SURFACE VEHICLE INFORMATION REPORT	J2344™	OCT2020
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(R) Guidelines for Electric Vehicle Safety

RATIONALE

SAE J2344 has been reaffirmed to comply with the SAE Five-Year Review policy.

FOREWORD

Vehicle safety is an important design element for all types of vehicles designed for use on public streets, roadways, and highways. Vehicles produced with liquid fuels have a long history of creating appropriate safety countermeasures. With the onset of new electric propulsion and charging systems, proposed for large scale production, new safety design parameters will need to be provided to vehicle developers. This SAE Information Report is an attempt to formalize a list of important safety items for vehicle developers. Automotive manufacturers, insurance companies, the repair industry, and first responders groups will need to work together to update this document as more data becomes available.

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SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit
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1. SCOPE

This SAE Information Report identifies and defines the preferred technical guidelines relating to safety for vehicles that contain High Voltage (HV), such as Electric Vehicles (EV), Hybrid Electric Vehicles (HEV), Plug-In Hybrid Electric Vehicle (PHEV), Fuel Cell Vehicles (FCV) and Plug-In Fuel Cell Vehicles (PFCV) during normal operation and charging, as applicable. Guidelines in this document do not necessarily address maintenance, repair, or assembly safety issues.

1.1 Purpose

The purpose of this SAE Information Report is to provide introductory safety guideline information that should be considered when designing electric vehicles for use on public roadways.

1.2 Field of Application

This document covers electric vehicles having a gross vehicle weight rating of 4536 kg (10 000 lb) or less that are designed for use on public roads.

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.

Applicable FMVSS standards and regulations shall supersede any SAE recommended practices as described in this document.

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.

SAE J1142 Towability Design Criteria and Equipment Use - Passenger Cars, Vans, and Light-Duty Trucks

SAE J1654 High Voltage Primary Cable

SAE J1673 High Voltage Automotive Wiring Assembly Design

SAE J1718 Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks During Battery Charging

SAE J1742 Connections for High Voltage On-Board Road 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 J1797 Recommended Practice for Packaging of Electric Vehicle Battery Modules

SAE J1798 Recommended Practice for Performance Rating of Electric Vehicle Battery Modules

SAE J2288 Life Cycle Testing of Electric Vehicle Battery Modules

SAE J2289 Electric-Drive Battery Pack System: Functional Guidelines

SAE J2380 Vibration Testing of Electric Vehicle Batteries

SAE J2464 Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing

SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety

SAE J2758 Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle

2.1.2 ANSI/IEEE Publications

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

ANSI/IEEE C62.41 Surge Voltages in Low-Voltage AC Power Circuits

ANSI/IEEE C62.45 Recommended Practice on Surge Testing for Equipment connected to Low-Voltage (1000 V and less) AC Power Circuits

2.1.3 FMVSS Publication

Available from the Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, DC 20402-9320.

FMVSS 305 Electric powered vehicles: electrolyte spillage and electrical shock protection

2.1.4 IEC Publications

Available from International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

IEC 60417 Graphical Symbols for use on Equipment

IEC 60479-1 Effects of current on human beings and livestock - Part 1: General aspects

IEC 60479-2 Effects of current passing through the human body - Part 2: Special aspects

2.1.5 ISO Publication

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

ISO 2575 Road vehicles - Symbols for controls, indicators and tell-tales

ISO 11451 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Vehicle Test Methods

2.1.6 UL Publications

Available from Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 991 Standard for Tests for Safety-Related Controls Employing Solid-State Devices

UL 1998 Standard for Safety-Related Software

UL 2202 Electric Vehicle Charging Equipment October 1996

UL 2231 Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: Part 1: General Requirements, July 1, 1996

UL 2251 Plugs, Receptacles, and Couplers for Electric Vehicles

UL 2279 Standard for Electrical Equipment for Use in Class I, Zone 0, 1, and 2 Hazardous (Classified) Locations

2.1.7 Other Publications

The following documents should be consulted for additional information regarding EV safety:

Applicable State and Local laws and regulations

FCC Rules and Regulations Parts 15 and 18

Canada's ICEs 002

European Union 72/245/EEC as amended by 95/54/EC

2.2 Related Publications

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

2.2.1 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.

