



SURFACE VEHICLE TECHNICAL INFORMATION REPORT

J3219™

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Hydrogen Fuel Quality Screening Test of Chemicals for Fuel Cell Vehicles

RATIONALE

This SAE Technical Information Report (TIR) complements the implementation of SAE J2719.

A key issue identified during the implementation of SAE J2719 standard involves contamination of hydrogen refueling stations (HRS) during their operation and maintenance. The contamination is due to common chemicals used during HRS operation that include refrigerants, lubricants, etc., and during HRS maintenance that include solvents cleaning agents, lubricants, etc.

This document provides common testing methods to evaluate the performance drop after exposure to the chemical.

Please send comments or suggestions to:

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1. SCOPE

The outcome of this TIR is to establish proton exchange membrane (PEM) testing methods and characterization of chemicals used in HRS, during operation and maintenance that can influence the performance of commercial PEM fuel cell vehicles.

Hydrogen quality standards such as SAE J2719 provide list of contaminants with maximum impurity levels that ensure safe operation of fuel cell vehicles. These contaminants are primarily from the hydrogen production. Less attention in these quality standards were given to the contaminants generated from the installation, operation and maintenance of HRS. Common chemicals used during HRS operation are refrigerants, lubricants, etc., and during HRS installation and maintenance are solvents cleaning agents, lubricants, etc. Some of these chemicals are found to have adverse impacts on PEM fuel cells.

The development of testing methods and characterization of chemicals in this report are based on similar methods used in SAE J2719 although the approach in this TIR is a direct evaluation of the chemical rather than specifying the contaminant level. These methods consider fuel cell performance characteristics for each chemical tested and the impacts of functional groups on PEM fuel cells. Adverse impact of contaminants on fuel cells are associated with performance drop after exposure to the chemical.

1.1 Purpose

The purpose of this document is to provide guidance to the industry meeting the H₂ quality standard because of lack of testing methods to characterize the adverse impacts of chemicals used during operation and maintenance in HRS.

SAE J3219 provides uniform testing methods to characterize chemicals considered in HRS during operation and maintenance.

1.2 Field of Application

The testing methods apply to products used in HRS during their operation and maintenance.

The approach of this TIR is to screen chemicals using the test method as a one-time evaluation to confirm that the chemical is fuel cell compatible. This HRS developer should only need to test the chemical once or ask their supplier to test the chemical according to this TIR.

1.3 Rationale

Optimal performance and durability of fuel cell (FC) systems rely heavily on the purity of the hydrogen fuel in the anode feed stream. Non-hydrogen constituents can cause deleterious impacts on the performance of the stack during operation. There are several ways for fuel impurities to enter into the stack from along the fuel production chain, mostly appearing in either gas or liquid phase. A significant amount of effort has been placed on the fuel quality of the hydrogen produced by processes such as steam methane reforming (SMR) and autothermal reforming (ATR); but little attention has been given to the cleaning agents that are used in routine maintenance of HRSs as a potential source of contamination at the anode as provided in 2.2.2.33. Previous tests were completed by injecting the cleansers at the cathode and hence they were exposed to a higher potential. The anode has a much lower potential and as a result the cleansers' behavior is expected to be different. Also, compressors in the hydrogen supply chain that utilize lubricants for operation can also be a potential source of impurities. The aforementioned hydrogen fuel quality efforts have led to the development of hydrogen fuel specifications for road vehicles that utilize PEM stacks SAE J2719 and ISO 14687-2.

During the creation of SAE J2719 the list of contaminants included in the standard were primarily based on the hydrogen production sources. Less attention was given to the contaminants generated from the operation and maintenance of HRS. Thus, a key issue identified during the implementation of SAE J2719 standard involves contamination of HRS during their operation and maintenance.

Contaminants can be introduced to the H₂ fuel supplied at the nozzle from oils and lubricants used in H₂ station components (compressor, refrigeration, etc.) and maintenance practices at the HRS. The contamination is due to common chemicals used during HRS operation that include refrigerants, lubricants, etc., and during HRS maintenance that include solvents cleaning agents, lubricants, etc. A detailed reference list is provided below.

Review of field data from several HRS around the world indicate fuel contamination associated with station operation and maintenance. Some of these chemicals are found to degrade PEM fuel cells. As a result, the housekeeping of HRS is an issue that needs to be addressed by the industry.

Currently, H₂ Quality Standards provide a good start to protect fuel cells from performance degradation. However, there are concerns that despite meeting the H₂ quality standard, fuel cells could show degradation of their performance due to contamination from HRS operation and maintenance. In such circumstances, there is no guidance to the station or to the industry on how to address such issues.

The industry recognizes the importance of the issues associated with housekeeping at HRS and has a growing interest in establishing methods for PEMFC testing and characterization in the presence of common chemicals that are used in routine maintenance and operations at HRSs. The chemicals typically used during maintenance are solvent-based cleaning agents and lubricants. Below we describe how to introduce contaminants into an operating FC, examine its performance (before, during, and after exposure), and perform diagnostics in order to probe for adverse impacts. The goal here is to develop a harmonized protocol for screen testing in order to bring to attention alternate sources of H₂ contaminants (outside of the standard H₂ production, delivery, and storage techniques).

This document provides common testing methods and acceptance criteria for chemicals used during operation and maintenance in HRS. The purpose of developing common testing methods is to evaluate performance drop of PEM fuel cells after exposure to the chemical. The aim of developing this uniform testing method is to evaluate the amount of irreversible losses of a PEMFC. The amount of irreversible losses for a non-contaminated membrane electrode assembly (MEA) should be understood over the same testing duration that would also be used for a contaminated MEA.

2. REFERENCES

2.1 Applicable Publications

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.

