



SURFACE VEHICLE INFORMATION REPORT

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Hydrogen Vehicle Crash Test Lab Safety Guidelines

RATIONALE

There are special risks associated with the destructive testing of hydrogen fuel cell vehicles (FCVs), fuel cell hybrid vehicles (FCHVs), and fuel cell electric vehicles (FCEVs). This information report is intended to inform crash test personnel and facility managers of the risks, and some countermeasures to help mitigate the risks to lab personnel safety, the facility, and the equipment used in the testing. This report is not intended as a stand-alone procedure for FCV crash test safety, as the technology is still evolving and cannot be represented fully in this context.

INTRODUCTION

Current manufacturers have various FCVs in various stages of development. Many share obvious characteristics with their internal combustion cousins. Crashworthiness is certainly one of these, requiring that regardless of the power source, all passenger vehicles must demonstrate compliance with manufacturer driven performance standards, government regulated crash test programs, and certain vehicle safety rating programs which provide information to potential buyers about the crash performance of the vehicle and other features related to safety.

FCVs have shown significant growth in development over recent years. The current administration has promoted the increase of E-vehicles on U.S. roadways as a means to reduce greenhouse emissions, and decrease the nation's dependence on foreign oil. Significant federal and corporate funding has been provided to help support lithium-ion (li-ion) battery research, establish infrastructure, and incentivize vehicle purchases. Parallel to these efforts, there is work ongoing to understand special risks to the general population, emergency responders, and automobile repair centers associated with the li-ion battery systems in these vehicles following roadway collision events. FCV development has expanded on just the battery technology to include hydrogen fuel with only water as an emission.

This SAE Information Report addresses the special risks associated with FCV collisions in the lab, which must be conducted not only on the final product as a means of certification or rating, but also throughout the development phase of the vehicle. The hazards associated with running crash tests on internal combustion vehicles (ICVs) is well understood and managed safely using established test protocol which requires testing to be conducted with surrogate, less flammable fuel in the vehicle.

As stated in the scope of this report, the unique risks associated with conducting crash tests on FCVs can be divided into three main categories: (1) failure of high pressure components and/or pressure vessels leading to explosion and/or rapid oxygen deprivation of the test area; (2) thermal activity inside the battery (resulting from electrical or mechanical abuse) may lead to energetic emission of harmful and/or flammable gases, thermal runaway, and potentially fire; and (3) the risk of electrocution. Specific measures to ensure protection to test personnel from all types of risk must be integrated into the entire test process from the point the vehicle arrives at the test facility up to the time it is hauled away. At this point in time, relatively mature procedures exist to protect against electrocution, utilizing personal protective equipment (PPE) rated for high voltage safety, and careful electrical measurements to ensure safe conditions when handling the vehicle both pre and post-crash. These procedures are described in detail in this report.

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Documents

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Current U.S. regulations require vehicle crash tests, when conducted for the purpose of certification, be run with fully operational and fully charged battery systems and fully filled pressure vessels. The level of risk assumed by the crash test lab is determined by the degree to which a specific li-ion battery system is susceptible to failure during mechanical abuse (shock, puncture, crush), or electrical abuse (internal or external short circuit), experienced during each type of test. As battery system design/technology advances, the level of risk will likely also be affected. The same is true for the high pressure components in the fuel system.

In summary, there is some level of risk that every facility will assume in conducting these tests, so each lab must establish its own safety procedures and determine its own risk tolerance. More data will help make decisions that can mitigate risks to personnel and reduce the chance of additional loss in the event of a total system failure

1. SCOPE

The scope of this document is to provide an overview of the risks and protective precautions to ensure safe and effective testing procedures for the test personnel and the vehicle during the testing of a hydrogen fuel cell vehicle. The main risks associated with a hydrogen fuel cell vehicle are the fuel cell stack, hydrogen storage vessel, fuel cell system components and the high voltage battery. Risks could be summarized from the battery into thermal runaway possibly leading to fire or explosion, electrolyte spillage and electrical shock or electrocution. The hydrogen fuel cell system risks include electrical shock or electrocution and possible release of hydrogen gas (if tested with). Vehicle crash testing protection should be coordinated with the system or component manufacturer(s) suggestions. Precautions should be taken with the handling, transportation, and storage of the vehicle pre-crash and post-crash. This document was written to provide an understanding of the risks and precautions and should be reviewed periodically to ensure conformance to new technological developments.

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 +1 724-776-4970 (outside USA), www.sae.org.

SAE J2578	Recommended Practice for General Fuel Cell Vehicle Safety
SAE J2579	Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles
SAE J2600	Compressed Hydrogen Surface Vehicle Fueling Connection Devices
SAE J2601	Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
SAE J2719	Hydrogen Fuel Quality for Fuel Cell Vehicles
SAE J2760	Pressure Terminology Used in Fuel Cells and Other Hydrogen Vehicle Applications
SAE J2799	Hydrogen Surface Vehicle to Station Communications Hardware and Software
2014-01-1990	Validation and Sensitivity Studies for SAE J2601, the Light Duty Vehicle Hydrogen Fueling Standard
2005-01-0002	Gaseous Hydrogen Station Test Apparatus: Verification of Hydrogen Dispenser Performance Utilizing Vehicle Representative Test Cylinders

2.1.2 ISO Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ISO 19880-1 Gaseous Hydrogen - Fueling Stations - Part 1: General Requirements

2.1.3 Other Publications

Flamberg S. et al., "Analysis of Published Hydrogen Vehicle Safety Research," DOT HS 811 267, SAE J2617 Testing performance of PEM Fuel Cell.

