MADSIF

DEALERS WORKING FOR DEALERS℠

ELECTRIC VEHICLE WORKPLACE SAFETY PROGRAM

AVI

BOSCH

Introduction

The MADSIF Loss Control Committee is proud to present:
The Electric Vehicle Workplace Safety Manual.

MADSIF acknowledges the fast pace at which electric vehicles and their components continue to evolve. We have created this manual in hopes that it will simplify information for you to prevent employee injuries related to the servicing of these vehicles, in the best way possible.

Please share this manual with all employees that are working on electric vehicles, conducting safety walk-throughs of your facility, and managing your internal safety programs. We offer MADSIF's loss control consultants as a resource, and also suggest you refer to the agencies listed below and your vehicle manufacturers' guidelines for professional advisement. This is also available in the Member Section of www.madsif.com.

Disclaimer

The information contained here is meant for informational purposes only and is not to be used as professional advisement by MADSIF. Contents in this manual do not supersede any safety standards set forth by the agencies listed in the resources below or manuals provided by your vehicle manufacturers.

Resources

Please refer to the following agencies for additional electrical vehicle safety information.

MIOSHA (Michigan Occupational Safety and Health Administration)
State agency in Michigan that regulates workplace safety and health.

OSHA (Occupational Safety and Health Administration)
Federal agency of the U.S. Department of Labor that sets and enforces standards for workplace safety and health.

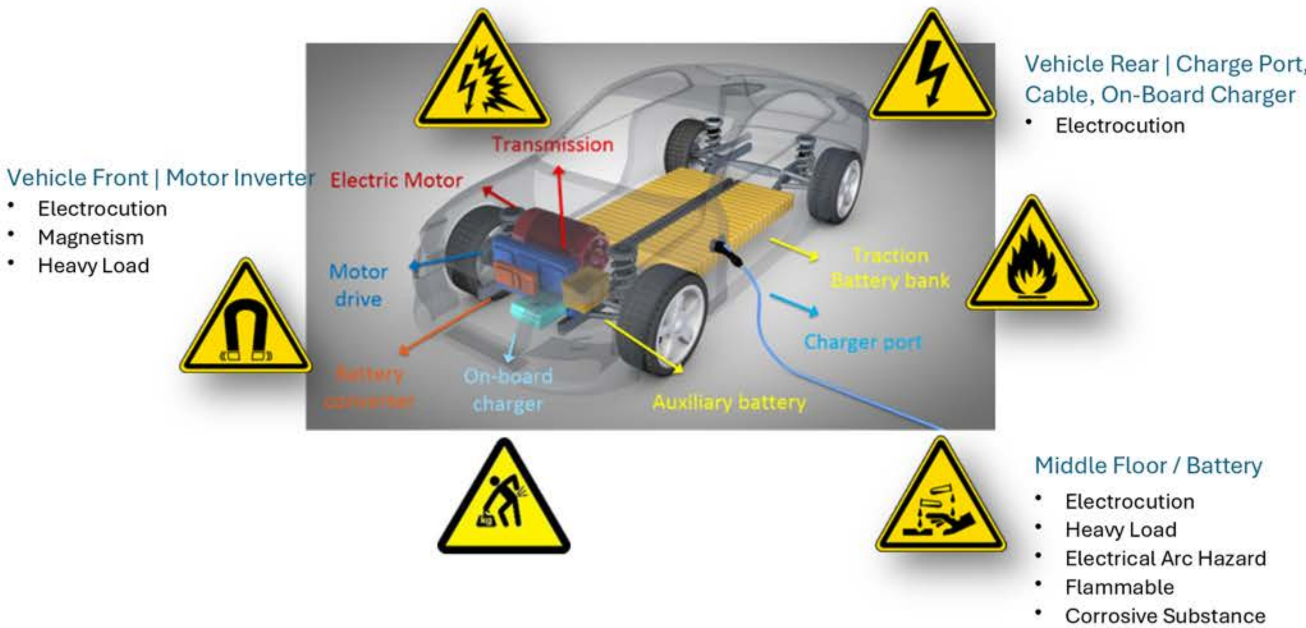
ASE (National Institute for Automotive Service Excellence)
This association offers a set of standards related to electric vehicle safety.