SAE TSB 002 Preparation of SAE Technical Reports

SAE TSB 003 Rules for SAE Use of SI (Metric) Units

SAE J551-1 Performance Levels and Methods of Measurement of Electromagnetic Compatibility of Vehicles, Boats (up to 15 m), and Machines (16.6 Hz to 18 GHz)

SAE J551-2 Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles, Motorboats, and Spark-Ignited Engine-Driven Devices

SAE J551-4 Test Limits and Methods of Measurement of Radio Disturbance Characteristics of Vehicles and Devices, Broadband and Narrowband, 150 kHz to 1000 MHz

SAE J551-5 Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz to 30 MHz

SAE J551-11 Vehicle Electromagnetic Immunity - Off-Vehicle Source

SAE J551-12 Vehicle Electromagnetic Immunity - On-Board Transmitter Simulation

SAE J551-13 Vehicle Electromagnetic Immunity - Bulk Current Injection

SAE J1113-2 Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft) - Conducted Immunity, 30 Hz to 250 kHz - All Leads

SAE J1113-3 Conducted Immunity, 250 kHz to 400 MHz, Direct Injection of Radio Frequency (RF) Power

SAE J1113-4 Immunity to Radiated Electromagnetic Fields - Bulk Current Injection (BCI) Method

SAE J1113-11 Immunity to Conducted Transients on Power Leads

SAE J1113-12 Electrical Interference by Conduction and Coupling - Capacitive and Inductive Coupling via Lines Other than Supply Lines

SAE J1113-13 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 13: Immunity to Electrostatic Discharge

SAE J1113-21 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber

SAE J1113-24 Immunity to Radiated Electromagnetic Fields; 10 kHz to 200 MHz - Crawford TEM Cell and 10 kHz to 5 GHz - Wideband TEM Cell

SAE J1113-25 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Immunity to Radiated Electromagnetic Fields, 10 KHz to 1000 MHz - Tri-Plate Line Method

SAE J1113-26 Electromagnetic Compatibility Measurement Procedure for Vehicle Components - Immunity to AC Power Line Electric Fields

SAE J1113-41 Limits and Methods of Measurement of Radio Disturbance Characteristics of Components and Modules for the Protection of Receivers Used on Board Vehicles

SAE J1113-42 Electromagnetic Compatibility - Component Test Procedure - Part 42 - Conducted Transient Emissions

SAE J1115 Guidelines for Developing and Revising SAE Nomenclature and Definitions

SAE J1142 Towability Design Criteria and Equipment Use - Passenger Cars, Vans, and Light-Duty Trucks

SAE J1715 Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

SAE J1752-1 Electromagnetic Compatibility Measurement Procedures for Integrated Circuits - Integrated Circuit EMC Measurement Procedures - General and Definitions

SAE J1752-2 Measurement of Radiated Emissions from Integrated Circuits - Surface Scan Method (Loop Probe Method) 10 MHz to 3 GHz

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

SAE J2574 Fuel Cell Vehicle Terminology

Format Guidelines Manual for the Electronic Capture of SAE Ground Vehicle Documents

SAE Committee Guidelines Manual

2.2.2 CISPR Publications

Available from International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +41-22-919-02-11, www.iec.ch.

CISPR 12 Vehicles, motorboats and spark-ignited engine-driven devices - Radio disturbance characteristics - Limits and methods of measurement

CISPR 22 Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement

CISPR 25 Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles

2.2.3 ISO Publications

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

ISO/WD 6469-1 Electric road vehicles - Safety specifications - Part 1: On-board rechargeable energy storage system - RESS

ISO/WD 6469-2 Electric road vehicles - Safety specifications - Part 2: Vehicle operational safety means and protection against failures

ISO/WD 6469-3 Electric road vehicles - Safety specifications - Part 3: Protection of persons against electric shock

ISO 11451-1, 2001 Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 1: General and definitions

ISO 11451-2, 2001 Road vehicles - Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 2: Off-Vehicle radiation sources

