identified with warning labels. HV cables are identified by color of the plastic conduit and are indicated by the following colors:

- **Blue or yellow**—Up to 60 volts (not a shock hazard, but an arc will be maintained if a circuit is opened). **SEE FIGURE 1-1a and 1-1b**.

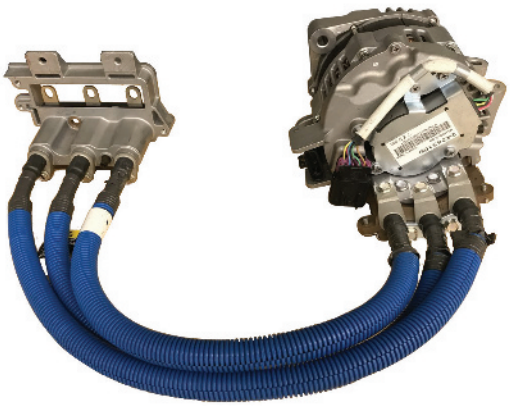

FIGURE 1-1a When the belt starter alternator assembly is installed, the three blue cables run between the inverter assembly and the alternator.

FIGURE 1-1b The yellow cable is part of the electric power steering system on a Toyota/Lexus vehicle.

FIGURE 1-2 The orange cables connect to the high power distribution module (HPDM) on the Chevrolet Bolt.

- **Orange**—Above 60 volts. ● **SEE FIGURE 1-2.**

Follow all precautions when working on or near HV wiring or components.

ELECTRIC SHOCK POTENTIAL

LOCATIONS WHERE SHOCK CAN OCCUR Accidental and unprotected contact with any electrically charged ("hot" or "live") HV component can cause serious injury or death. However, receiving an electric shock from a hybrid vehicle is highly unlikely because of the following:

1. Contact with the battery module or other components inside the battery box can occur only if the box is damaged and the contents are exposed, or the box is opened without following proper precautions.
2. Contact with the electric motor can occur only after one or more components are removed.
3. The HV cables can be easily identified by their distinctive orange color, and contact with them can be avoided.
4. The **system main relays (SMRs)** or contactors disconnect power from the cables the moment the ignition is turned off.

ELECTRIC VEHICLES IN THE SERVICE AREA

For a safe working environment:

- Be sure the work area is clean and dry.
- Care should be taken that HV warnings and safety cones are posted.
- Additional precautions, such as a roof cone or warning tape, are also recommended.

They are used to establish a safety zone around the vehicles so that other technicians will know that a possible shock hazard may be present. ● **SEE FIGURE 1-3**.

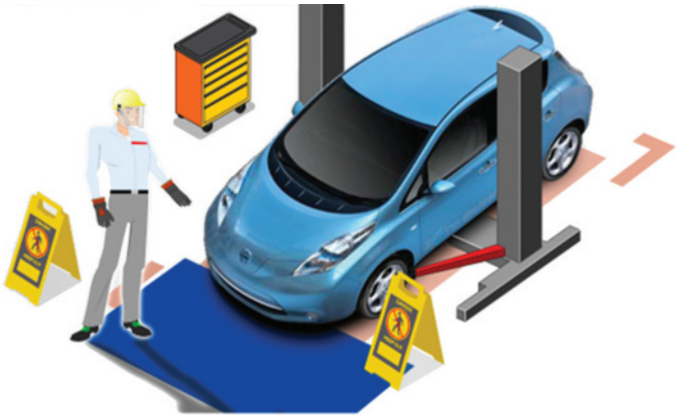

FIGURE 1-3 A clearly defined safety zone needs to be established in the area where a hybrid or electric vehicle is being repaired.

TECH TIP

Silence Is NOT Golden

Never assume the vehicle is shut off just because the engine is off. When working with a hybrid electric vehicle, always look for the READY indicator status on the dash display. The vehicle is shut off when the READY indicator is off.

The vehicle may be powered by:

1. The electric motor only.
2. The gasoline engine only.
3. A combination of both the electric motor and the gasoline engine.