NFPA (National Fire Protection Association)
This is a non-profit organization that develops & publishes codes & standards related to fire & electrical safety. NFPA 70E specifically addresses electrical safety & arc flash.

NEC (National Electric Code)
This is a U.S. standard for the safe installation of electrical wiring and equipment; published by the National Fire Protection Association.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Hazard Overview



Electronic vehicles (EV) utilize high-voltage systems, typically ranging from 200-800 volts DC.

While extensive safety measures are implemented, potential for electrical breakdown exists.

Damaged battery casings, compromised insulation on high-voltage wiring, or malfunctioning control systems could create a current path capable of exceeding the human body's dielectric breakdown threshold, resulting in serious or fatal electrocution.

EVs generate magnetic fields due to high currents flowing through batteries, motors, and power electronics.

These fields are strongest near the source, typically around the battery pack, motor, and cables.

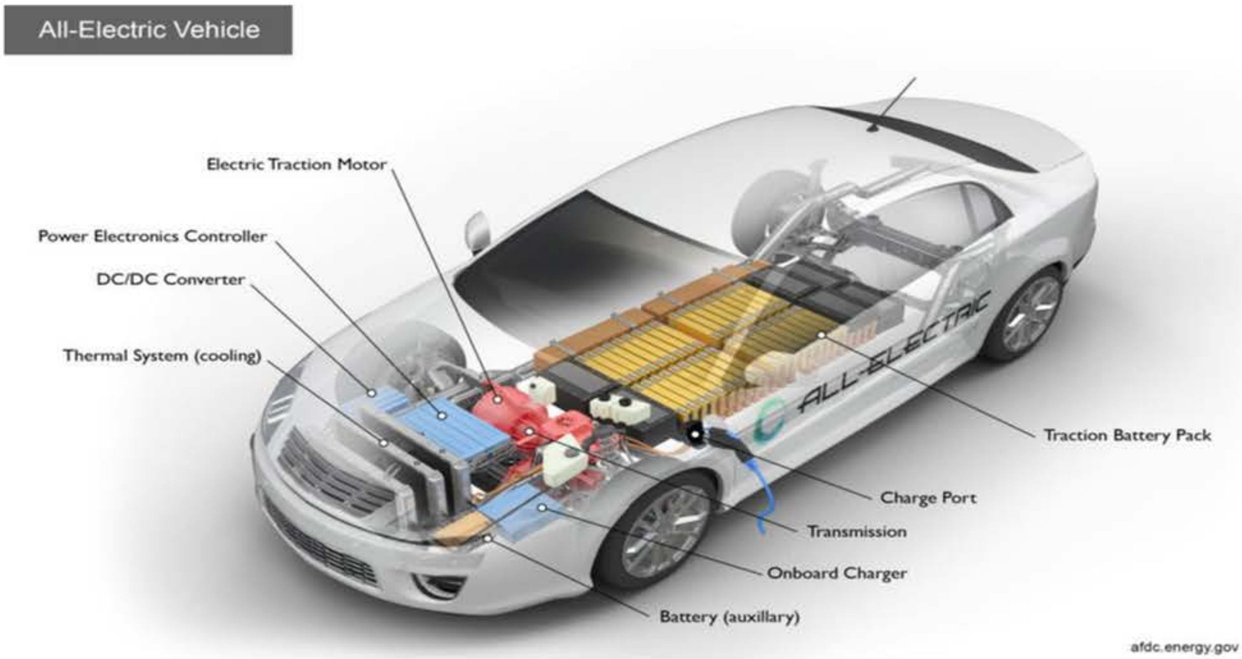
Strong magnetic fields can disrupt some implanted medical devices like pacemakers or defibrillators. This is why some EVs have restricted areas where people with such implants shouldn't stay for extended periods.

