SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J1766

REV. APR2005

Issued 1996-02
Revised 2005-04

Superseding J1766 JUN1998

(R) Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing

Foreword

This SAE Recommended Practice describes methods for evaluating the vehicle high voltage system performance when subjected to various FMVSS crash test procedures. It addresses battery retention, electrical isolation and electrolyte spillage. It is intended to provide Electric, Fuel Cell and Hybrid vehicle designers with recommended tests and performance criteria relating to Electric, Fuel Cell and Hybrid vehicles. Test personnel should exercise caution when conducting the procedures described in this document. Each testing organization is encouraged, upon experience, to send comments and suggested revisions to these procedures. Please send comments or suggestions to: Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001, attention: Fuel Cell Standards Committee.

TABLE OF CONTENTS

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE 100 Leading Our World In Motion

1. Scope

Electric, Fuel Cell and Hybrid vehicles may contain many types of high voltage systems. Adequate barriers between occupants and the high voltage systems are necessary to provide protection from potentially harmful electric current and materials within the high voltage system that can cause injury to occupants of the vehicle during a crash. This SAE Recommended Practice is applicable to all Electric, Fuel Cell and Hybrid vehicle designs that are comprised of at least one voltage bus with a nominal voltage greater than or equal to 60 Volts DC or 30 VAC. This Recommended Practice addresses electrical isolation integrity, electrolyte spillage, and retention of the battery system.

1.1 Purpose

The purpose of this document is to define test methods and performance criteria which evaluate high voltage system spillage, battery retention, and electrical system isolation in Electric, Fuel Cell and Hybrid vehicles during specified crash tests.

1.2 Field of Application

The vehicles covered in this document are Electric, Fuel Cell and Hybrid vehicles with a gross vehicle weight of 4536 kg (10 000 lb) or less and whose speed attainable in 1.6 km on a paved level surface is more than 40 km/h.

1.3 Product Classification

Not available.

1.4 Form

Not available.

1.5 Rationale

Time

Previous revisions of this document did not include a time limit in which the vehicle had to comply to the test procedure. The 5 second time frame was chosen as a reasonable system response time that also protects vehicle occupants and bystanders. UL 2202 Section 6.2, Stored Energy, references this time as the time to measure voltage across capacitors after energy has been removed.

Voltage

The addition of the voltage criteria in this document provides an alternative means of shock protection by discharging high voltage to non-harmful voltage levels.

Isolation

The change to allowable isolation of fuel cells is based on recognition that fuel cell stacks, unlike batteries, operate only as DC systems that are not charged or back-fed.

The allowable impedance for Electric Vehicles (EV) was based on the possibility that EVs may contain or be connected to utility power grids for the purpose of charging batteries. As such, the requirement for EVs was conservatively set to 500 ohms per volt based on safety characteristics of AC systems. Given that fuel cell hybrid vehicles will likely contain battery systems, power converters and motor controllers, and traction motors similar to the original EVs, changes to existing isolation requirements for high voltage AC (or potentially AC charged) systems are not necessary or appropriate; however, requirements for new DC systems in fuel cell vehicles need to be examined with regard to safety.

The selection of 100 ohms/volt as total impedance is consistent with international standards for electric vehicles and electrical equipment.

a. ISO 6469-3 (working group of TC22/SC21) indicates that the total allowable impedance to chassis from isolated loads is 100 ohms per volt for Evs and drafts of fuel cell electrical requirements.
b. IEC curves for allowable AC and DC both allow 100 ohms per volt.

Fuel cell vehicles have aqueous coolant in direct contact with the fuel cell active area. The conductivity of this coolant is a key factor in the isolation characteristics of a fuel cell. Coolant conductance increases with time which decreases isolation. It is expected that fuel cells will maintain an isolation of 125 ohms/volt with aged coolant. With the remaining high voltage system maintaining an isolation of 500 ohms/volt, the total high voltage system isolation shall not be less than 100 ohms/volt (1/125 ohms/volt + 1/500 ohms/volt = 1/100 ohms/volt).

