The European Research Project on Metrology for Hydrogen Vehicles - MetroHyVe

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Abstract. A large hydrogen infrastructure is currently in development across Europe. However, the industry faces the dilemma that they are required to meet certain measurement requirements set by European legislation that cannot currently be followed due to the lack of available methods and standards. The EMPIR Metrology for Hydrogen Vehicles project will be the first large scale project of its kind that will tackle the four measurement challenges that currently prevent the industry from meeting requirements set by International Standards such as flow metering, quality control, quality assurance and sampling. This paper presents a brief overview of the specific objectives of the project and focuses on the flow metering work package and the presentation of its planned tasks, which comprise laboratory and measurements in the field. Laboratory work will assess the use of substitute fluids to hydrogen to provide a safer and more cost effective method for the type approval of Hydrogen Refuelling Stations (HRS). To be able to link laboratory work to field testing, mobile primary standards will be developed and the design of a field testing primary standard will be addressed. The aim is to inform what the European national metrology institutes are currently developing in the field of hydrogen flow metering and quality control of HRS.

1. Introduction
Hydrogen vehicles are now commercially available to purchase from automobile manufacturers. Many countries worldwide are encouraging the introduction of hydrogen vehicles onto their roads, with significant efforts being made in Japan, USA and Europe. Hydrogen vehicles provide the benefits expected of an electric vehicle by allowing no carbon-containing gases to be produced in the exhaust, but their performance also remains very similar to conventional vehicles with regards to range and speed.
The development of the hydrogen economy is still in its infancy in Europe but several countries are aiming to employ sizable hydrogen fuelling infrastructures of the next few decades. In order to ensure that the hydrogen economy can grow, there are several measurement challenges that must be addressed, among which 4 main ones: flow metering, hydrogen quality assurance, hydrogen quality control and sampling of hydrogen at refuelling stations.

The Metrology for Hydrogen Vehicles – MetroHyVe (www.metrohyve.eu) – project within the framework of the European Metrology Programme for Innovation and Research (EMPIR) is a collaborative project that comprises technical work packages corresponding to the four measurement challenges mentioned above. The project also has an additional work package dedicated to creating impact from the project outputs, along with a stakeholder advisory board to help ensure the project maximises the benefits it will bring to industry and metrology. Partners in the project include organisations from the metrology, scientific and hydrogen industry communities. The project started in June 2017 and ends in June 2020.

2. Challenges and objectives

The first challenge is flow metering for which no traceable measuring capabilities currently exist in laboratories for calibrating and testing flow meters used in hydrogen refuelling stations at nominal working pressure of 70 MPa with hydrogen under similar pressure and temperature conditions. Among NMIs, only the National Institute of Standard and Technology (NIST) in the USA have constructed a Transient Flow Facility to test gas flow meters at an initial pressure of 42 MPa with helium or nitrogen [1]. The objective of the work package dedicated to flow metering is to develop a metrological infrastructure for testing hydrogen meters used to measure the mass of hydrogen dispensed into a fuel cell vehicle from a refuelling station and support laboratories by providing good practice guides describing the calibration and validation of flow meters used at HRSs. The metrological and technical recommendations stipulated in OIML R139-1 [2] and international standard SAE J2601 [3] should be followed.

The second identified challenge is hydrogen quality assurance. Based on fuel cell electric vehicles (FCEV) and fuel cell manufacturer’s requirements and hydrogen sector capability, international standards on hydrogen quality and purity for FCEVs were prepared. In Europe, it will be mandatory to follow the technical specifications contained in the ISO 14687-2 standard [4] by 18 November 2017. In the course of the MetroHyVe project, offline gas analysis methods, primary reference gas mixtures and metrological tools to enable the introduction of low cost gas analysers suitable for use commercial gas analysis laboratories will be developed.

Quality control refers to the methods that HRS operators can use to maintain quality of the hydrogen provided to the vehicles as detailed in the ISO/DIS 19880-8 standard [5]. The third objective aims at performing purity measurements of hydrogen following the implementation of quality control techniques specified in the aforementioned ISO standard and validating continuous online hydrogen purity analysers for measuring key impurities that guarantee global quality of the hydrogen at the HRS.

Finally, the issue of representative sampling at the refuelling stations will be addressed. Indeed, even if traceable methods did exist for all specifications of ISO 14687-2, erroneous results could still arise from using an inappropriate sampling approach or choosing the wrong sampling container. The MetroHyVe project will develop procedures for correctly preparing gas sampling vessels and performing gas sampling at the station. A focus will be made to prevent contamination of moisture and air ingress during sampling.

3. The flow metering work package

The aim of the flow metering work package is to realize a traceability chain for hydrogen flow metering in the range typical for fuelling applications up to a nominal working pressure of 70 MPa and in accordance with the worldwide accepted standard SAE J2601.
This work package is divided into 5 tasks. First, various designs of existing fuelling stations will be documented to establish a firm understanding of operating ranges, working principles and filling types. Based on the collected results, a report will be written describing the various designs and providing estimations of the sources of uncertainty.