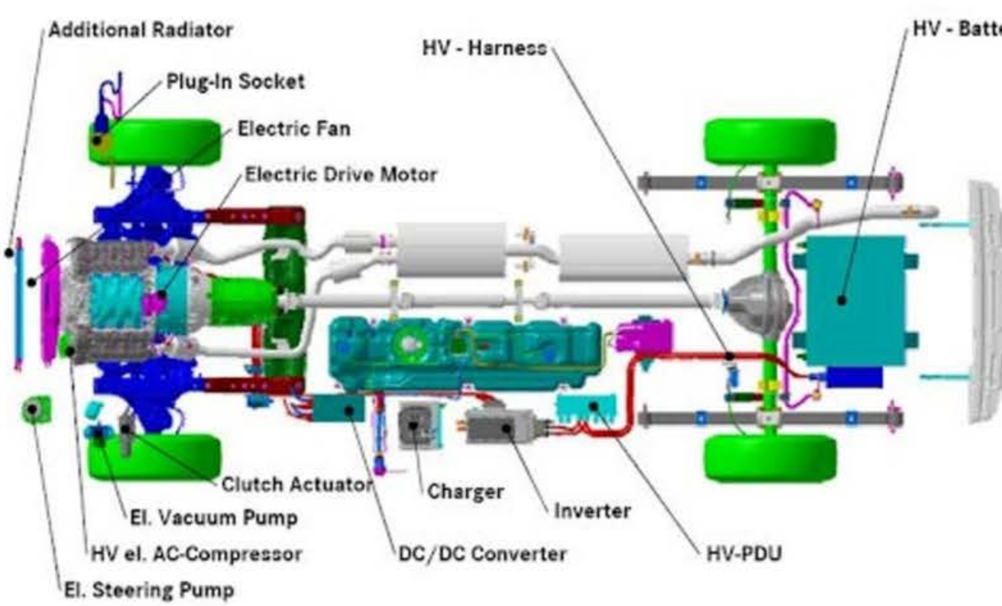
Due to thermal runaway, lithium-ion batteries in EVs possess the potential to undergo an exothermic reaction, releasing significant heat and transitioning to self-sustaining fire.

In the event of a breach, electrolytes within lithium-ion batteries of electric vehicles can pose a chemical hazard due to their corrosive and flammable properties.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Components Overview





© 2025 MADSIF | Proprietary Information | Do Not Distribute

Dangers of Electrocution

People with pacemakers should avoid working on high-voltage cars, as strong magnetic fields can affect the operation of the pacemaker.

Anything over 500mA can be enough to cause fatal electrocution.

The high-voltage DC nature of electric (EV) batteries presents an electrocution hazard.

Unlike AC (alternating current) where the threshold for ventricular fibrillation (disruption of the heart's rhythm) is generally around 50-60 Hz, even relatively low DC voltages (as low as 60V) can disrupt this rhythm due to its continuous nature, potentially leading to cardiac arrest.

This risk is exacerbated by the ability of DC current to cause sustained muscle contractions, making it difficult to break free from the electrical path.

Danger Voltage Level of DC (Direct Current):

>60 volts and < 1500 volts DC

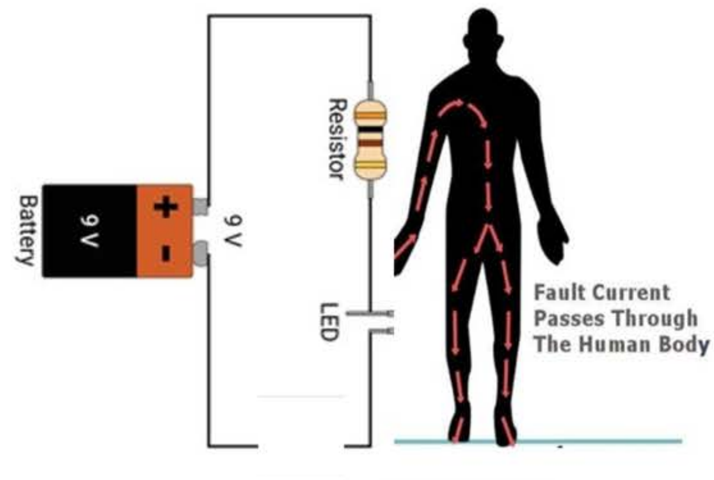
Danger Voltage Level of AC (Alternating Current):

>30 volts and < 1000 volts AC RMS*

*True RMS or RMS (Root Mean Square) refers to the specific way of measuring the effective value of an alternating current (AC) or voltage, particularly for waveforms that deviate from the perfect sinewave.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Electrical Resistance



400v / 1000 Ohms = 0.4A = 400mA Electricity of more than 5mA through the human body is dangerous!