Global Technical Regulations (GTR) for Fuel Cell Vehicles; working part 29 United Nations.

Stephens, D. et al., "Failure Modes and Effects Analysis for Hydrogen Fuel Cell Vehicles - Subtask 1," DOT HS 811 075, 2009.

Hennessey, B. and Nguyen, N., "Status of NHTSA'S Hydrogen and Fuel Cell Vehicle Safety Research Program", ESV 09-0507.

3. DEFINITIONS

FCV	Hydrogen Fuel Cell Vehicle
MSDS	Material Safety Data Sheet
BMS	Battery Management System
SOC	State of Charge
PEM	Proton Exchange Membrane
PPE	Personal Protective Equipment

4. MITIGATION OF ELECTRICAL SHOCK RISK (ELECTROCUTION)

4.1 General

It is recommended that any personnel working with a HV system in a vehicle should have basic HV training on E-vehicle systems such as the "SAE Basic Hybrid and Electrical Vehicle Safety" class. Knowledge regarding PPE and internal safety procedures in a HV setting is vital in protecting yourself and your facility. Key laboratory personnel should be advised by the OEM or HV battery final assembler regarding their specific battery so that knowledge is transferred to the test facility. This will be discussed in detail below.

4.2 Personal Protective Equipment (PPE)

PPE for electrical hazards is required when working with a HV system. The work should be done in view of other laboratory personnel. Recommended safety equipment includes, but is not limited to:

- Class 0 HV gloves with protectors. These gloves should be replaced periodically (CFR 29 part 1910.137 requires rubber insulating gloves to be electrically tested on an interval of 6 months) and should undergo a visual inspection and glove pressure test before each use.
- Face shield.
- HV rescue hooks.
- Electrical shock-resistant footwear.

- Self-contained breathing apparatus (SCBA).
- Protective coverall.
- Gas detection warning device—flammable hydrocarbons, carbon dioxide (CO₂), carbon monoxide (CO), hydrogen (H₂), fluoro-organics, and hydrogen fluoride (HF).

Digital multi-meter, such as Fluke Model 87 V. The multi-meter should be specifically designed for high voltage and designated it is capable of high voltage measurements. Use the digital multi-meter to verify the absence or presence of voltage for the high voltage system. For proper process and measuring methods of V1, V2, and Vb, refer to the latest version of 49 CFR 571.305 - Standard No. 305. Verify the accuracy of the multi-meter before and after each test.

Table 1 - Reference table for applicable PPE standards

Standard ID	Similar Standard	Explanation	Equipment
ASTM F1506		Flame-resistant garment labeled with an arc energy rating, ATPV.	Coverall
ASTM F1956	IEC 61482-1-2	Protective clothing against the thermal hazards of an electric arc.	Coverall
EN 1149		Electrostatic properties	Jacket, pants
EN 13034 type 6		Garments that provide a limited protection against liquid chemicals.	Jacket, pants
EN 136		Respiratory protective devices—full face masks.	Respiratory protection
EN 140		Respiratory protective devices—half masks and quarter masks.	Respiratory protection
EN 14387		Respiratory protective devices. Gas filter(s) and combined filter.	Respiratory protection
EN 166		Eye and face protection.	Eye protection, e.g., glasses, visor/screen guard
EN 170		UV protection.	Eye protection, e.g., glasses, visor/screen guard
EN 470-1	ISO 11611	Protective clothing for use in welding and allied processes. General requirements.	Jacket
EN 471		High-visibility warning clothing.	Jacket, pants
EN 531	ISO 11612	Protective clothing for workers exposed to heat.	Jacket, pants, base- and mid-layer clothing
EN ISO 15090 HI3 F2A P.T.Cl		Fire shoes. Suitable for fire rescue, fire suppression . General Type 2 requirements + antistatic properties.	Boots
EN ISO 17249		Safety footwear with resistance to chain saw cutting.	Boots
EN ISO 20345 S5 HRO SB		Safety footwear standards. A + FO + E + P + waterproof. Resistance to hot contact of outsole. Toe protection.	Boots
ENV 50354	IEC 61482-1-2	Protection against electric arc. Electrical arc test methods for material and garments, for use by workers at risk from exposure to an electrical arc.	Bas- and mid-layer clothing
IEC 61482-1-2	ENV 50354	Protective clothing against the thermal hazards of an electric arc.	Jacket, pants, coverall
IEC-60903		Electrical insulating gloves.	Gloves
ISO 11611	EN 470	Protective clothing for use in welding and allied processes. General requirements.	
ISO 11612	EN 531	Protective clothing for workers exposed to heat.	