f-cell Forum
Stuttgart, Germany, October 9 – 11, 2017

Hydrogen Quality Measurement According to SAE J2719 Using Ion Mobility Spectrometry

Marcel Corneille

EMCEL GmbH
Brüsseler Str. 85
D-50672 Köln
mc@emcel.com

Executive Summary

EMCEL is presenting a measuring device – an ion mobility spectrometry **-** proofing hydrogen purity (e.g. on-site at hydrogen generation plants or at passenger car fueling stations). The measuring device is a powerful and cost-efficient tool constantly monitoring the gas quality of any hydrogen source. At the moment the prototype is being tested at a CEP Hydrogen Refueling Station (HRS) and the approval process is monitored together with a German car manufacturer.

SAE J2719 / ISO 14687 define concentration levels of harmful gases emitted as by-products of hydrogen used at HRS. Although truck-delivered hydrogen complies with this standard (which is tested by random sampling), it occurs over and over again, that stack and tank of fuel cell vehicles reveal impurities which are inserted by hydrogen. The quality of on-site produced hydrogen by electrolysis and its direct use in vehicles is currently not being tested at all.

SAE J2719 / ISO 14687 specifications regarding harmful gases of hydrogen are very low and it is difficult to provide evidence accordingly. Conventional devices measuring hydrogen impurities are mass spectrometers. They can detect chemical elements and compounds with high accuracy. Due to technical requirements, mass spectrometers are designed primarily for laboratory use and are priced accordingly.

For the daily use at hydrogen refueling stations, instead of a mass spectrometer an ion mobility spectrometer (IMS) has been analyzed and adapted. They are powerful, cost-efficient and robust tools. For example, IMS are used to detect explosive substances at airports.

IMS are eligible for analyzing chemical elements. It has been technically adapted for measuring harmful gas concentrations within hydrogen as defined in the SAE J2719 / ISO 14687. Analysis reveal that IMS can measure all ionizable substances in the ppb (parts per billion)-range (even ppt (parts per trillion)-range). In addition, it is constantly running at fueling stations under all meteorological conditions.

Operating principle of IMS

General Background

Like any other conventional fuel, hydrogen needs to be relatively clean when it is used as fuel in engines. Only good fuel quality ensures for instance high catalyst performance in the fuel cell and keeps the amount of expensive catalyst material at acceptable levels to prevent fuel cell performance losses due to fuel quality monitoring of the hydrogen quality is required.

SAE J2719 / ISO 14687 define concentration levels of harmful substances emitted as by-products of hydrogen used at HRS. Although truck-delivered hydrogen complies with this standard (which is tested by random sampling), it occurs over and over again, that stack and tank of fuel cell vehicles reveal impurities which entered the fuel cell vehicle by hydrogen. The quality of on-site produced hydrogen by electrolysis and its direct use in vehicles is currently not being tested at all.

At the moment, there is no measurement device available on the market which is able to detect all impurities as defined in the SAE J2719 and ISO 14687. Due to this fact, in 2016 the development of an ion mobility spectrometry (IMS) for the use of analyzing hydrogen purity has been started. This technology is a very powerful, cost-efficient and robust tool to detect explosive substances at airports. IMS can detect chemical elements and compounds at very high accuracy (in the parts per billion (ppb) and even parts per trillion (ppt) ranges).

Design of IMS

Although clean hydrogen is dispensed at fueling stations, a method is required which can measure the by-products such as carbon monoxide (CO), ammonia (NH3), hydrogen sulfide (H2S) and other harmful impurities as listed in the SAE J2719 and ISO 14687. The concentrations of these substances are limited to parts per billion (e.g. 200 ppb for CO, 100 ppb for NH3 and 4 ppb for H2S). In order to detect impurities at these low concentration levels, a measuring system has been developed which is able to measure values in the ppb-range at very high accuracy.

The core component of the measuring system is an ion mobility spectrometer. Beside the IMS, the device consists of a control unit, data collection, sensor technology as well as piping and venting. The overall measuring system also includes operating and analyzing procedures, which allow automatic data acquisition and evaluation with subsequent error notification as well as remote monitoring. In addition, an internal control system was implemented to allow safe operations. If value limits are exceeded, responsible persons will be automatically informed by email.