Electrical resistance is a material's feature that opposes the flow of electric current. It's like friction for electrons, caused by collisions with atoms in the material.

Resistance is measured in Ohms. Human body resistance is variable due to the interplay of skin (high resistance when dry) and internal tissues (lower resistance). Dry skin offers high resistance (up to 100,000 Ohms) due to its keratin layer. Conversely, wet skin significantly reduces resistance (down to 1,000 Ohms) as electrolytes conduct current much more easily.

The amount of current passing through the body (I) depends on voltage (V) and resistance (R) following Ohms Law (I = V/R). This current can disrupt nerve impulses and muscle function, leading to varying consequences from tingling to severe pain and burns to cardiac arrest, depending on the severity.

Effects of DC current running through the body (1 Amp = 1,000 mA):

1 mA: Barely perceptible.
2-10mA: Extremely painful sensations.
16 mA: Paralysis of arms. This is considered the maximum current an average person can "let go".
Current greater than this causes so much involuntary muscle contraction that the victim is
unable to let go of the electrical source.
20 mA: Paralysis of respiratory muscles, leading to difficulty breathing.
100 mA: Ventricular fibrillation threshold. The heart starts to beat irregularly, potentially leading to cardiac arrest and death if not treated immediately.
1-2 Amps: Cardiac standstill and internal organ damage.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

First Aid

High-Voltage Accidents

1. Ensure Scene Safety: Only approach if the power source is off or safely disconnected. Use non-conductive materials (dry wood, plastic, fiberglass) to remove the victim from contact.
2. Assess Consciousness and Breathing: Check for responsiveness and pulse, if unconscious and not breathing immediately begin CPR, use AED.
3. Minimize Further Injury: Cover burns with sterile dressings (avoid ointments). If the person is breathing but disoriented, keep them calm and monitor vitals until emergency help arrives.
4. Call Emergency Services: Even if the victim seems okay, hidden cardiac issues, internal injuries and delayed effects are possible. Medical professionals will perform advanced assessments and interventions not possible in a first aid setting.
5. Have These First-Aid Items on Hand:
   - AED (Automated External Defibrillator)
   - First Aid Kits
   - Bleeding control kits
   - Eyewash stations
   - Bloodborne Pathogen Spill Kits
   - Emergency Blankets

NOTE: We always recommend that formal first aid training is undertaken.

Safety Rules for High-Voltage Vehicles

Electrical work must only be started when protective measures have been taken against electric shock, short circuit, and electric arcs. Work is normally only carried out in de-energized mode. To put the car in de-energized mode, the manufacturer's instructions and the six (6) safety rules must be followed in a specific order to prevent electric shock and ensure a safe work environment:

1. Protect Yourself:
   - Personal Protective Equipment (PPE): Always wear the appropriate PPE, including insulated gloves, safety glasses/eye protection, and protective clothing, when working on an EV.
   - Insulated tools should also be used to minimize the risk of electric shock.
2. Secure The Area:
   - Place vehicle and floor warning signs to ensure people are aware of the potential risk.
   - Place barriers and/or barricades to prevent accidental entry.
   - Communicate with others in the vicinity, such as colleagues or nearby workers, about the ongoing work on the EV.
3. Isolation (Manufacturer's Instructions):
   - Ensure that the vehicle's power source is completely isolated.
   - Disconnect the battery and disable any high-voltage systems to prevent accidental electrical shocks.
   - Wait for sufficient time to allow capacitors to discharge completely; Some EVs have capacitors that store electrical energy even when the battery is disconnected, as specified by the manufacturer.
4. Secure Against Reconnection (Manufacturer's Instructions):
   - Implement lockout/tagout procedures to ensure that the EV's power source is completely isolated and cannot be activated (accidentally or purposely).
   - This involves disconnecting the battery and disabling any high-voltage systems, using lockout devices and tags to indicate that the vehicle is not to be operated.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Safety Rules for High-Voltage Vehicles (continued)