It is assumed that the vehicle complies with these isolation criteria in normal operation.

Energy

Energy is based on voltage, current and the duration of the voltage-current flow. If energy, time and current are sufficiently low then voltage can be quite high and not result in a hazard. This is what occurs in a typical shock generated from static build up.

Using IEC 479-1 as a guide, a body current of 200 mA for 10 msec yields the lowest energy level that may produce a shock hazard. (Here a shock hazard is defined to be a body current / time duration that is in the DC-3 zone defined in IEC 479-1.) Assuming this minimum as an upper safety bound. Figure 1 below shows Current Duration versus Voltage at 200 mA for various energy levels. Using the target of 200 mA for less then 0.01 seconds as an upper safety bound, an energy of 0.4 J would satisfy the target values. A factor of two is included yielding the final energy limit of 0.2 J.

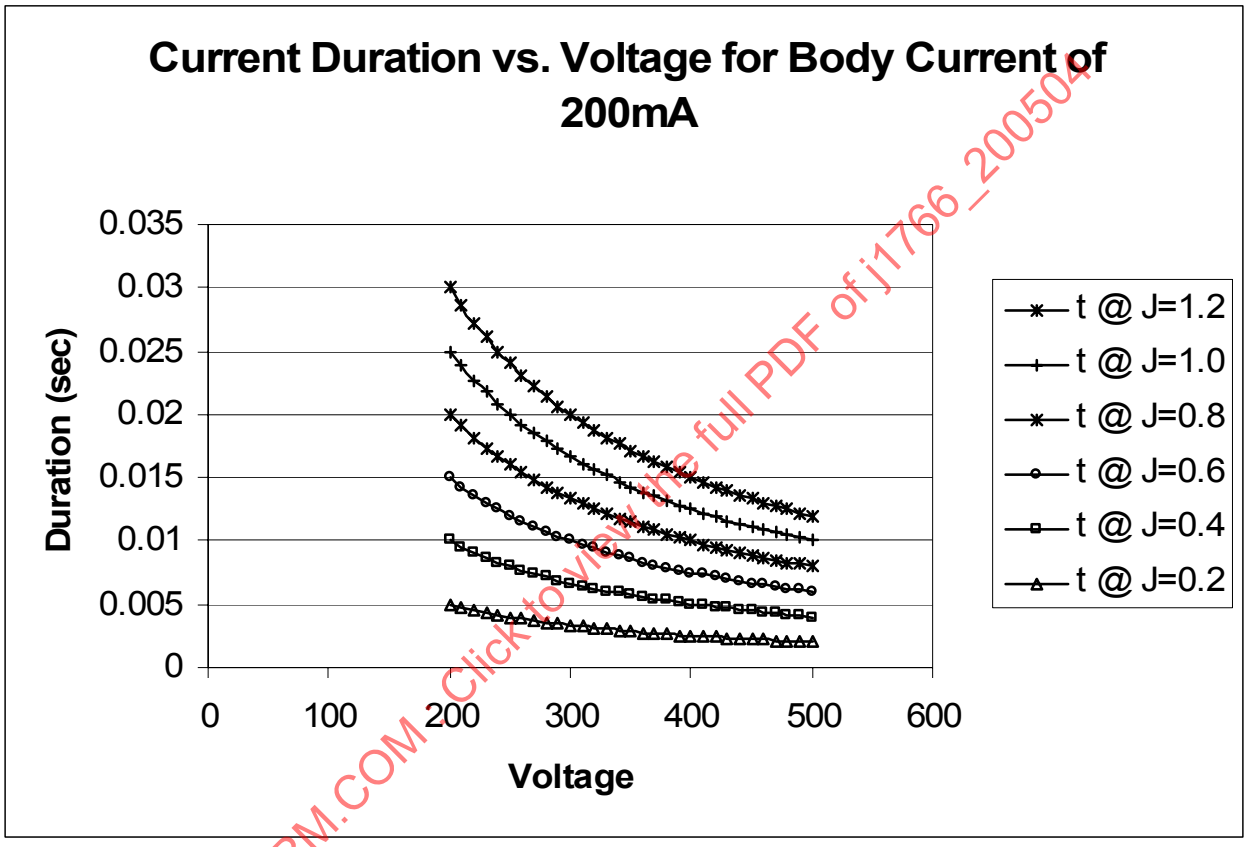

FIGURE 1

2. References

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. The latest issue of Federal Motor Vehicle Safety Standards or SAE publications shall apply.

Applicable FMVSS standards and regulations shall supersede any SAE Recommended Practices referenced in this document.

2.1.1 SAE PUBLICATIONS

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1715—Electric Vehicle Terminology
SAE J2344—Guidelines for Electric Vehicle Safety
SAE J2578—Recommend Practice for General Fuel Cell Vehicle Safety

2.1.2 FEDERAL MOTOR VEHICLE SAFETY STANDARDS

Code of Federal Regulations, Title 49, Part 500-599 which contains the current FMVSS regulations issued under Chapter V – National Highway Traffic Safety Administration—Available from Superintendent of Documents, Government Printing Office, Washington, DC 20408, Phone: 202-366-3238.

FMVSS Test Procedures

Available from Administration/Technical Reference Division, NHTSA, NAD-52, Phone: 202-366-4946.

FMVSS 571.208 Standard No. 208—Occupant Crash Protection
FMVSS 571.214 Standard No. 214—Side Impact Protection
FMVSS 571.301 Standard No. 301—Fuel System Integrity

2.2 Related Publications

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

2.2.1 SAE PUBLICATIONS