Feeding hydrogen to the measuring system by proper piping, is the principal part.. All data is collected and can be accessed by a web-based gateway. The device is operated by programmable control units responsible for the safe operation.

Measuring method

The measuring method of an IMS is based on ionizing the test gas by a radioactive source. Afterwards, the ions enter an electric field in which they are accelerated in the direction of a detector. Gas is flowing in the opposite direction. The gas flow is impeding the ions depending on their shape and mass. This results in different drift times for each molecule. The higher the quantities of ionized molecules reaching the detector are, the higher the voltage to be detected. Molecules are sorted and then rated. Involving gas chromatography leads to a three-dimensional image. This image is called spectrum. From the resulting spectra conclusions about the concentrations of the substances can be drawn. The principle of an IMS is shown in figure 1.

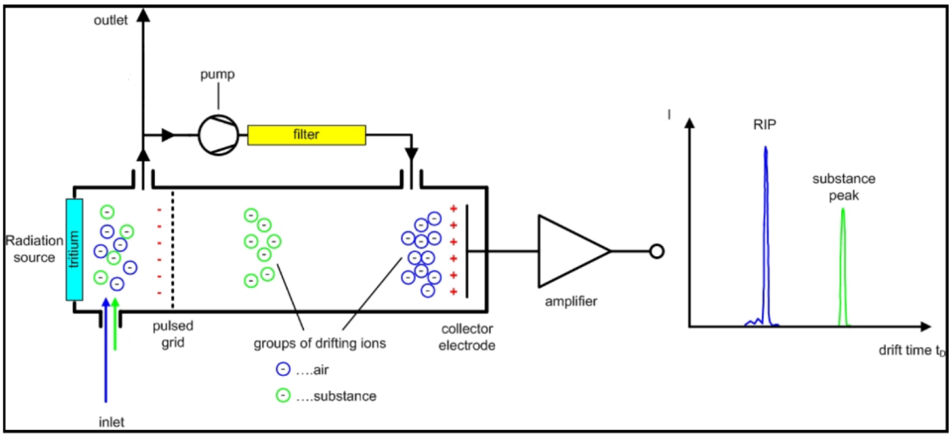

Figure 1: Technical principle of an IMS

Calibration

To enable the IMS to assign substances and their concentration values properly, calibration is required. Pure hydrogen is therefore polluted with those substances which shall be detected eventually. In this case the substances are CO, NH3, H2S and others. In order to increase the value of the IMS, further harmful substances as defined in SAE J2719 / ISO 14687 can be considered. Additional calibration is required then. Even hydrogen by-products not listed in the SAE J2719 / ISO 14687 can be detected if calibrated accordingly.

Operating modes

For protection and safety reasons operating modes and workflows have been developed. These consist of starting, starting ready, stand-by, measuring, pre-alarm and alarm. The IMS is fully housed and ready to run even in an outdoor environment at subzero temperatures. The device measures fully automatic. It generates data, predefined reports and sends alarm messages via email in case impurities are detected.

Goals

Together with the cooperation partners the next research and development step will be further calibration of even more harmful substances beyond the current standards (SAE J2719 / ISO 14687) like mercaptans, different types of oils, etc..

Conclusion

The device can be calibrated according SAE J2719 / ISO 14687 and is suitable of measuring the main harmful hydrogen impurities. The device measures fully automatic and provides alarms in case of impurities. Additional substances can be determined and calibrated. All impurities can be detected accurately in the required ppb-and sub ppb-range. At the moment, a device is implemented at a HRS and the approval process is monitored together with a German car manufacturer. Constant measuring during normal HRS operation has been demonstrated. Other H2 sources (like H2 from natural gas) can be considered as well.

The author of this paper is Marcel Corneille.
He studied at the universities of applied sciences in Cologne and Hamburg and graduated in mechanical engineering in 1998.
After studying, he had different employments as a development engineer at XCELLSIS GmbH, as well as project manager at Ballard Power Systems GmbH and DaimlerChrysler AG.
Today, Marcel Corneille is managing director of EMCEL GmbH, which he founded in 2009.