Then it will be investigated whether non-flammable substitute substances to hydrogen to allow easier and safer measuring conditions during type approval can be used to characterize and calibrate mass flow meters used for hydrogen metering up to 70 MPa. Temperature and pressures will be chosen to cover the density range of hydrogen between around 23 kg m\(^3\) (equivalent to hydrogen at a temperature of 30°C and pressure of 35 MPa) up to around 46 kg m\(^3\) (equivalent to hydrogen at a temperature of -40°C and pressure of 70 MPa) for the alternative gases (air and nitrogen). The influence of pressure on the measurement accuracy of Coriolis mass flow meters (CMF) will be investigated in a third task.

Moreover, 4 field test standards based on gravimetric systems suited for measuring hydrogen flow under changing conditions will be developed for testing and calibrating hydrogen flow meters in the field up to 87.5 MPa (1.25 x nominal working pressure). These facilities will allow the dispensed mass of hydrogen passing through the flow meter to be determined through weighing the total amount of hydrogen collected in a high pressure vessel placed on a weighing scale. The mass dispensed into the tank is determined by weighing the tank before and after filling it with hydrogen. Field testing at HRSs using the developed gravimetric standards at 35 MPa and 70 MPa to assess the accuracy of existing hydrogen flow meters will be carried out. The collected knowledge will be disseminated through best practice guides and verification procedures. This will allow establishing a legal metrological control system for hydrogen dispensers currently lacking in many countries and will provide a method to validate these refuelling stations against standards and regulations.

Finally, complete uncertainty budgets for the methods developed in the previous tasks will be provided. A proper method on estimating venting losses after depressurization of the line will be developed. The aim is to assess whether these uncertainties are suitable for validation and type approval of HRS against the requirement of OIML R139. A cost estimate for a dedicated traceable primary test bench capable of simulating hydrogen refuels for directly calibrating hydrogen flow meters will be developed.

4. Design of the METAS mobile test standard

The design of the METAS field test standard, currently under construction, will be presented here. The METAS Hydrogen Field Test Standard (HFTS) consists of two 36 L composite reinforced pressure tanks from Hexagon Lincoln mounted into an aluminium frame which can each contain 1.4 kg hydrogen at 70 MPa. The storage tanks are type 4 cylinders (carbon fibre-reinforced epoxy with a plastic liner) with a service pressure of 70 MPa and a maximum filling pressure of 87.5 MPa. The nominal empty mass of each tank is 33 kg with dimensions of 320.8 mm x 910.3 mm. Pressure and temperature are monitored inside the tanks and in the piping system leading from the HRS nozzle to the tanks. The Plumbing & Instrumentation Diagram (P&ID) of the field test standard is shown in Figure 1 where the components located in the blue box are part of the frame that is being weighed on the scale. The hydrogen from the dispenser enters the HFTS through a same nozzle as mounted on a car and is guided into the pressure vessels. A RHM 04L Coriolis mass flow meter from Rheonik with Autoclave 3/8” process connections is also part of the plumbing system and can be placed in series with the tubing leading to the tanks, depending on the position of valves, for monitoring and eventual calibration purposes. All the plumbing in contact with hydrogen is made of medium pressure ¼” tubing, NPT fittings and valves in 316 stainless steel.

After filling the tanks with hydrogen and the weighing, the hydrogen will be vented in the atmosphere through a blow-down emission stack (blower). At the end of a set of measurements, all the plumbing and the vessels will be flushed several times with nitrogen to remove any dangerous quantity of hydrogen from the system. During storage and transport, the HFTS will always be pressurised (> 1 MPa) with nitrogen. Check valves prevent any air from the atmosphere from entering the HFTS and
rupture discs with a burst pressure of 90 MPa have been mounted before the pressure vessels as a safety measure.

The frame is mounted on a 300 kg scale from Mettler-Toledo with 0.1 g resolution. The weight of the frame can be lifted from the scale by a load removal system activated by a hand pump. This will be used during transport of the field test standard to prevent damage to the scale. It will also be used to assess if the coupling to the HRs before/during/after filling influences the weighing results. The complete frame is housed in an ESD plastic frame to protect it from air movements. The complete system is grounded to the HRS.

**P&I METAS- Hydrogen Field Test Standard (HFTS)**

![P&I Diagram](image)

**Figure 1:** P&I diagram of the METAS hydrogen field test standard.

### 5. Conclusions

Several of the metrological challenges that need to be addressed to ensure a rapid growth of a hydrogen economy will be treated in the course of the MetroHyVe project. The outcomes of the project are expected to provide positive impact to the hydrogen community through improved new standards, measurement services and good practice guides.

### 6. References

1. Pope J G and Wright J D, 2014 *Flow Measurement and Instrumentation* 37 42
2. OIML R 139-1 2014 (E), International recommendation: Compressed Gaseous Fuel Measuring Systems for Vehicles, International Organization of Legal Metrology
3. SAE J2601 2016, Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles
4. ISO 14687-2:2012, Hydrogen Fuel - Product Specification - Part 2: Proton Exchange Membranes (PEM) Fuel Cell Applications for Road Vehicles
5. ISO/DIS 19880-8:2017, Gaseous Hydrogen - Fueling Stations - Part 8: Fuel Quality Control