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE TSB 001—SAE Technical Standards Board Rules and Regulations
SAE TSB 002—SAE Preparation of SAE Technical Reports
SAE TSB 003—Rules for the SAE Use of SI (Metric) Units
SAE J1115—Guidelines for Developing and Revising SAE Nomenclature and Definitions
SAE J1772—Electric Vehicle Conductive Coupling
SAE J1773—Electric Vehicle Inductive Coupling
SAE J1797—Packaging of Electric Vehicle Battery Modules
SAE J1798—Electric Vehicle Battery Performance
SAE J2574—Fuel Cell Vehicle Terminology
SAE Report—Format Guidelines for Electronic Capture of SAE Documents
SAE Committee Guidelines Manual

2.2.2 OTHER PUBLICATIONS

UL 2202—Electric Vehicle (EV) Charging System Equipment

3. Definitions

The definitions provided in SAE J1715, shall apply to this document. The following definitions, which are not provided in SAE J1715, also apply:

3.1 Charging System

Means the device(s) and associated equipment necessary to properly recharge the high voltage energy storage system in an Electric or Hybrid vehicle from the electrical grid or ot her off board power source.

3.2 Continuously Monitored

Includes a digital sampling or analog measurement system that provides warning.

3.3 Energy Storage System Components

Means the components comprising, but not limited to, the high voltage battery system or capacitor system in an Electric or Hybrid vehicle. These include the battery or capacitor modules, interconnects, venting systems, battery or capacitor restraint devices, and energy storage box or container that holds the individual battery or capacitor modules.

3.4 Power Generation System Components

Means the components comprising the high voltage power generating system in an Electric, Fuel Cell or Hybrid vehicle. These include, but are not limited to, generators, fuel cell modules, DC/DC converters and interconnects.

3.4.1 Electrical Isolation

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

3.4.2 Disconnect

Means a condition in which a high voltage source is electrica lly separated from a high voltage bus, as for example by an automatic disconnect device. Such electrical separation normally requires that both the high voltage positive and return leads be disconnected.

