Measurement uncertainty in the totalisation of quantity and gas quality measurement in gas grids

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Abstract

The total quantity and energy delivered through a gas grid is calculated using simple formulae that sum the increments measured at regular time intervals. These calculations are described in international guidelines (e.g., OIML R140) and standards (e.g., ISO 15112 and EN 1776). Currently, in the evaluation of the associated measurement uncertainty the measurement results that enter the calculation are assumed to be mutually independent. This assumption can lead to costly errors once hydrogen (and hydrogen blends) are introduced into gas grids. There is a growing concern among transmission and distribution system operators that these assumptions and the obtained values for the measurement uncertainty are not fit for purpose when fluctuations in gas quantity and quality increase.

In a new project in the European Partnership for Metrology programme, "Metrology for the hydrogen supply chain", the underlying assumptions of these uncertainty evaluations are revisited and reworked to be more adequate. The dependence of measurement results coming from, e.g., the same flow meter and gas chromatograph will be assessed for correlations, as well as other effects, such as the effect of the chosen mathematical approximation of the totalisation integral, and fluctuations in flow rate and gas quality. The poster presentation gives an impression of the models being developed, the first findings and the magnitudes of the effects concerned.

Needs & drivers

Rationale for the project "Metrology for the hydrogen supply chain" (Met4H2):

- "Unless there are rapid and large-scale reductions in greenhouse gas emissions, limiting warming [...] to 1.5 °C will be beyond reach" (IPCC, 2021)
- European Green Deal (EGD) is Europe's response to decarbonise energy use and to shift to renewable energy sources
- Hydrogen, produced from electricity from renewable sources, is at the centre of this energy transition
- To make the transition, hydrogen supply chains need support by reliable measurements for health, safety, environment and fiscal purposes
- Project addresses the industrial needs, supports actions needed in the short-term as well as in the longer-term and contributes to a sustainable measurement infrastructure

Project objectives

The overall objective of the project Met4H2 is to further develop and integrate the metrology necessary to support the entire supply chain of hydrogen, from production to storage and end-use. The specific objectives are:

1. To develop calibration and measurement methods to support traceable and accurate measurements for safety, process efficiency and environment, ensuring that online instruments and sensors are operating within their specifications.
2. To develop flow standards for calibrating of flow metering equipment under actual conditions to accurately measure flow rates of hydrogen (including blended hydrogen) through the hydrogen supply chain.
3. To develop and improve measurement standards and methods to enable traceable validation and performance evaluation of gas quality measurement methods for hydrogen, focusing on equivalence of results for impurities, e.g., oxygen, hydrogen sulfide, moisture, ammonia, hydrogen chloride and chlorine.
4. **To develop novel methods for the evaluation of measurement uncertainty along the supply chain as a whole, namely with regard to the measurement of total quantity, and energy and impurity content of hydrogen and hydrogen blends.**

Acknowledgement

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Instrumentation

Flow rate measurements and gas composition measurements in the supply chain are usually performed with a single instrument, with a single calibration. In the case of a flow meter, such calibration may be done once in several years of operation, whereas for other devices the calibration is more frequent. This fact alone should dismiss the idea that the results of these measurement devices are independent. Hence, their correlation should be taken into account.

Models for totalisation should be elaborated to account for these correlations, based on uncertainty budgets already devised for these instruments. The dependence between measurement results can be conveniently summarised as correlation coefficient and propagated using the currently employed methods.

Integration over time

Measurements of flow rate and gas composition are made at discrete points in time. The total volume would be given by

$$V_{\mathrm{tot}} = \int_{t_1}^{t_2} q_V(t)\mathrm{d}t \quad (1)$$

which in practice is approximated by the summation

$$V_{\mathrm{tot}} \approx \Delta t \sum_{i=1}^{N} q_V \quad (2)$$

where q_V denotes the volume flow rate and Δt the time interval between two subsequent flow measurements.

Numerical integration methods provide a basis for assessing this uncertainty component as shown in 17NRM05 "Examples of measurement uncertainty evaluation". In energy measurement, the situation is more complex, for the integration is over two variables (energy content and quantity), and these are not necessarily measured with the same time intervals.

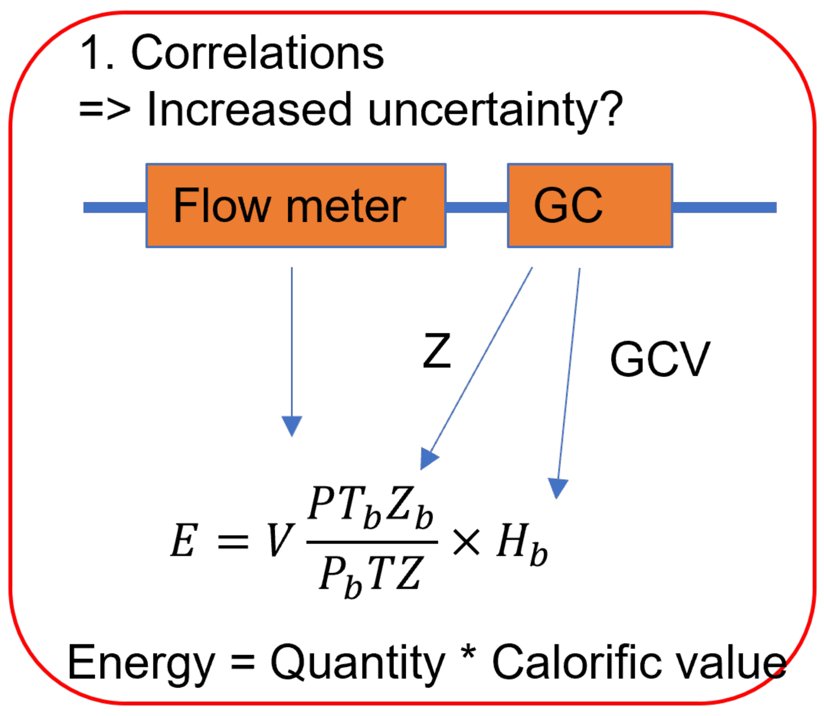
Fluctuations in gas flow

Models currently used in, e.g., ISO 15112, OIML R140 and EN 1776 are based on averages over a specified time period. Increased fluctuations in gas quantity and composition should increase the uncertainty of these averages, for they are based on data with larger dispersion.

