



SURFACE VEHICLE RECOMMENDED PRACTICE

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Recommended Practice for the Design and Test of Hybrid Electric
and Electric Trucks and Buses for Electrical Safety

RATIONALE

Hybrid Electric powertrain technology has been newly introduced to the commercial Class 4 through 8 truck and bus market. With this introduction, hybrid trucks and buses now contain components with higher voltages and stored potential energy. The presence of high voltage batteries, motors, and electronics therefore creates new potential electrical hazards that were not before present on non-hybrid trucks and buses.

The safer operation of trucks and buses is a shared priority of all truck and bus operators, fleet owners, OEMs, and suppliers and is not a basis for competition. Therefore, the SAE Truck and Bus Council formed the Truck and Bus Hybrid Safety committee. The committee members have volunteered to develop common, consistent design and test practices that can be applied to hybrid technology for Class 4 through 8 vehicles, in order to benefit the drivers, maintainers, and emergency personnel who come in contact with these vehicles.

Although specifications for hybrid electric technology have been developed and published for passenger cars, specifications have yet to be adopted for Class 4 through 8 vehicles. This recommended practice is intended to leverage the existing body of SAE hybrid standards, and to also leverage procedures already developed individually by truck and bus industry manufacturers for the safer operation and service of their vehicles. The focus of this document will be the documentation of practices for those aspects of hybrid technology that relate uniquely to Class 4 through 8 trucks and buses.

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1. SCOPE

This document will cover the aspects of the design and test of Class 4 through 8 electric and hybrid-electric trucks and buses for electrical safety. The document is intended to address the safety concerns of electrical systems in commercial vehicles that employ voltages greater than 60 VDC or 30 VAC RMS.

1.1 Purpose

The document is intended to provide direction to manufacturers of hybrid electric trucks and buses and their suppliers on design requirements and test procedures that are intended to make these vehicles safer to operate, service, or recover from an accident.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

The following SAE requirements for high voltage components, wiring, and energy storage are incorporated:

SAE J1113	Electromagnetic Susceptibility Measurement Procedures for Vehicle Components (Except Aircraft)
SAE J1654	Unshielded High Voltage Primary Cable
SAE J1673	High Voltage Automotive Wiring Assembly Design

SAE J1742	Connections for High Voltage On-Board Vehicle Electrical Wiring Harnesses - Test Methods and General Performance Requirements
SAE J1766	Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing
SAE J1772	SAE Electric Vehicle and Plug In Hybrid Electric Vehicle Conductive Charge Coupler
SAE J1773	SAE Electric Vehicle Inductively Coupled Charging
SAE J2074	The Air Bag Systems in Your Car "What the Public Needs to Know"
SAE J2344	Guidelines for Electric Vehicle Safety
SAE J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
SAE J2929	Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells
SAE J2950	Recommended Practices (RP) for Shipping Transport and Handling of Automotive-Type Battery System - Lithium Ion

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

The following ISO requirements for high voltage components, wiring, and energy storage were used for reference in developing this standard:

ISO 6469-1	Electric Road Vehicles - Safety Specifications - Part 1: On-Board Electrical Energy Storage
ISO 6469-2	Electric Road Vehicles - Safety Specifications - Part 2: Functional Safety Means And Protection Against Failures
ISO 6469-3	Electric Road Vehicles - Safety Specifications - Part 3: Protection of Persons Against Electric Hazards
ISO 14572	Road Vehicles - Round, Sheathed, 60 V And 600 V Screened and Unscreened Single- or Multi-Core Cables - Test Methods and Requirements for Basic- and High-Performance Cables
ISO 16750	Environmental Conditions and Testing for Electrical and Electronic Equipment

ANSI/IEC 60529 Degrees of Protection Provided by Enclosures

2.1.3 Federal Motor Vehicle Safety Standards (FMVSS)

The following U. S. Federal Motor Vehicle Safety Standard, that applies to electrical safety of hybrid automobiles less than 10 000 pounds, is referenced.