ISO 11451-3, 1994 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Vehicle test methods - Part 3: On-Board transmitter simulation

ISO 11451-4, 1995 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Vehicle test methods - Part 4: Bulk current injection (BCI)

ISO 11452-1, 2001 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 1: General and definitions

ISO 11452-2, 1995 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods - Part 2: Absorber-Lined chamber

ISO 11452-3, 2001 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 3: Transverse electromagnetic (TEM) cell

ISO 11452-4, 2001 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 4: Bulk current injection (BCI)

ISO 11452-5, 1995 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods - Part 5: Stripline

ISO 11452-6, 1997 & Technical Corrigendum 1: 02-01-1999 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods - Part 6: Parallel plate antenna

ISO 11452-7, 1995 Road vehicles - Electrical disturbances by narrowband radiated electromagnetic energy - Component test methods - Part 7: Direct radio frequency (RF) power injection

2.2.4 Federal and Military Publications

The following documents should be consulted for additional information regarding Hybrid and Fuel Cell Vehicle safety control systems:

FCC Rules and Regulations Parts 15 and 18

CAN/CSA-C108.4M-1992, Limits and Methods of Measurement of Radio Interference Characteristics of Vehicles, Motor Boats, and Spark-Ignited Engine-Driven Devices

CSA Component Acceptance Service No. 33

ICES-002, Spark Ignition Systems of Vehicles and Other Devices Equipped with Internal Combustion Engines

MILSTD-1472B for Thermal Hazards

3. DEFINITIONS

3.1 FEDERAL MOTOR VEHICLE SAFETY STANDARD

Means a minimum standard for motor vehicle performance (written by the National Highway Traffic Safety Administration), or motor vehicle equipment performance, which is practicable, which meets the need for motor vehicle safety and which provides objective criteria.

3.2 HIGH VOLTAGE SOURCE

A High Voltage Source is either an electrical power-generating device or an energy storage device that produces voltage levels equal to or greater than 30 VAC (rms value) or 60 VDC.

3.3 MOTOR VEHICLE

Means any vehicle driven or drawn by mechanical power manufactured primarily for use on the public streets, roads, and highways.

3.4 MOTORING

Defined as the Key (power-enabling device) in the “on” position and that mode in which the transmission selector is in a forward or reverse drive position.

3.5 POTENTIALLY HAZARDOUS VOLTAGE

Means voltage levels that can harm humans through electric shock. Hazardous voltage levels are defined in the Outline of Investigation for Personnel Protection Systems for High Voltage (HV) Supply Circuits; General Requirements, UL 2231 July 1996 in Section 5 and in UL 2202 Electric Vehicle Charging Equipment October 1996 in Section 6. Systems which are 30 VAC or 60 VDC and above should be designed to protect against direct contact.

3.6 POTENTIALLY HAZARDOUS ENERGY

Means the capability for damage to property or injury to persons, other than by electric shock. Potentially hazardous energy is considered to exist, if between a live part and an adjacent dead metal part or between live parts of different polarity. Refer to SAE J1766 and UL 2202 for further definition on hazardous energy levels.

3.7 HAZARDOUS VOLTAGE INTERLOCK LOOP (HVIL)

Means a continuous electrical circuit which begins and ends in an automatic disconnect device and sends a small (non-hazardous) electric current through a loop, where hazardous voltage is present, to check for electrical continuity.

3.8 ELECTRICAL ISOLATION

Means the electrical resistance between the vehicle high-voltage system and any vehicle conductive structure.

3.9 RECHARGEABLE ENERGY STORAGE SYSTEM (RESS)

Any energy storage system that has the capability to be charged and discharged (example: batteries, capacitors, and electro mechanical flywheels).

3.10 DISCONNECT

Means a condition in which the HV source is deliberately disconnected from external circuitry, as for example by an automatic disconnect device. Such disconnect normally requires that both the positive and negative HV source leads be disconnected.

4. TECHNICAL SAFETY GUIDELINES

4.1 EV Crashworthiness

Crashworthiness guidelines for HV vehicles are contained in SAE J1766 and FMVSS 305.