5. Confirm De-Energized State (Manufacturer's Instructions):
   - Use a suitable multimeter or voltage detector to check for the absence of voltage at critical points in the EV's electrical system.
   - This can include checking voltage at the battery terminals, high-voltage cables, or other relevant components. Ensure that the voltage reading is zero or close to zero to confirm de-energization.

6. **<u>PRIOR</u> TO STARTING WORK ON AN ELECTRIC VEHICLE**, make sure the high-voltage rescue hook is ready and accessible.

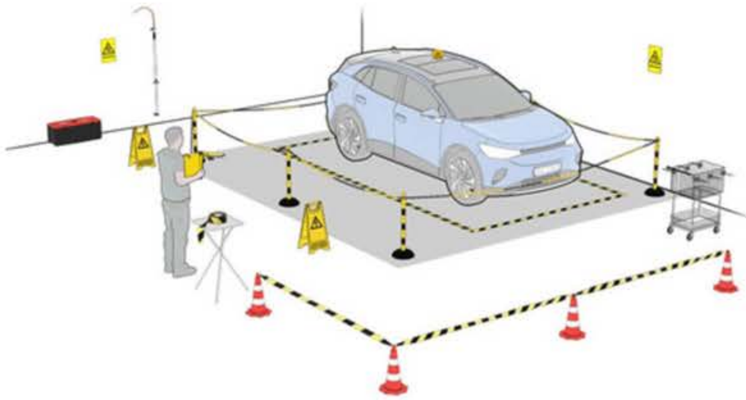
DOUBLE- CHECK!

Perform a visual inspection of the EV's electrical components and wiring to ensure that everything is properly disconnected and de-energized. Look for any signs of residual power or potential hazards.

Always follow the manufacturers' specific safety guidelines, protocols and recommendations for working on EV's. If you are unsure about any step or lack proper training, never attempt to work on a high-voltage vehicle. Always consult a qualified technician for EV system repairs or maintenance.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

REMEMBER: SAFETY FIRST................ALWAYS!



Rescue hook, Barriers, Cones, and Signs

Personal Protective Equipment

Note: If your manufacturer has not supplied you with these materials, we advise that you reach out to them for best ordering resources

Use EV Battery Lift Tables to remove and move batteries.

Personal Protective Equipment (PPE)





Technicians working on high-voltage systems and vehicles require specialized PPE:

Insulated Gloves:

- Primary defense against electrical shock.
- Manufactured from rubber compounds with high dielectric strength, giving the material the ability to resist the passage of an electric current.
- Rigorously-tested by manufacturers to ensure they can withstand the maximum voltage a technician might encounter, typically 1,000 volts for electric vehicles (EVs).
- Specific to ASTM D1701 test, high voltage is applied to the gloves while submerged in water to identify any breakdown points in the material.

Cotton Under-Gloves:

- Thin, absorbent gloves worn underneath the insulated gloves to enhance comfort and wick-away sweat and moisture.
- Moisture build-up can deteriorate the electrical insulating properties of the gloves and increase the risk of shock.

Note: Per OSHA, glove testing is required. In most cases, this will be before initial use and then every six (6) months. Be sure to follow manufacturer's instructions on the packaging.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Personal Protective Equipment (PPE) (continued)

Arc Flash and High-Voltage Protecting Suits:

- Arc flashes occur due to a low-impedance connection between energized conductors, resulting in an explosive release of energy.
- Flame-retardant garment shields technicians from the intense heat and ultraviolet (UV) radiation generated during an electrical arc flash.
- Suit is typically made of woven fabrics with high thermal protective ratings (ATPV), which is the amount of heat energy a material can withstand for a specific time before sustaining a second-degree burn.