The vehicle computer determines the mode in which the vehicle operates to improve fuel economy and reduce emissions. The driver cannot manually select the mode. ● **SEE FIGURE 1-4.**

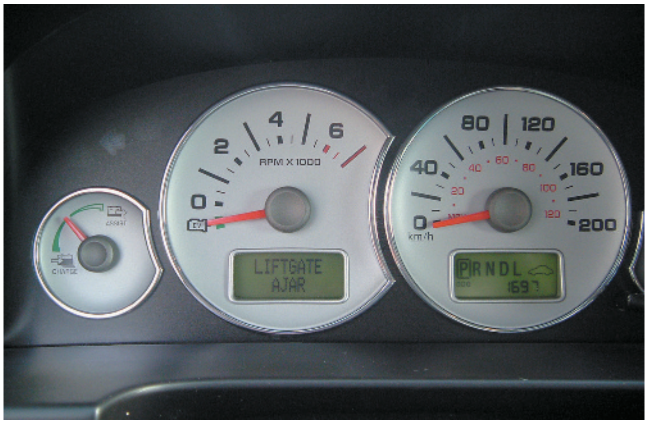

FIGURE 1-4 The Ford Escape Hybrid instrument panel showing the vehicle in park and the tachometer on "EV" instead of 0 RPM. This means the gasoline engine could start at any time depending on the state of charge of the HV battery and other factors.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

EYE PROTECTION Eye protection should be worn when testing for high voltage, which is considered by many experts to be over 60 volts. Eye protection should include the following features:

1. Plastic frames (Avoid metal frames as these are conductive and could cause a shock hazard.)
2. Side shields
3. Meet the standard ANSI Z87.1

NOTE: Some vehicle manufacturers specify that full-face shields be worn instead of safety glasses when working with HV circuits or components. ● SEE FIGURE 1-5.

HIGH-VOLTAGE GLOVES Before working on the HV system of a hybrid electric vehicle, ensure that HV lineman's gloves are available. Be sure that the gloves are rated at least 1,000 volts and class "0" by ANSI/ASTM. ● **SEE FIGURE 1-6.** The **American National Standards Institute (ANSI)** is a private, nonprofit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system. ANSI International, originally known as the **American Society for Testing and Materials (ASTM)**, was formed over a century ago to address the need for component testing in industry. The **Occupational Safety and Health Administration (OSHA)** requirements specify that the HV gloves get inspected every six months by a qualified glove inspection laboratory. Do not use gloves on which the expiration date has expired. Inspect the gloves carefully before each use. High voltage and current (amperes) in combination are fatal.

Before using the rubber gloves, they should be tested for leaks using the following procedure:

1. Roll the glove up from the open end until the lower portion of the glove begins to balloon from the resulting air pressure. Make sure to "lean" into the sealed glove to raise the internal

FIGURE 1-5 Safety glasses or a full-face shield similar to the items depicted must be worn when testing for the presence of high voltage.

FIGURE 1-6 The gloves should be clearly marked indicating that they are class "0" and rated for 1,000 volts.

FIGURE 1-7 The glove is rolled up on the open end to check for air pressure and any air leakage.

air pressure. If the glove leaks any air, discard the gloves. ● **SEE FIGURE 1-7.**

2. An approved electric glove inflator can also be used to test the gloves before use. ● **SEE FIGURE 1-8.**
3. The gloves should not be used if they show any signs of wear and tear.

LEATHER PROTECTORS Use an outer leather glove to protect the HV rubber gloves. Be sure the rubber lineman's glove extends at least 50 mm beyond the leather protector. The leather

FIGURE 1-8 An electric glove inflator similar to this may be used for testing.

WARNING

Do not use shop air to test HV gloves. The high air pressure will damage the gloves and lead to a lack of personal protection against high voltage.

FIGURE 1-9 Clean leather gloves must be used to protect the HV rubber gloves.

gloves should be clean and free of any material that might puncture the lineman's glove or conduct electricity. ● **SEE FIGURE 1-9.**

SHOP UNIFORM Some manufacturers recommend arc flash clothing or long sleeve, 100% cotton clothing that is tucked into the gloves when working on HV components. Remove all jewelry, rings, watches, and bracelets before working on the vehicle.

INSULATED SHOES OR BOOTS Some manufactures recommend the use of insulated boots or shoes to protect against exposure to high voltage. These are particularly useful in areas where water, oil, and other substances cannot be wiped off the floor. ● **SEE FIGURE 1-10.**

INSULATED RUBBER MATS AND BLANKETS Insulated rubber mats are placed on the floor when there is an exposure to high voltage. Insulated blankets are placed over

FIGURE 1-10 The sole of this shoe is designed to prevent the transfer of electrical current.