4.2 Single-Point Failure

A single-point hardware/software failure or single failure of trained personnel to follow documented procedures should not result in an unreasonable safety risk to any person.

4.3 Electrical Safety

EV, HEV, PHEV, FCV & PFCVs typically contain potentially hazardous levels of electrical voltage or current. It is important to protect persons from exposure to this hazard. Under normal operating conditions, adequate electrical isolation is achieved through physical separation means such as the use of insulated wire, enclosures, or other barriers to direct contact. There are conditions or events that can occur outside normal operation that can cause this protection to be degraded. Some means should be provided to detect degraded isolation or loss of separation, so that action can be taken to mitigate the degradation. In addition, processes and/or hardware should be provided to allow for controlled access to the high-voltage system for maintenance or repair. A number of alternative means may be used to achieve these electrical safety goals, including Automatic Hazardous Voltage Disconnects, Manual Disconnects, Interlock System(s), Special Tools, and Grounding. The intention of all these means is either to prevent inadvertent contact with hazardous voltages or to prevent damage or injury from the uncontrolled release of electrical energy.

4.3.1 Electrical Isolation

Hazards of electric shock can occur when electric current depending on value and duration passes through the human body. Harmful effects of such body currents - flowing continuously - are prevented, if they do not exceed 10 mA DC or 2 mA AC respectively as shown in Figures 22 and 20 respectively of IEC 60479-1. These harmless body currents correspond to the minimum insulation resistance requirements of 100 or 500 Ω/V respectively. Isolation is measured from both the positive and negative high voltage bus relative to the vehicle conductive structure.

The isolation resistance when measured from any DC bus to the electrically-conductive chassis should be at least 100 Ω per volt (by itself) and when measured from any AC bus to the electrically-conductive chassis should be at least 500 Ω per volt (by itself). If the DC and AC are conductively connected in one circuit, there are two options: (1) Meet at least 500 Ω per volt for the combined circuit or (2) Meet at least 100 Ω per volt for the combined circuit and use the measures defined in SAE J2578 (additional barriers) for AC circuits.

NOTE: When AC and DC circuits are conductively connected, the more stringent isolation requirement of at least 500 Ω per volt should be met for the combined circuit unless direct contact with the AC circuits is prevented by additional measures in SAE J2578 such that isolation to at least 100 Ω per volt is acceptable.

4.3.2 High Voltage Withstand Capability

For design verification, each high voltage system should demonstrate adequate dielectric strength such that there is no indication of a dielectric breakdown or flashover after the application of a voltage. The focus of the test is to confirm that the harnesses, bus bars, and connectors have adequate margin for operating at high voltage. See SAE J2578, Appendix B for guidance in establishing test voltages and conducting the test. Tests may be conducted individually or as part of assemblies. The RESS and other equipment/circuits that could be damaged during assembly tests may be disconnected.

4.3.3 Automatic Hazardous Voltage Disconnects

An automatic hazardous voltage disconnect function provides a means of electrically separating hazardous voltage of the high voltage source from external circuitry or components without user intervention, based on some input triggering event. An automatic disconnect device should also provide a reset capability for restoring the traction voltage after the initiating condition has been cleared. Several types of events are commonly used as inputs to an automatic disconnect function.

4.3.3.1 Typical Automatic Disconnect Function Inputs

4.3.3.1.1 Vehicle Crash Sensor

Actuating an automatic disconnect that is contained within the High Voltage System, in the event of a crash may be an appropriate means for assuring what is required by SAE J1766 is maintained after a crash, provided that the automatic disconnect function is qualified to operate in the crash tests described in SAE J1766 and FMVSS 305.

4.3.3.1.2 Detected Loss of High Voltage Isolation (Ground Fault)

It is desirable to monitor the degree of electrical isolation between the high voltage systems and the vehicle conducting structures. Loss of such isolation is not in and of itself an unsafe condition; however, detection of a loss of isolation may be used to activate an automatic disconnect. If the vehicle is in operation when the loss of isolation is detected, the disconnect action should occur only in the non-motoring mode (e.g., Examples: Key (power-enabling device) off, key removed, or in Park).