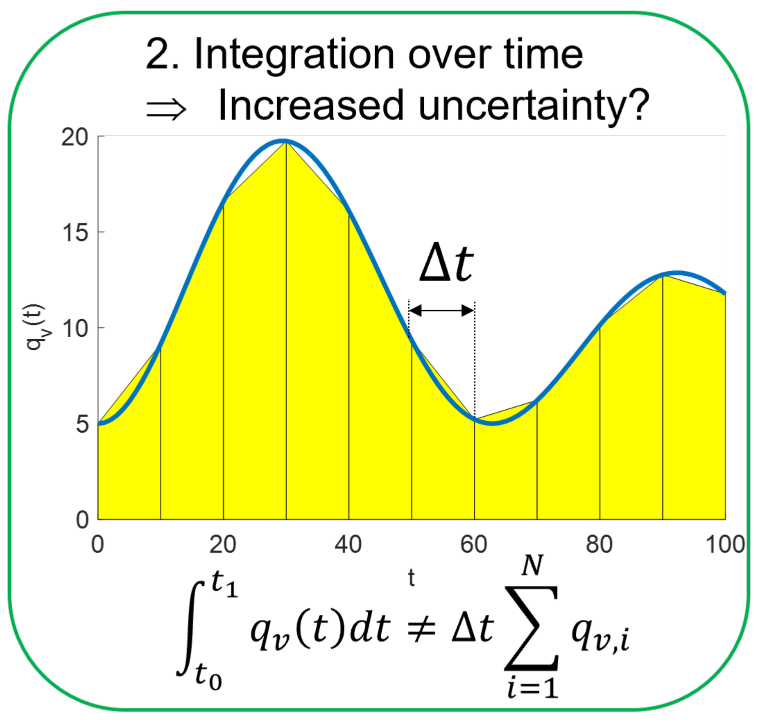
This dispersion should be duly accounted for in the uncertainty budget. Where appropriate, the use of time series models, such as autoregressive models will be considered to address these effects.

Modelling effects

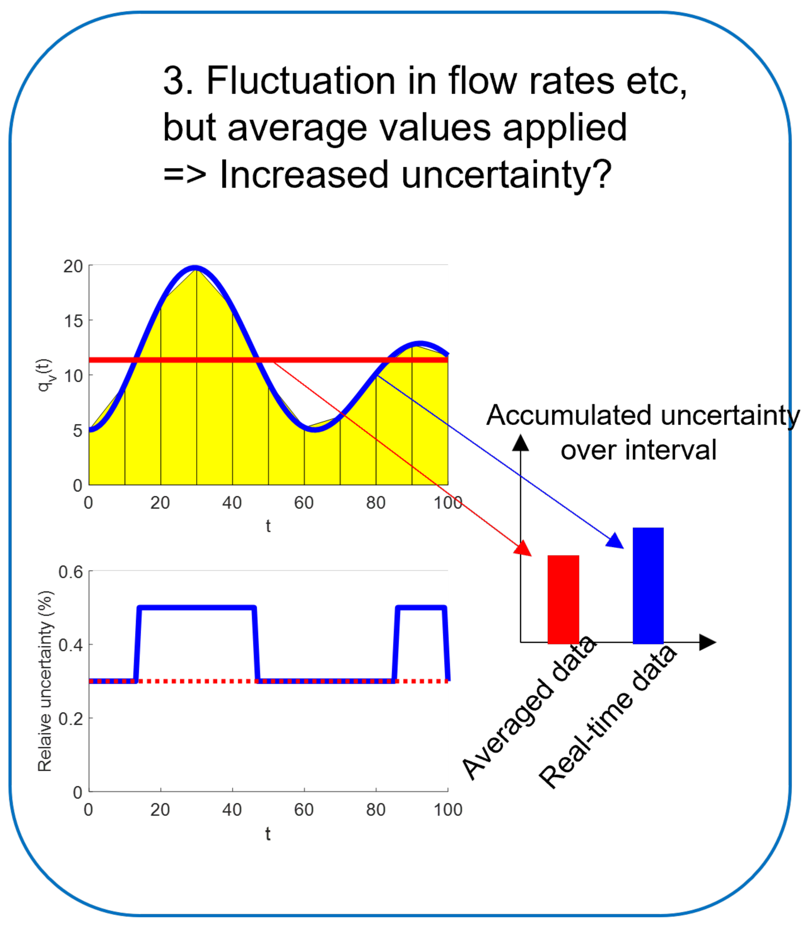
Using the same instrumentation for making the measurements contributes to correlations between results.



The totalisation is actually an approximation of an integral of a smooth function, thereby it contributes to the uncertainty.



Fluctuations in time in, e.g., flow rate and composition make averages less representative for time interval.



Concluding remarks and outlook

With the envisaged work, the models used for fiscal metering will become more robust and the calculated measurement uncertainty more realistic. The output of these efforts will be offered to OIML, ISO, and CEN committees for consideration to be included in OIML R140, ISO 15112 and EN 1776, thereby preparing the methods for fiscal metering for a future with renewable energy flowing through gas grids.