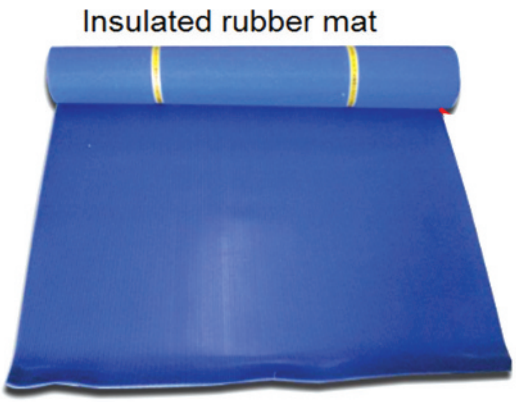

FIGURE 1-11 Some work locations require the use of insulated rubber mats in the work area.

the battery or other HV components after removal and during disassembly. ● **SEE FIGURE 1-11.**

FIRE EXTINGUISHERS Use ONLY a Class C fire extinguisher rated for electrical fires. An ABC rated fire extinguisher may be used if a Class C is not available. ● **SEE FIGURE 1-12.**

OTHER PERSONAL PROTECTION EQUIPMENT Some manufactures recommend that a 10-foot insulated fiberglass pole be available outside the safety zone to be used to pull a technician away from the vehicle in the unlikely event of an accident where the technician is shocked or electrocuted. Other manufacturers require a second set of safety equipment be available.

FIGURE 1-12 Make sure a proper fire extinguisher is available in the work area.

? FREQUENTLY ASKED QUESTION

Is the Radiation from a Hybrid Dangerous?

No. While there is a changing magnetic field surrounding any wire carrying an electrical current, the amount of electromagnetic radiation is very low. ● **SEE FIGURE 1-13.**

FIGURE 1-13 The radiation emitted from a hybrid electric vehicle is very low and is being measured in units of milligauss.

HIGH-VOLTAGE TOOLS AND EQUIPMENT

CAT III RATED DIGITAL MULTIMETER Hybrid and electric vehicles are equipped with electrical systems whose voltages can exceed 600 volts DC. A **category three (CAT III)** certified **digital multimeter (DMM)** is required for making measurements on these high-voltage systems.

The **International Electrotechnical Commission (IEC)** has several categories of voltage standards for meter and meter leads. These categories are ratings for over voltage protection and are rated CAT I, CAT II, CAT III, and CAT IV. The higher the category (CAT) rating of the meter, the greater the level of protection to the technician when measuring high-energy voltage. Under each category, there are various voltage ratings.

- **CAT I**—Typically a CAT I meter is used for low-voltage (LV) measurements, such as voltage measurements at wall outlets in the home. Meters with a CAT I rating are usually rated at 300–800 volts. CAT I is for relatively low-energy levels. While the voltage level is high enough for use when working on a hybrid electric vehicle, the protective energy level is lower than what is needed.

- **CAT II**—A CAT II meter is a higher-rated meter that would be typically used for checking voltages at the circuit-breaker panel in the home. Meters with a CAT II rating are usually rated at 300–600 volts. CAT II-rated meters have similar voltage ratings as the other CAT ratings, but the energy level of protection is higher with a CAT II compared to a CAT I.

- **CAT III**—CAT III is the minimum-rated meter that should be used for hybrid and electric vehicles. Meters with a CAT III rating are usually rated at 600–1,000 volts and the highest energy level which is needed to protect the servie technician. ● **SEE FIGURES 1-14 and 1-15.**

- **CAT IV**—CAT IV meters are for clamp-on meters only. A clamp-on meter is used to measure current (amperes) in a circuit by placing the clamp around the wire carrying the current. If a clamp-on meter also has meter leads for voltage measurements, that part of the meter will be rated as CAT III.

FIGURE 1-14 Use only a meter that is CAT III rated when making electrical measurements on an electric or hybrid electric vehicle.

FIGURE 1-15 The meter leads should also be CAT III rated when checking voltages on an electric or hybrid electric vehicle.

MEGOHMMETER (INSULATION TESTER) A megohmmeteror insulation tester is used to check for continuity between the HV cables and the vehicle chassis. It contains an internal DC-DC converter that allows for the continuity test to occur at a much higher voltage than a conventional ohmmeter. ● **SEE FIGURE 1-16.**

INSULATED HAND TOOLS Although they are not required by all manufacturers, insulated tools such as a ratchets, extensions, sockets, pliers, and screwdrivers provide an additional margin of safety to the service technician when working around HV components and systems. ● **SEE FIGURE 1-17.**

FIGURE 1-16 The Fluke 1587 is an example of an insulation tester that is able to test the HV circuit insulation to 1,000 volts. The resistance between the HV circuit and ground should be higher than one million ohms (1.0–22.2 MΩ).