4.3.3.1.3 Hazardous Voltage Interlock Loop (HVIL)

The general intent of the HVIL is to monitor the integrity of the high voltage system and prevent access while energized. In general, the HVIL circuit should cross user access panels, service disconnects, electrical connectors, etc that provide access to high voltage. The removal of any of these items should result in loss of HVIL continuity.

4.3.3.1.4 Overcurrent

In addition to other functions as described in the preceding sections, an automatic disconnect device may be used to perform either a primary or secondary/redundant overcurrent protection function. If some other device acts as the primary overcurrent protection means, it may also be desirable to actuate the automatic disconnect device in the event of an overcurrent condition, either to perform its disconnect function or to provide more accurate overcurrent protection.

4.3.3.2 Other Automatic Disconnect Function Guidelines

a. It is desirable for the automatic disconnect device to be located as close to the high voltage source output terminals as possible to minimize the external circuitry which is not de-energized when it actuates.

b. Reset of an automatic disconnect device should require a deliberate action of the operator. Reset should not expose the operator to hazardous voltages.

c. An automatic disconnect should, where practical, detect failures of its function (e.g., welded contacts) and provide an indication of such condition to a manufacturer-specified interface such that the driver or service personnel may be alerted to the existence of this condition.

d. An automatic disconnect should not require power to actuate (i.e., it should be normally open ("fail-safe") when in the unpowered state).

e. An automatic disconnect should actuate when any associated supply voltage(s) falls to a level below which the disconnect may not function properly.

f. An output signal may be needed from the automatic disconnect to permit de-energizing other power sources on the load side of the automatic disconnect.

4.3.4 Manual Disconnects

A Manual Disconnect can provide manually operated hazardous voltage electrical isolation for vehicle assembly, service, and maintenance operations. The following guidelines are provided for manual disconnects:

4.3.4.1 Suggested Disconnect Location and Type

A single-pole manual disconnect, if used, should be located as close as possible to the electrical center of the RESS. Alternatively, a single two-pole manual disconnect can be used to disconnect both the positive and negative terminals of the RESS. The use of multiple manual disconnects is not recommended.

4.3.4.2 Disconnect Function

Opening a manual disconnect should remove any voltage between positive and negative RESS output terminals.

4.3.4.3 Disconnect Operation

Removal of or opening the manual disconnect itself, should not require tools and should require a force that a person can easily provide. Manual disconnect devices should be electrically insulated to prevent personnel from inadvertently completing a conductive path.

4.3.5 Interlocks

4.3.5.1 Hazardous Voltage Bus Discharge

When high-voltage circuitry is disconnected from the high voltage source (e.g., when the hazardous voltage automatic disconnect or manual disconnect is opened), it may be necessary to discharge the capacitance of the hazardous voltage bus to a non-hazardous level. This is a manufacturer-specific choice depending on the voltage and energy present and the time required for voltage to decay (see UL 2202 for guidance).

4.3.5.2 Access Cover Interlocks

An interlock, or other means, may be provided on any cover whose removal provides direct access to exposed conductors with hazardous voltage. If a Hazardous Voltage Interlock Loop is used (see next section), such interlocks should be a part of this monitoring loop.

4.3.5.3 Hazardous Voltage Interlock Loop

A Hazardous Voltage Interlock Loop (HVIL) is a type of interlock system which typically uses a small (non-hazardous) signal through a loop connecting a set of conductors and connectors where hazardous voltage is present to check for electrical continuity. In the event of a loss of electrical continuity through the loop, for example due to opening a connector, the automatic disconnect device is opened to remove hazardous voltage from potentially exposed points. Methods other than a HVIL may be used to detect the loss of electrical continuity. The HVIL may also be routed through other vehicular devices at the vehicle manufacturer's option (e.g., a power-enabling switch or a "manual disconnect" which could be used as a lock out device for system maintenance operations).