3.4.3 High Voltage Bus Discharge

When high voltage sources are disconnected from a high voltage bus (e.g., when the high voltage automatic disconnect or manual disconnect is opened), it may be necessary to discharge the input capacitive energy of auxiliary high voltage loads. 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.)

3.4.4 High Voltage

For purposes of this document, voltage levels greater than 30 VAC or 60 VDC.

4. Technical Requirements

NOTE—During, before, and after functional Electric, Fuel Cell and Hybrid vehicle crash testing, appropriate safety precautions must be taken to prevent possible injury to test personnel. Safety hazard training should be given to test personnel before testing.

4.1 Electric, Fuel Cell and Hybrid Electric Vehicle Testing – Energy Storage Preparation

The energy storage system in the test vehicle shall be in an operational configuration.

4.1.1 POWER GENERATION AND ENERGY STORAGE COOLANT

For purposes of 4.4.1, battery, fuel cell and other coolant is not considered electrolyte. When necessary, a colorant, chemical analysis, or other means may be used to distinguish between electrolyte and coolant spillage.

4.1.2 ENERGY STORAGE SYSTEM STATE-OF-CHARGE

The energy storage system shall be fully charged prior to the crash test in accordance with the vehicle manufacturer's recommended charging procedures.

4.1.3 ENVIRONMENTAL PREPARATION

The environmental conditions shall be those specified in the relevant FMVSS test procedures.

4.2 Static Rollover Procedure

After each of the crash tests described in 4.3, the vehicle is statically rolled on a fixture according to the rollover procedure specified in FMVSS 301.

4.3 Crash Test Procedures

Electric, Fuel Cell and Hybrid vehicles shall meet the performance criteria established in 4.4 tested to the following crash procedures:

a. FMVSS 208 frontal impact (including the full frontal and 30 degree front angle impacts)
b. FMVSS 214 side impact
c. FMVSS 301 rear impact

4.4 Performance Criteria

4.4.1 ELECTROLYTE SPILLAGE

4.4.1.1 Spillage Identification

Before and after each of the test procedures in 4.2 and 4.3, the vehicle shall be inspected for electrolyte spillage. Verification of electrolyte may be determined by visual inspection, litmus paper testing, and/or chemical analysis of the fluid.

4.4.1.2 Electrolyte Spillage Inside the Occupant Compartment

No spillage of electrolyte is permitted into the occupant compartment when tested to the procedures specified in 4.2 and 4.3 of this document.

4.4.1.3 Electrolyte Spillage Outside the Occupant Compartment

When tested to any one of the crash tests specified in 4.3 and the subsequent vehicle rollover procedure specified in 4.2, the total electrolyte spillage from the vehicle shall not exceed 5.0 L. Total electrolyte spillage is determined from measurements taken from the time vehicle motion ceases after the crash test, during a 30-min period after vehicle motion ceases, and throughout the post-crash rollover test. This 5 L limit is intended to constrain electrolyte spillage only.

4.4.2 ENERGY STORAGE SYSTEM RETENTION

Energy storage devices must stay restrained to the vehicle throughout the test procedures described in 4.2 and 4.3. Intrusion of energy storage system components into the occupant compartment is not permitted before, during, or after any of the crash and rollover tests.

4.4.3 ELECTRICAL LIMITS

The vehicle shall meet one of the following voltage, isolation or energy criteria for each high voltage bus of the vehicle after coming to rest following the crash test. The manufacturer can choose the methodology (testing, simulation, or engineering analysis) to demonstrate this requirement is met.

4.4.3.1 Voltage

The voltage of the bus at each of the locations shown in Appendix A shall be less than or equal to 60 volts for DC buses or 30 volts for AC buses within 5 seconds of the vehicle coming to rest following the crash test.

4.4.3.2 Isolation

The isolation between any high voltage bus and the vehicle conducting structure after the crash shall meet one of the following criteria, as applicable.

It is understood that during a crash, electrical isolation may be lost momentarily provided that it is subsequently restored.