FIGURE 1-17 Insulated tools, such as this socket set, provide an additional margin of safety to the service technician when working around HV components and systems.

SAFETY INTERLOCK SYSTEM

PURPOSE AND FUNCTION The HV system uses contactors or heavy-duty relays to detect opens in the HV circuits.

This is a safety system that keeps the power circuits from closing with an open HV circuit. The manual safety disconnect switch protects the HV battery pack and it includes a safety interlock switch that uses two small terminals. With an open detected, the HV controller does the following to keep the vehicle safe. ● **SEE FIGURE 1-18.**

FIGURE 1-18 The manual disconnect on this Ford battery contains a fuse and safety interlock.

- On a hybrid vehicle, if the engine is running, it will detect a fault and set a diagnostic trouble code (DTC). It also opens the power relays, turning off the "ready" light.
- If the hybrid vehicle is moving, it will allow it to continue until a stop, and will disable the internal combustion engine (ICE).
- If the hybrid vehicle is not moving, it will disable the ICE immediately.
- The HV system will be depowered on an electric vehicle.

LOCAL INTERLOCK A local interlock is a LV circuit that uses separate switches and contacts to detect when there has been an open in LV circuits or components that are associated with the HV system. The local interlock can detect the removal of items such as covers, battery disconnects, air-conditioning compressors, or any other component that is associated with a HV circuit. ● **SEE FIGURE 1-19**. If an open has been detected, the controller (ECM) signals the hybrid controller to open the contactors or power relays and discharge the HV capacitors.

FIGURE 1-19 The small white connector is the local interlock on the HV connection to the battery.

FIGURE 1-20 A lock box is a safe location to keep the ignition keys of a hybrid or electric vehicle while it is being worked on.

DEPOWERING THE HIGH-VOLTAGE SYSTEM

THE NEED TO DEPOWER THE HIGH-VOLTAGE SYSTEM

During routine vehicle service work, there is no need to go through any procedures needed to depower or shut off the HV circuits. However, if work is going to be performed on any of the following components, service information procedures must be followed to prevent possible electrical shock and personal injury.

- The HV battery pack
- Any of the electronic controllers that use orange cables, such as the inverter and converters
- The air-conditioning compressor, if electrically driven, and has orange cables attached

To safely depower the vehicle, always follow the instructions found in service information for the exact vehicle being serviced. The steps usually include the following:

STEP 1 Turn the ignition off and remove the key (if equipped) from the ignition and store it in a lock box to prevent accidental starting. ● **SEE FIGURE 1-20.**

CAUTION: If a push-button start is used, remove the key fob at least 15 feet (5 meters) from the vehicle to prevent the vehicle from being powered on. With the key fob out of the vehicle, attempt to start the vehicle to confirm no other key fobs are present in the vehicle.

STEP 2 Remove the 12-volt power source to the HV controller and wait 10 minutes for all capacitors to discharge. This step could involve:

- Removing a fuse or a relay
- Disconnecting the negative battery cable from the auxiliary 12-volt battery

STEP 3 Remove the HV fuse or service plug or switch.

STEP 4 Confirm there is no HV power present before beginning the repair.

HOISTING A HYBRID OR ELECTRIC VEHICLE

When hoisting or using a floor jack, refer to the manufacturer's service information for proper lift points. ● **SEE FIGURE 1-21**. Orange cables run under the vehicle just inside the frame rails on most hybrid and electric vehicles. The battery for many electric vehicles is underneath the vehicle and can be easily damaged by a hoist. In addition to the electrical circuits, many electric vehicles use coolant or refrigerant to maintain the temperature of the battery. Caution should be used to avoid damaging these lines. Some Honda hybrid vehicles use an aluminum pipe painted orange that includes three HV cables for the starter/generator and also three more cables for the HV air-conditioning compressor. If any damage occurs to any HV cables, the malfunction indicator; Lamp (MIL) will light up and a no-start will result if the powertrain control module (PCM) senses a fault. The cables are not repairable and are expensive. The cables can be identified by an orange outer casing, but in some cases, the orange casing is not exposed until a black plastic underbelly shield is removed first.