4.3.5.4 Charge Interlocks

There should be no accessible contacts carrying hazardous voltage during or in connection with charging operations. The vehicle should be equipped with an interlock that will prevent application of drive power while the vehicle is still mechanically connected to the charging power source (refer to SAE J1772™ and SAE J1773).

4.3.6 Special Tools

In general, special tools should not be used as a substitute for fail-safe design features. However, they may be appropriate in some cases as a substitute for interlocks or automatic disconnects for restricting access to non-user-serviceable functions. Use of such tools should be coupled with appropriate safety handling procedures and/or labeling practices.

4.3.7 Grounding

If hazardous voltages are contained within a conductive exterior case or enclosure that may be exposed to human contact as installed in the vehicle, this case should be provided with a conductive connection to the vehicle chassis.

Rechargeable energy storage system components (i.e., batteries and ultracaps) and major power electronics components should have their external conductive cases connected directly to the vehicle conductive structure (chassis) by a ground strap, wire, welded connection or other suitable low-resistance mechanical connection. Case ground connectors routed from other components (as noted as follows) should be connected to this grounding means.

Other components which receive hazardous voltages from sources outside their conductive enclosures may have their cases grounded either directly as previously stated or indirectly through the wiring harness which carries the voltage(s) from the external source. The intent of this guideline is that disconnecting a wiring harness used to provide indirect case grounding should also disconnect the source of hazardous voltages.

4.3.8 High-Voltage Wiring Assemblies

It is recommended that high-voltage wiring assemblies for EVs should follow the guidelines established in both SAE J1654 and SAE J1673.

4.3.9 High Voltage Connectors

Connectors for high voltage components for HV vehicles should comply with the test methods and general performance requirements established in SAE J1742.

4.3.10 Fusing

Fuses are protective devices designed to interrupt the electrical circuit when subjected to excessive current. They are nonreversible and must be replaced after the circuit malfunction is corrected. They should not be used as personnel protection devices, since they do not respond sensitively enough to protect persons from injury due to contact with hazardous high voltage.

4.4 Fault Monitoring

The vehicle operator should be alerted to the existence of a propulsion system fault or condition that could lead to further damage to propulsion system hardware and should not be allowed to persist uncorrected. The following are instances of faults which might need to be indicated (as applicable to a particular design):

Loss of High Voltage System Isolation
Low State-of-Charge
Low Oil Pressure (analogous to Engine Oil Pressure)
Over Temperature, Temperature Fault, or Temperature Out-of-Range
Hazardous Voltage Fault
Failure of Contactor to Open When Commanded (Welded Contacts)

4.5 Hazardous Liquid Leakage

The rechargeable energy storage system shall not leak any hazardous liquids in any position during normal storage, shipment, assembly, driving, or charging. Post-crash leakage guidelines are provided in SAE J1766.

4.6 Hazardous Gas Leakage

Hydrogen gas accumulation, in HV battery packs should be limited to less than 2% of the total free volume of the battery pack as described in SAE J2289. For other vehicle compartments, outside the battery pack, it is recommended that the vehicle design preclude accumulation of hazardous gas beyond the same limit stated previously. Specific attention to placement of vent tube exhausts is required in order to assure the limits are met. Vehicle level testing for hydrogen gas emissions during charging is described in SAE J1718.

4.7 Vehicle Immersion

Total or partial immersion of an EV, HEV, PHEV or PFCV in water as specified by the vehicle manufacturer should not result in electric potential or current flow, gas or liquid emissions, or explosion that is hazardous to any person inside or outside the vehicle. Refer to SAE J2464 for immersion guidance.

4.8 Electromagnetic Compatibility (EMC) and Electrical Transient

All electrical assemblies on HV vehicles, which could affect safe operation of the vehicle, should be functionally tolerant of the electromagnetic environment to which the vehicle will be exposed. This includes fluctuating voltage and load conditions, which may occur during normal operation of the vehicle during driving and fueling. Also, electrical transients resulting from normal operation of the vehicle should not cause false shutdowns of the vehicle.

The vehicle should meet the applicable government regulatory requirements for EMC. See industry standards and guidelines in 2.2.1, 2.2.2, and 2.2.3.