2.1.1.1 SAE J2719, Hydrogen Fuel Quality for Fuel Cell Vehicles

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 ISO Publications

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

2.2.1.1 Grade D of ISO 14687

2.2.2 Other Publications

2.2.2.1 G. Bender, M. Angelo, K. Bethune, S. Dorn, T. Thampan, R. Rocheleau, Method Using Gas Chromatography to Determine the Molar Flow Balance for Proton Exchange Membrane Fuel Cells Exposed to Impurities, *J. Power Sources*, **193** (2009) 713.

2.2.2.2 X. Wang, J. Qi, O. Ozdemir, A. Uddin, U. Pasaogullari, L. J. Bonville, T. Molter, Ca²⁺ as an Air Impurity in Polymer Electrolyte Membrane Fuel Cells, *J. Electrochem. Soc.*, **161** (2014) F1006.

- 2.2.2.3 J. St-Pierre, Y. Zhai, M. S. Angelo, Effect of Selected Airborne Contaminants on PEMFC Performance, *J. Electrochem. Soc.*, **161** (2014) F280 and **162** (2015) X7.
- 2.2.2.4 *Single Cell Test Protocol*, document 05-014B.2, United States Fuel Cell Council, Washington DC (2006).
- 2.2.2.5 J. Zhang, B. A. Litteer, F. D. Coms, R. Makharia, Recoverable Performance Loss Due to Membrane Chemical Degradation in PEM Fuel Cells, *J. Electrochem. Soc.*, **159** (2012) F287.
- 2.2.2.6 A. J. Spears, T. Rockward, R. Mukundan, F. Garzon, Investigation of Membrane Chemical Degradation as a Function of Catalyst Platinum Loading, *J. Electrochem. Soc.*, **168** (2021) 064503.
- 2.2.2.7 M. O. Ozdemir, Investigation and Mitigation of Anode and Cathode Impurities to Improve Polymer Electrolyte Fuel Cell Performance, doctoral dissertation 1561, University of Connecticut (2017).
- 2.2.2.8 M. A. Uddin, X. Wang, J. Qi, M. O. Ozdemir, U. Pasaogullari, L. Bonville, T. Molter, Effect of Chloride on PEFCs in Presence of Various Cations, *J. Electrochem. Soc.*, **162** (2015) F373.
- 2.2.2.9 J. Qi, X. Wang, M. O. Ozdemir, M. A. Uddin, L. Bonville, U. Pasaogullari, T. Molter, Effect of Cationic Contaminants on Polymer Electrolyte Fuel Cell Performance, *J. Power Sources*, **286** (2015) 18.
- 2.2.2.10 J. Park, M. A. Uddin, U. Pasaogullari, L. Bonville, Changes in the Wettability of Polymer Electrolyte Fuel Cells Components during Cationic Contamination and Mitigation, *Int. J. Hydrogen Energy*, **42** (2017) 21146.
- 2.2.2.11 M. A. Uddin, X. Wang, J. Park, U. Pasaogullari, L. Bonville, Distributed Effects of Calcium Ion Contaminant on Polymer Electrolyte Fuel Cell Performance, *J. Power Sources*, **296** (2015) 64.
- 2.2.2.12 C. J. Banas, L. Bonville, U. Pasaogullari, Linking Foreign Cationic Contamination of PEM Fuel Cells to the Local Water Distribution, *J. Electrochem. Soc.*, **164** (2017) F1100.
- 2.2.2.13 M. A. Uddin, J. Qi, X. Wang, U. Pasaogullari, L. Bonville, Distributed Cation Contamination from Cathode to Anode Direction in Polymer Electrolyte Fuel Cells, *Int. J. Hydrogen Energy*, **40** (2015) 13099.
- 2.2.2.14 J. St-Pierre, Y. Zhai, M. Angelo, Quantitative Ranking Criteria for PEMFC Contaminants, *Int. J. Hydrogen Energy*, **37** (2012) 678.
- 2.2.2.15 Y. Zhai, J. St-Pierre, Proton Exchange Membrane Fuel Cell Cathode Contamination - Acetylene, *J. Power Sources*, **279** (2015) 165.
- 2.2.2.16 Y. Zhai, O. Baturina, D. Ramaker, E. Farquhar, J. St-Pierre, K. Swider-Lyons, Chlorobenzene Poisoning and Recovery of Platinum-Based Cathodes in Proton Exchange Membrane Fuel Cells, *J. Phys. Chem. C*, **119** (2015) 20328.
- 2.2.2.17 J. St-Pierre, M. B. V. Virji, Cell Performance Distribution in a Low-Temperature Proton Exchange Membrane Fuel Cell Stack during Propene Contamination, *J. Appl. Electrochem.*, **46** (2016) 169.
- 2.2.2.18 J. St-Pierre, Y. Zhai, J. Ge, Relationships between PEMFC Cathode Kinetic Losses and Contaminants' Dipole Moment and Adsorption Energy on Pt, *J. Electrochem. Soc.*, **163** (2016) F247.
- 2.2.2.19 Y. Zhai, J. Ge, J. St-Pierre, The Ionic Conductivity and Catalyst Activity Effects of Acetonitrile on Proton Exchange Membrane Fuel Cells, *Electrochem. Commun.*, **66** (2016) 49.
- 2.2.2.20 Y. Zhai, O. Baturina, D. Ramaker, E. Farquhar, J. St-Pierre, K. Swider-Lyons, Bromomethane Contamination in the Cathode of Proton Exchange Membrane Fuel Cells, *Electrochim. Acta*, **213** (2016) 482.
- 2.2.2.21 Y. Zhai, J. St-Pierre, Acetylene Contamination Mechanisms in the Cathode of Proton Exchange Membrane Fuel Cells, *ChemElectroChem*, **4** (2017) 655.