Arc Flash Face Shield:

- Crucial PPE that safeguards technician's face and eyes from intense light, heat, and flying debris produced during an arc flash.
- Shield utilizes a special filter material with high arc-rating to absorb or reflect UV radiation and minimize the risk of burns.

Dielectric Footwear:

- Insulated boots designed to protect the technician from electrical shock if they encounter a live conductor on the ground.
- Soles of the boots are made from electrically non-conductive materials like rubber and are rigorously tested to withstand special voltage levels.

Safety Glasses:

- Essential protection from flying debris and dust particles that may be present while working on high-voltage systems.
- Should be made of impact-resistant polycarbonate to withstand potential hazards.
- Should meet the minimum ANSI Z87+ standard. This rating ensures the glasses are impact-resistant and provide protection against high-velocity projectiles.

Insulated Helmet:

- Protect against electric shocks and prevention of dangerous electrical current passing through the head.
- Constructed using modified high impact polyamide, suitable for working with live electrical connections.

High Voltage Rescue Hook:

- Helps to detach wounded person from a High-Voltage source.
- Must be fiberglass.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

In the Workshop

In an electric vehicle (EV) workshop, the following non-personal safety equipment plays a critical role:

1. Insulating Floor Mats (optional):
   - These high-voltage rated mats (exceeding 1,000V) provide electrical insulation for technicians working on the vehicle.
   - These mats prevent current passing through the technician's body in case of accidental grounding contact.
2. High-Voltage Warning Signage:
   - Clearly visible signage with standardized hazard symbols is crucial for alerting all personnel to the presence of high-voltage within the workspace.
3. Barriers and Floor Signs:
   - Visible ribbon or chains with pillars and/or floor signs create physical barriers around the working space.
4. Fire Extinguishers and Fire Blanket:
   - Use approved CO2 or F500, NEVER USE WATER!! If possible, place working area in front of car exit door, which can be opened quickly in an emergency.
5. Insulating Tools:
   - Specialized tools with non-conductive handles and tips, are essential for safely working on high-voltage components within an EV. These tools minimize the risk of electrical shock and short circuits during maintenance procedures.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Isolation

Pre-Work Safety:

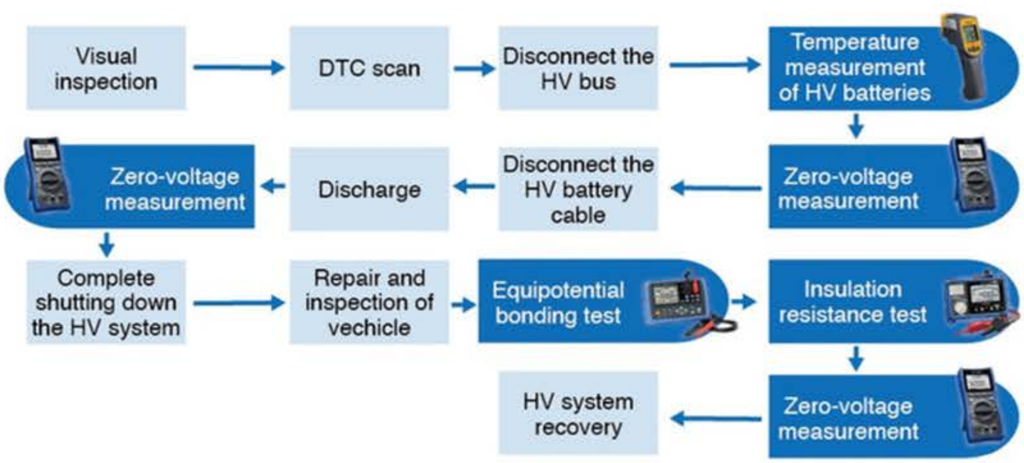
- Review the manufacturer's specific instructions for the vehicle model being serviced. This ensures proper identification of high-voltage component and de-energization procedures.

Key Fob Deactivation:

- Booklet Deactivation: Some electric vehicles may require booklet deactivation of the key fob using a designated button or switch within the vehicle cabin. Consult the service booklet for specific instructions on deactivating the key fob electronically.
- Physical Removal: Remove the key fob from the vehicle entirely, at the safe distance. This prevents accidental activation of the vehicle's electrical systems during service work.