FMVSS-124	Accelerator Control Systems
FMVSS-305	Electric Powered Vehicles Electrolyte Spillage and Electrical Shock Protection

2.1.4 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Code of Federal Regulations, 49 CFR Parts 100-185

Code of Federal Regulations, 49 CFR Part 390.21

Code of Federal Regulations, 29 CFR Part 1910.147

UN38.3 Recommendations on the Transportation of Dangerous Goods – Manual of Tests and Criteria Provisions for the classification of lithium batteries (sub-section 38.3)

ECE R100 Protection from Electrical Shock, Battery Electric Vehicles

National Fire Protection Agency Part 70 (National Electric Code)

- Article 480 Storage Batteries
- Article 490 Equipment, Over 600 V, Nominal

Article 625 Electric Vehicle Charging System

Underwriters Laboratories UL2202 (October 1996) Electric Vehicle (EV) Charging System Equipment

Underwriters Laboratories UL2231 (July 1996) Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits

IEEE 1584-2002 IEEE Guide for Performing Arc Flash Hazard Calculations

3. DEFINITIONS

3.1 Terms

3.1.1 Hybrid Electric Vehicle

A motor vehicle whose motive power is derived from a combination of torque generated by an internal combustion engine and an electric machine.

3.1.2 Hybrid Electric System

An electric drive system coupled to the powertrain or drive train of a hybrid electric vehicle. The purpose of the hybrid electric system is to add functionality to the vehicle that improves the efficiency of the vehicle. The hybrid electric system will consist of an electric machine, an energy storage system, and an electronic converter that controls the flow of electricity between the electric machine and energy storage system.

Hybrid Electric System

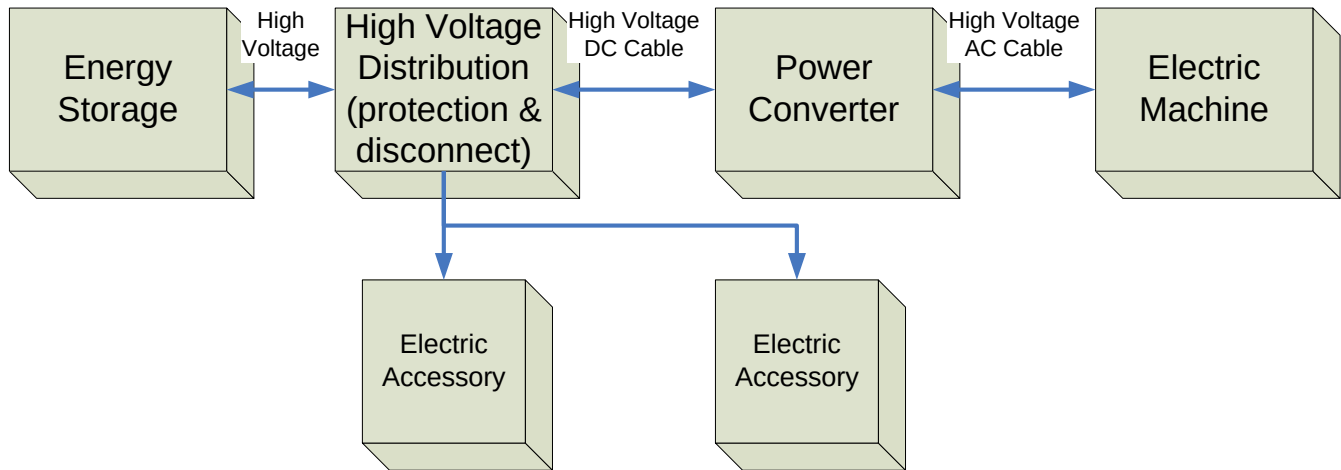


FIGURE 1 - BLOCK DIAGRAM OF TYPICAL HYBRID ELECTRIC DRIVE SYSTEM

3.1.3 Withstand Voltage, AC

An AC test voltage defined as two times the peak working AC voltage plus 1,000 VAC. Withstand Voltage is greater than or equal to $(2 \times \text{Peak Voltage} + 1000)$ VAC RMS

3.1.4 Chassis Ground

Those metal or conducting parts that are electrically connected to the frame of the vehicle and at the same potential as the frame and body structure of the vehicle.

3.1.5 Co-routed wires

Any wire that is routed in the same wire harness bundle as a high voltage wire.

3.1.6 De-energized

The state of the hybrid electric system in which the energy storage system has been disconnected and the external high voltage circuits have been discharged to a low voltage state.

3.1.7 Dielectric Strength

A measure of the ability of an insulation system to maintain separation between high voltage conductors and adjacent conducting components.

3.1.8 Direct Contact

The physical contact and electrical connection between a human and a wire or enclosure designed to conduct a potentially hazardous voltage.

3.1.9 Electrical Insulation

The materials that physically separate high voltage conductors to prevent transfer of electrical current or energy to other conductors and to prevent direct contact with humans.

3.1.10 Electrical Isolation

The measure of separation between high voltage conductors and their surroundings.