4.4.3.2.1 At least 500 Ohms/volt if the high voltage bus is;

- AC high voltage OR
- DC high voltage bus that can be connected to the electrical grid (e.g. for charging) OR
- Not continuously monitored during operation for electrical isolation.

4.4.3.2.2 At least 100 Ohms/volt if the high voltage bus is;

- DC high voltage AND
- DC high voltage bus that does not connect to the electrical grid or other off board AC electrical source AND
- Continuously monitored during operation for electrical isolation.

4.4.3.3 Energy

For vehicles with at least one high voltage bus, the energy limit after the specified crash tests as shown in Appendix A shall be less than 0.20 Joules within 5 seconds of the vehicle coming to rest following the crash test. This amount of energy would prevent exposure to hazardous body current.

Appendix A contains a flowchart and descriptive test procedure that may be used for evaluating an Electric, Fuel Cell or Hybrid vehicle to these electrical requirements. It is recognized that the procedure described in Appendix A is not the only acceptable means to determine compliance with the above electrical requirements.

For example, an alternative approach would be to use an isolation resistance tester before and after the specified crash tests to assess electrical isolation between the high voltage bus and vehicle chassis. The procedure specified in Appendix A is for reference purposes only, and is not intended to stipulate a required test procedure.

5. Notes

5.1 Marginal Indicia

The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE FUEL CELL STANDARDS SAFETY WORKING GROUP
OF THE SAE FUEL CELL STANDARDS COMMITTEE

APPENDIX A
MEASUREMENT OF ELECTRICAL ISOLATION

Introduction

This Appendix describes a test procedure that may be used to determine electrical voltage, isolation and energy levels between an Electric, Fuel Cell, and Hybrid vehicle high voltage systems and the vehicle conducting structure. Paragraph 4.4.3 stipulates minimum levels of electrical isolation. The following test procedure should be performed before and after each of the rollover and crash tests specified in 4.2 and 4.3.

Test Setup And Equipment

The high voltage system shall be charged in accordance with 4.1.2 to provide a voltage at or above the nominal operating voltage, as defined by the vehicle manufacturer.

The high voltage system shall be connected to the vehicle propulsion system, and the vehicle ignition shall be in the 'on' (high voltage system energized) position.

If contactors are used and the contactors are integral to the energy source / storage device (s), measurements are taken downstream of contactors.

If contactors are used and the contactors are not integral to the energy source / storage device (s), measure the voltage upstream of contactors.

The voltmeter used in this test shall measure DC values and have an internal resistance of at least 10 Million Ohms.

NOTE—Meter resistance is neglected in the calculation of Electrical Isolation in that which follows.