System Power Down:

- Power Off Sequence: Follow the manufacturer's instructions to turn off the vehicle and ensure all high-voltage systems are deactivated. This may involve powering down the 12V system, and a dedicated high-voltage disable switch (safety switch).



© 2025 MADSIF | Proprietary Information | Do Not Distribute

Isolation (continued)

High Voltage Isolation:

- Service Disconnect: Locate the high-voltage service disconnect point (often located near the battery pack). This is a specialized connector designed to be opened safely while the vehicle is de-energized.
- Open Service Disconnect: Using the correct tools and following manufacturer's instructions, carefully open the service disconnect to physically isolate the battery pack from the rest of the high-voltage system.

Passive Discharge:

- Wait Time: Allow sufficient time for the capacitors within the inverter to passively discharge. These capacitors store residual energy that can still pose a shock hazard.

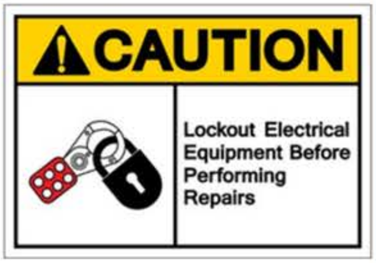
Important Note: These are general guidelines.

ALWAYS PRIORITIZE THE MANUFACTURER'S INSTRUCTIONS for the specific model being serviced.

WARNING: NEVER attempt to work on a high-voltage system unless the technician is properly trained and qualified.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Secure Against Reconnection



It is important to make sure the vehicle cannot be used by a person who is not permitted to do so. There are various ways to secure the EV against reconnection, depending on whether it is a high or low voltage disconnect.

Using an EV Lockout Kit will help prevent the unauthorized reconnection or mobilization of the vehicle.

Implement Lockout & Tagout Procedures:

- If working on the high-voltage system requires physical access to components or areas where the high-voltage system is located, implement lockout/tagout procedures to prevent accidental re-energization.

Safety Switch Locking:

- Locking Mechanism: The safety switch will likely have a dedicated locking mechanism, such as a padlock hasp or keyed switch. Utilize the appropriate locking device as specified in the service booklet.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

De-Energized State



After de-energizing the high-voltage system, verify that it is properly isolated before working on the vehicle.

Always follow the manufacturer's instructions.

Ensure high-voltage system is voltage-free, using a suitable meter to confirm.

Once the high-voltage system is confirmed as safe, maintenance, servicing, and repair tasks can be performed on the vehicle.

Voltage Verification:

1. Utilize a properly rated multi-meter or voltage tester with leads designed for high-voltage applications.
2. Carefully measure the voltage at designated test point on the battery pack or inverter terminals as specified in the service booklet.
3. Ensure the voltage has dropped to a safe level, typically below 60V DC.

Strictly follow the manufacturer's procedures & safe voltage levels shown in the service booklet.

Note: Always follow proper safety procedures per the manufacturer's instructions and always use appropriate personal protective equipment.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

Bosch High-Voltage Risk Assessment

1. Is the workshop lighting, cleanliness, and workshop area size adequate to make working on High-Voltage safe?
2. Is the work area free from trip hazards, obstructions, and other hazards/exposures?
3. Is the work area far enough away from public walkways to make working on High-Voltage safe? No person should be able to reach and come into contact with live equipment.

1. Is adequate High-Voltage PPE available, inspected, and tested before each use?
2. If required, are correctly rated insulated tools available?
3. Where are the nearest fire extinguishers? Are they the correct type?
4. Are there any fire hazards such as fuel, flammable liquids or combustible materials in the High-Voltage work area?
5. Can the High-Voltage work area be cordoned off adequately?
6. Is there a fiberglass rescue hook and "hook-man" available in case pull of is required?
7. Does another person know how to isolate the High-Voltage in case of an accident?
8. Is there a "first aider" on site? If so, how will they be notified in an emergency?
   - "You should take every precaution that you reasonably can ensure that an incident will not happen. If all of these safety measures are in place, then an incident should be unlikely. However, if an incident does occur and a first aider is not present, then it is important that your processes ensure that someone else already knows what to do, even if that is only to ensure that the power is safely isolated, and that immediate alerting of the emergency services is guaranteed. This could be the function of the First Aid "Appointed Person."
9. Where is the first aid kit located?
10. Is there a defibrillator (AED) available at the site? It is charged? Who is trained to use?
11. Where is the nearest telephone for calling emergency service (911)? If is is a mobile phone, is it sufficiently charged and has a strong enough signal?
12. Where can an ambulance park? What is the easiest route to the casualty (with equipment) and who would direct the ambulance crew to the casualty location?

