EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-i12**
Version: 1.0

Title: Metrology for industrial flow metering

Abstract

Accurate flow rate measurements are of crucial importance for many different applications including fiscal monitoring and custody transfer, but flow rate measurements under high pressures, high temperatures or unstable conditions can be subject to significant uncertainties. Flowmeters are often calibrated under conditions that differ noticeably from the conditions in use, and new and improved methods and procedures are therefore required to better quantify and to reduce the flow rate measurement uncertainty for industrial applications.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 12 and 37.

Keywords

Dynamic flow, installation effects, computational fluid dynamics, flow metering, polynomial chaos theory, calibration inter- and extrapolation, design optimisation, operating conditions, metering accuracy.

Background to the Metrological Challenges

Correct fluid flow measurements are important for industry: they define the quality of products, of production processes and are necessary for an economical and safe operation of the processes. Additionally, accurate flow metering is required for a sound custody transfer with low financial exposure. Industrial applications of flow measurements cover a wide range of operating conditions, for example, pipe diameters from a few millimetres up to 3 metres, flow rates between a few µl/h and 100 000 m^3/h, well developed flow versus fully detached flow, line pressures from ambient up to 300 bar, etc.

For legal applications, the uncertainty requirement for flow rate measurement is between 0.2 % and 2.0 % [1-3] reducing to 0.1 % for special applications in process engineering and control. Uncertainties increase significantly when the measurements are performed at high pressure and/ or high temperature, with unstable flow or not fully-developed flow, etc, however, even under conventional conditions flow metering may be subject to significant measurement uncertainties. In fact, these measurement uncertainties can be significantly larger than commonly accepted and prescribed by existing norms and standards.

There are a number of components whose uncertainties may be comparable to the desired overall uncertainty in the flow measurement that are not currently taken into account, for example: Reynolds interpolation, flow disturbances, thermodynamic expansion and pressure effects. This is because existing standards do not address the conditions under which the measurements are made (flow rate stability, flow profile, temperature homogeneity, pressure stability etc.), but only the hardware configuration, e.g. the flow meter should be placed 10 diameters downstream of the nearest flow disturbance. Consequently, just following the standards on flow rate measurement may not be sufficient to achieve the required measurement uncertainty.

In order to perform flow measurements with low uncertainties for all the possible operating conditions, it would be necessary to have primary measurement standards for every combination of operating conditions (flow rate, flow rate stability, velocity profile, temperature, viscosity, pressure, etc), which is neither feasible nor desirable. Consequently, flowmeters are generally calibrated in the laboratory under ‘ideal and probably non representative conditions’ and then used under real and different operating conditions. Despite the numerous primary standards covering a wide range of flow rates and media, interpolation and extrapolation of calibration data are still required. Current models for calibration interpolation are typically based on the Reynolds number assuming that the calibration curve only depends on the Reynolds number and is applicable to the whole range of the flow meter. Improved Reynolds interpolation assumes that the interpolation is not valid for the whole flow meter range, but only between a minimum and maximum flow rate. Nevertheless, this may still result in significant measurement uncertainty (around 0.1 % to 0.4 %), especially for Reynolds extrapolation.

There are various examples in the literature where computational fluid dynamics (CFD) has been used to predict flow metering performance, however, typically crude approximations have been applied (e.g. 1 dimensional model). Additionally, the current software packages that can be used to propagate flow pulsations are not suited for flow metrology, for example the impact of the pulsation on the metering accuracy is not determined, flow induced pulsations (e.g. vortex shedding from a T-junction) are not always taken into account, nor pulsation interactions. Uncertainty propagation utilising ‘polynomial chaos theory’ is a relatively new method, but this has yet to be applied to flow metrology in general.

Scientific and Technological 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 JRP-Protocol.

The JRP shall focus on the quantification and reduction of measurement uncertainty for industrial flow metering for liquid and gases.

The specific objectives are

1. To improve the quantification of flow rate measurement uncertainties under industrial conditions.
    a. To develop new and improved methods and procedures to determine the measurement uncertainty for cases where a flowmeter is calibrated under certain operating conditions, but is used under different conditions. Particular consideration shall be given to dynamic flow, installation effects, pressure, temperature and viscosity.
    b. To develop methods to quantify the effect of ill-defined or variable operating conditions on the measurement uncertainty by developing effective means of propagating these uncertainties into the final and total measurement uncertainty, for example using 'polynomial chaos theory' and computational fluid dynamics.
2. To reduce flow rate measurement uncertainties under industrial conditions.
    a. To improve calibration inter- and extrapolation methods used to transform calibration curves for flowmeters from a given set of conditions to the different conditions in use. In addition to the Reynolds number, the methods developed should incorporate dimensionless parameters such as Nusselt, Grashoff, Mach, Prandtl and the Strouhal numbers and dimensional parameters as appropriate.
    b. To develop methods to correct flowmeter indications for the velocity profile, thus reducing the measurement uncertainty.
    c. To develop a procedure for the in-situ inline calibration of industrial flowmeters, which cannot be removed from their locations for calibration.

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.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 42 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the industrial flow and fiscal monitoring sectors.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] OIML R 49 (2006): Water meters intended for the metering of cold potable water and hot water. Part 1. see chapter 3.2 Accuracy class and maximum permissible error, page 11.

[2] OIML R 117 (2007): Dynamic measuring systems for liquids other than water – Part 1. see chapter 2.4 Accuracy classes, page 20.

[3] OIML R 137 (2006): Gas meters – Part 1. see chapter 5.3 Accuracy classes and maximum permissible errors, page 15.