Test Procedure

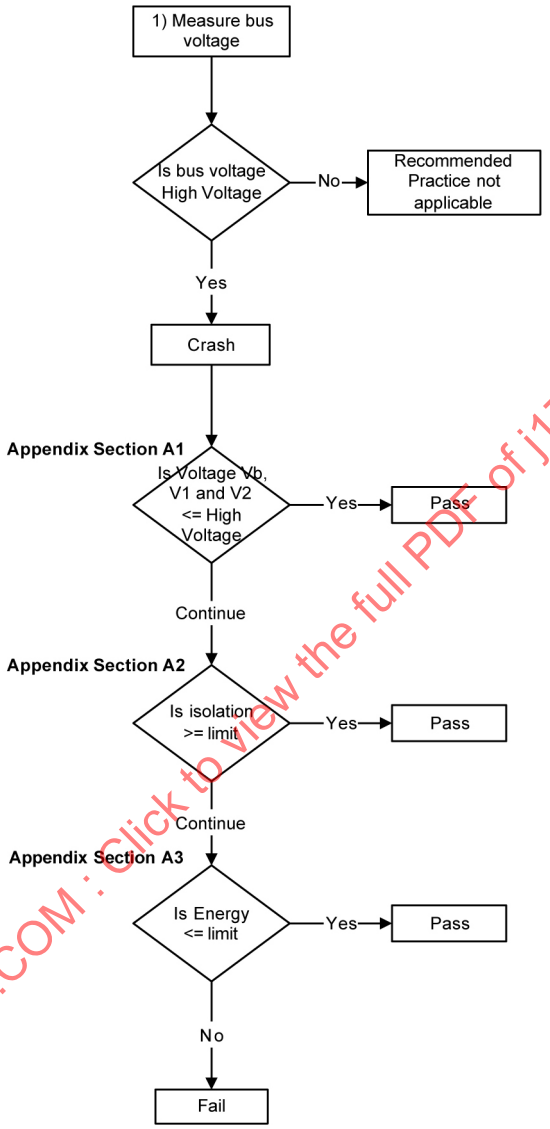

FIGURE A1

A.1 Bus Voltage

The following instructions may be used if voltage is measured.

Prior to the vehicle crash test measure and record the high voltage bus voltage (Vb) (see Figure A1.1). If Vb is high voltage, conduct a crash test from those specified in sections 4.2 and 4.3. After the vehicle crash test determine the high voltage bus voltages (Vb, V1, V2) (see Figure A1.1). If the Energy Storage Device Assembly is designed to be isolated with respect to vehicle chassis, measure the voltage V3 between any conductive portions of the assembly and vehicle chassis.

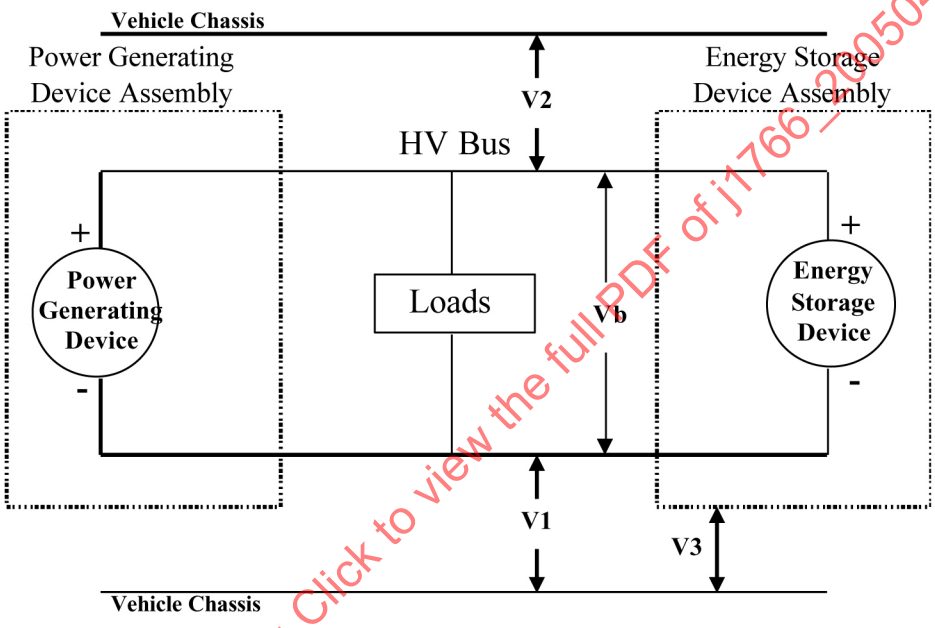

FIGURE A1.1—MEASUREMENT OF HIGH VOLTAGE BUS VOLTAGE

A.2 Isolation

The following instructions may be used if isolation is measured.

Before the vehicle crash test, measure and record the high voltage bus voltage (Vb) (see Figure A1.1). Vb must be equal to or greater than the nominal operating voltage as defined by the vehicle manufacturer. It is acceptable for vehicle manufacturer to elect to calculate, simulate this value instead of measuring this after the crash.

Measure and record the voltage (V1) between the negative side of the high voltage bus and the vehicle chassis (see Figure A2.1):