3.1.11 Energy Storage System

An array of electrochemical battery cells or electrostatic capacitors that can accept or store electrical energy for use by the hybrid electric system. The energy storage system will typically also contain electrical circuit protection, monitoring, and electrical disconnect functions.

3.1.12 External Area

The outer surface of the high voltage components that can be accessed without de-energizing the high voltage system.

3.1.13 High Voltage

A voltage potential greater than or equal to 60 VDC or 30 VAC RMS. Voltages exceeding this threshold are potentially hazardous to humans. The voltage potentials required to operate a hybrid electric motor commonly fall into the classification of high voltage.

3.1.14 High Voltage Conductor

A wire or circuit that by design will conduct electric current with a high voltage potential.

3.1.15 High Voltage Disconnect

A means or device to electrically break the circuit connection between the high voltage conductors contained within an electrically energized high voltage device and its external connectors.

3.1.16 High Voltage Systems

The entirety of electrical components and wires that are associated with circuits connected to the vehicles high voltage circuits. This includes energy storage, high voltage distribution, energy conversion, electric drive motor, and electric accessories.

3.1.17 High Voltage Distribution System

The electrical components and wires that interconnect high voltage sources and loads. This excludes the high voltage energy storage system.

3.1.18 Indirect Contact

The physical contact and electrical connection between a human and a wire or enclosure that is not intended to carry potentially hazardous voltage but is unintentionally conducting hazardous voltage.

3.1.19 Interlock

A circuit intended to automatically de-energize or disable high voltage in the event that any of the intended connections between components carrying high voltage are broken.

3.1.20 Low Voltage

A voltage potential less than 60VDC or 30VAC RMS.

3.1.21 Low Voltage Systems

Those electrical components and wires that operate with low voltage. These circuits are typically associated with functions connected to the vehicle's 12V or 24V battery or chassis ground.

3.1.22 Plug-In Hybrid

A hybrid electric vehicle that incorporates an electric plug intended for charging the vehicle's hybrid battery from a power source external to the vehicle. The energy received by the vehicle through this plug is used to provide motive power to the vehicle.

3.1.23 Potentially Hazardous Voltage

A voltage level that may harm humans through electric shock. Hazardous voltage levels are defined in the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; General Requirements, UL 2231 in Section 5 and in UL 2202 Electric Vehicle Charging Equipment in Section 6.

3.1.24 Withstand Voltage, DC

The withstand voltage based on UL and ISO standards is twice the peak voltage DC plus 1000VDC.

3.1.25 Working Voltage

The maximum RMS voltage developed during system operation.

3.2 Symbols

Labels should be posted on high voltage devices such as battery packs and power inverters to identify them as components conducting high voltage potential. The following labels are examples:

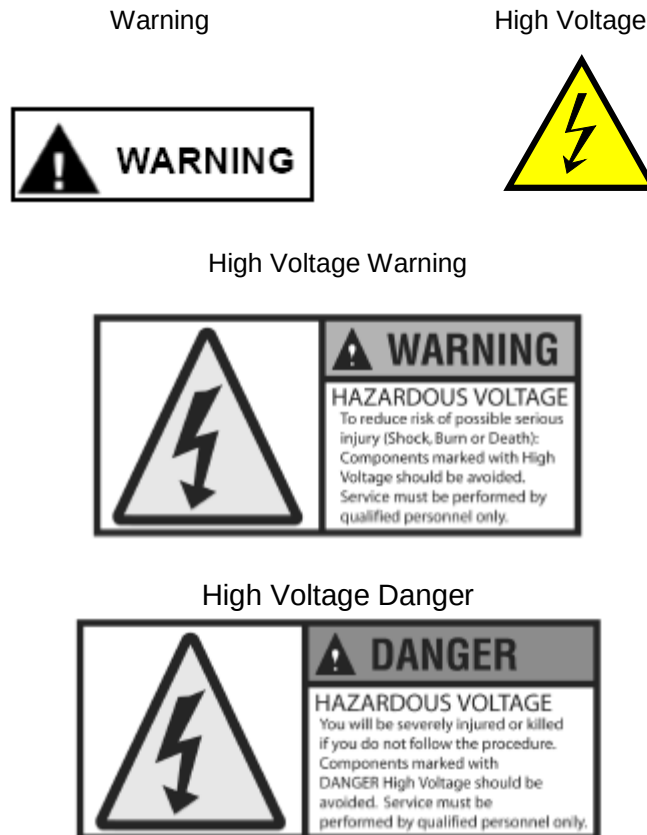


FIGURE 2 - EXAMPLES OF HIGH VOLTAGE WARNING SYMBOLS AND LABELS