© 2025 MADSIF | Proprietary Information | Do Not Distribute

NOTE: THIS IS AN EXAMPLE ONLY.

A CUSTOMIZED ASSESSMENT FORM SHOULD BE DEVELOPED FOR YOUR FACILITY, OPERATION, EQUIPMENT, ETC.

Electric vehicle risk assessment forms are documents employed to proactively identify and evaluate potential hazards associated with the operation, maintenance, and emergency response scenarios for EVs.

A comprehensive risk assessment form for an electric vehicle workshop should incorporate both traditional mechanical workshop hazards and those specific to high-voltage systems. The form should identify potential risks such as:

- Electrical shock from exposed high-voltage components during service, maintenance, and repair.
- Thermal runaway and fire risks associated with damaged, defective, or improperly handled lithium-ion batteries.
- Inhalation hazards from electrolyte fumes released during battery breaches.
- Arc flash injuries due to short circuits within the high-voltage system.

The form should then outline control measures, including:

- Mandatory training for technicians on safe handling procedures for EVs and high-voltage systems.
- Use of appropriate personal protective equipment (PPE) like high-voltage rated gloves, face shields, and arc flash suits.
- Clearly define protocols for battery handling, charging, storage, and disposal.
- Implementation of a documented lockout/tagout procedures/program to isolate high-voltage components before work commences.

By systematically evaluating and mitigating these risks, the workshop can ensure a safe working environment for technicians and minimize the potential for accidents and emergencies involving electric vehicles.

NOTE: Consult with appropriate agencies when developing the assessment form. This includes but is not limited to MIOSHA, NEC, NFPA, Federal and State Standards, and Local Fire Marshal Codes.

© 2025 MADSIF | Proprietary Information | Do Not Distribute

References

ANSI (The American National Standards Institute): Roadmap of Standards and Codes for Electric Vehicles

SAE (Society of Automotive Engineers): J2908 Electrified Vehicles Standard

In late February 2023,SAE International announced the release of a standards document to provide a common testing procedure to rate the maximum power of electrified powertrains. The new J2908 standard, titled "Vehicle Power and Rated System Power Test for Electrified Powertrains," is a voluntary procedure to more easily measure and compare the maximum power of electrified powertrains used in hybrid-electric vehicles (HEVs), plug-in hybrid-electric vehicles (PHEVs), and battery electric vehicles (EVs).

SAE (Society of Automotive Engineers): J2344: Guidelines for Electric Vehicle Safety

ISO (International Organization for Standardization) 6469: Electrically Propelled Road Vehicles -Safety Specifications

IEC (International Electrotechnical Commission) 61851: International Standard for Electric Vehicle Conductive Charging Systems

BOSCH Automotive Service Solutions LLC: Phase 2 - Technology and Repair Training Manual AVI Conference 2025: AVI (Automotive Video Innovations) Bosch Hybrid/EV Phase 3: Advanced High-Voltage Systems and Diagnostics

NFPA (National Fire Protection Association) 70E: Standard for Electrical Safety in the Workplace (Arc Flash)

Further Assistance

Thank you for your commitment to MADSIF.
We strive to provide you with all you need to keep your employees safe from injury.

Please reach out to MADSIF's Loss Control Consultants with any questions or concerns:
Ken Smylie, Vice President, Comprehensive Risk Services (248) 915-7403 ksmylie@crsmi.com

Login to www.madsif.com for an online version of this manual, located in the member section.

© 2025 MADSIF | Proprietary Information | Do Not Distribute