EMPIR Call 2020 – Fundamental, Industry and Normative

Selected Research Topic number: **SRT-i01**
Version: 1.0

Title: Metrology infrastructure for high-pressure gas and liquified hydrogen flows

Abstract

The European Green Deal provides a roadmap to boost the efficient use of resources, restore biodiversity and cut pollution. Reaching this target will require certain actions including investments into environmentally friendly technologies, such as the use of hydrogen. A metrological infrastructure for the industries in the growing hydrogen market is needed. It is expected that liquified hydrogen will play an important role as a fuel for vehicles. Investigation of different meter types for process application and billing is based on calibrated nozzles. The aim of the project is to provide solutions for testing flow meters with liquified hydrogen and to develop and investigate different methods for nozzle calibration in the interested pressure range.

Keywords

Flow metering, high pressure hydrogen, liquified hydrogen, cryogenic gas, sonic nozzles, pressure, volume, temperature and time method (pVTt), Coriolis meter, scaling up method, Laser Doppler Velocimetry, CFD

Background to the Metrological Challenges

Just like electricity, hydrogen is an energy vector which can be produced only from other sources of energy like wind, solar radiation, biogas or fossil fuels. It can be stored relatively easy in a gaseous and liquified state, the latter one allows a very high energy density which makes it very interesting for the transport sector. For some applications like steel production, it can be used directly as a process gas. During the development of a hydrogen-based economy, the fossil fuels may be used in parallel which allows a smooth reduction of fossil energy usage. The application strategy of renewable energy vectors needs to investigate the overall efficiency taking into account specific features of the different cases. A sound judgement requires an accurate determination of hydrogen quantities and flow rates.

Currently the realisation of the units for flow rate and quantity of hydrogen is based on test rigs which determine the amount of gas nearly at atmospheric conditions and relatively small flow rates. In Europe, no test rigs are available which are usable at high pressure level, except some for refuelling stations for cars. Nozzles which are used in critical mode (sonic nozzles) are very reliable flow standards which are widely spread for air applications and, to a relatively small extend, for other gases like natural gas. In order to improve the traceability of hydrogen flow measurements, test rigs which are able to calibrate nozzles up to 100 MPa are needed. Such nozzles are required for the validation of different calibration methods and the dissemination of the flow rate unit by nozzles as transfer standards.

The behaviour sonic nozzles may be characterised by the dependency of the discharge coefficient Cd which is described in ISO 9300. The Cd value depends on the Reynolds number, the nozzle size and the shape. The thermodynamic behaviour of the gas influences the speed of sound and the boundary layer. First published results of high-pressure nozzle calibrations show that ISO 9300 is not applicable for hydrogen with sufficient accuracy. Adequate database of nozzle calibration results with hydrogen is not available. The data are needed in order to update sections of ISO 9300 for hydrogen.

Although the currently available mechanical and static (electronic) meters are, in principle, usable for hydrogen, their behaviour in the medium pressure range is not known. Due to hydrogen's special properties, such meter types need to be investigated individually. Sonic nozzles are well suited as flow standards in test rigs for different meter principles in whole pressure range of application, provided that the p- and T- dependency of the nozzles (as described in an improved ISO 9300) is known. The calibrated meters are needed for a reliable process control, e.g. for the flow control of fuel cells. Depending on their application, different meter types are required (e.g. types having a low-pressure loss or a fast response in case of dynamic processes). At the time being, no traceable test rigs are available for quality assurance.

Coriolis meters have been applied successfully with liquefied natural gas (LNG) and/or liquified nitrogen. Test rigs using LNG and liquified nitrogen are available for calibration of such meters. However, liquid hydrogen has a considerably lower temperature which requires the investigation of potential additional influences on the accuracy at temperatures below 20 K. By analysing the results of liquid nitrogen and liquid hydrogen calibrations, the influence of the fluid temperature on Coriolis meters can be determined.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement for medium and high pressure hydrogen, and characterisation of calibrating meters for liquified hydrogen.

The specific objectives are

1. To develop and investigate methods for the calibration of critical nozzles and master meters as calibration standards for gaseous hydrogen at high pressure (p_{max} = 100 MPa) and flow rates up to 10 kg/min. To enhance methods available for air and inert gases (N2) for the use with hydrogen such as (i) gravimetric/volumetric methods, (ii) pressure, volume, temperature and time (pVTt) method, (iii) scaling up method. This includes comparison of calibration results of nozzles, and determination and validation of uncertainty budgets.
2. To perform calibrations of sonic nozzles up to high pressure (p_{max} = 100 MPa) with different size, shape, and surface roughness, using e.g. vaporized or bottle-stored hydrogen and to analyse the nozzle behaviour and comparison with dependencies described in ISO 9300. Contributing to amendments and restrictions for the applicability of ISO 9300 for using nozzles with hydrogen.
3. To provide strategy for developing a CFD model for high pressure hydrogen flows, taking into account the most important influences of real gas effects (such as due to heat capacity). This shall be based on a comprehensive literature study.
4. To develop a design for test rigs using critical nozzles for flow calibrations at medium pressure and to investigate the test rig feasibility for the determination of the flow rate and of the metering deviation of Coriolis meters by vaporisation method. In addition, to characterise the behaviour of master meters such as Coriolis, ultrasonic and differential pressure devices for a flow rate range up to $Q_{N,max}$ = 4 kg/h (about 100 kW fuel cell power) and p_{max} = 3 MPa. To determine the uncertainty of Coriolis meters calibrated by water and/or by other cryogenic liquids.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (calibration laboratories, NMIs, DIs), standards developing organisations (ISO 9300, ISO 5167) and end users (hydrogen industry).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR projects 16ENG01 MetroHyVe and 18NRM06 NEWGASMET and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the hydrogen industries.

You should detail other impacts of your proposed JRP as specified in the document "Guide 4: Writing Joint Research Projects (JRPs)".

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.