SURFACE VEHICLE INFORMATION REPORT

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Electric Vehicle (E-Vehicle) Crash Test Lab Safety Guidelines

RATIONALE

This document has been updated to address the need for using gloves to prevent shock. Other changes were to update the document to the current SAE format.

INTRODUCTION

Current E-vehicles in production and in various stages of development share many 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.

The electric vehicle is certainly not a new concept, but it has shown significant growth in development, production, and sales over recent years. The current administration has promoted the increase of E-vehicles on U.S. roadways as a means to promote further development of this technology, 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.

This SAE Information Report addresses the special risks associated with E-vehicle 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. Some special risks are associated with pressurized tanks in natural gas, propane, and hydrogen vehicles, but these are outside the scope of this report.

As stated in the scope of this report, the unique risks associated with conducting crash tests on E-vehicles can be divided into two main categories: (1) 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 (2) 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.

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. 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.

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 special risks associated with conducting crash tests on E-vehicles can be divided into two main categories: (1) 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 (2) the risk of electrocution. Procedures to ensure protection from all types of risk must be integrated into the entire crash test process. This SAE Information Report is intended to provide guidance in this endeavor using current best practices at the time of this publication. As both battery technology and battery management system technology are in a phase of expansion, the contents of this report must then be gaged against current technology of the time and updated periodically to retain its applicability and usefulness.

The scope of this document is to provide an understanding of the risks and an overview of the techniques established to reduce the likelihood that an event would cause harm to laboratory personnel and/or property. A laboratory considering E-vehicle crash testing should work closely with the E-vehicle manufacturer to identify and understand the risks associated with shipping and handling of their vehicle (pre- and post-crash), storage of the vehicle (pre- and post-crash), battery system diagnostics procedures, and operation of the vehicle.

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 Publication

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 J1715/2 Battery Terminology

2.1.2 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

FMVSS 305 Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

TP 305 Laboratory Test Procedure for FMVSS 305, Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

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 Other Publications

Arora, P. and Zhang, Z. “Battery Separators.” Chem. Rev., 2004, 104, 4419-4462.

Hammami, A., Raymond, N., and Armand, M. “Runaway Risk of Forming Toxic Compounds.” Nature Publishing Group, 2003, 424, 635-636.

Long, T.R. Jr., Sutula, J.A., and Kahn, M.J. “Li-Ion Batteries Hazard and Use Assessment Phase IIB: Flammability Characterization of Li-Ion Batteries for Storage Protection.” Exponent, Inc. The Fire Protection Research Foundation, April 2013.

Sturk, D., Hoffmann, L., and Tidblad, A.A. “Fire Tests on E-Vehicle Battery Cells and Packs.” Traffic Injury Prevention. doi:10.1080/15389588.2015.1015117.

Wang, Q., Sun, J., Yao, X., and Chen, C., “Micro Calorimeter Study on the Thermal Stability of Lithium-Ion Battery Electrolytes.” Journal of Loss Prevention in the Process Industries, 19, 2006, 561-569.

Wech, L., Richter, R., Rainerr, J. and Schoneburg, R. “Crash Safety Aspects of HV Batteries for Vehicles.” 22nd ESV Conference, 2011-0302.

Wilken, S., Treskow, M., Scheers, J., Johansson, P., and Jacobsson, P. “Initial Stages of Thermal Decomposition of $LiPF_6$-Based Lithium Ion Battery Electrolytes by Detailed Raman and NMR Spectroscopy.” RSC Advances, 2013.

Yang, H., Amiruddin, S., Bang, H.J., Sun, Y.K., and Prakas, J. “A Review of Li-Ion Cell Chemisitries and Their Potential Use in Hybrid Electric Vehicles.” J. Ind. Eng. Chem., Vol. 12, No. 1, 2006, 12-38.

Yang, H., Zhuang, G.V., and Ross, P.N. Jr. “Thermal Stability of $LiPF_6$ Salt and Li-Ion Battery Electrolytes Containing $LiPF_6$.” Journal of Power sources, 161, 2006, 573-579.

3. DEFINITIONS

3.1 BMS

Battery management system.

3.2 E-VEHICLE

A vehicle with an electrified drivetrain, such as EVs, HEVs, and PHEVs.

3.3 EV

Electric vehicle.

3.4 HV

High voltage.

3.5 HEV

Hybrid electric vehicle.

3.6 INERT BATTERY

A battery that has the same physical properties as an HV battery pack (dimensions, stiffness, weight), but with no active chemistry (no electrical or thermal risk).

3.7 LI-ION

Lithium-ion battery.