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Flow metering of renewable gases (biogas, biomethane, hydrogen, syngas and mixtures with natural gas)

Report A2.1.15

Effect of the renewable gases on the uncertainty budgets of gas meters

Lead partner: FORCE Technology

Contributing partners: Cesame, CMI, NEL, PTB, VSL and ISSI

Work package: 2

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Contents

1. Introduction.

During the study of the CEN/TC 237 standards "Gas meters" in the European Metrology Programme for Innovation and Research (EMPIR) project named NEWGASMET, the impact of the renewable gases (biogas, biomethane, hydrogen, syngas and mixtures with natural gas) on the uncertainty on the gas meter was discussed and described in several recommendation reports.
This report is on the activity A2.1.15 where the objective is *"Using input from A2.1.2-A2.1.8, FORCE with support from Cesame, CMI, NEL, PTB, VSL and ISSI will write a report on the effects of renewable gases on the uncertainty budgets of gas meters."*

2. Recommendations from the expert group-

The expert group- which were defined in the NewGasMet project under work package 2 has made recommendations reports on several EN-standards covered by the CEN/TC 237. These recommendations, made for each EN-standard/gas meter individually, could lead to a change in the measuring uncertainty when testing the gas meter. If one is looking at all the recommendations some common denominator can be found.

3. Contributions to an extended uncertainty from the recommendations

3.1 Test-gases

In all the EN standards it is permitted or recommended to use air as a test medium when doing metrological performance testing.
Generally, it is recommended by the expert groups to use a test-gas which is identical with the gas intended for the meter to measure or make a transferability to another gas from air or natural gas.

In all the recommendations from the expert groups a common point can be found within test-gases.

Recommendations listed in the recommendation reports:

- EN 12480; *"For renewable gas use, the expert group recommends validating the meter's metrological performance with the test gas from Table 1 in this document closest to its intended use"*
- EN 1359; *"For renewable gas use, the expert group recommends validating the meter's metrological performance with the test gas from Table 1 in this document closest to its intended use especially when the content of hydrogen is higher than 10% or the transferability from air to the gas from table 1 should be verified before testing."*

- EN 12261; *"When renewable gases are considered, the expert group recommends validating the meter's metrological performance with the test gas from Table 1 in this document closest to its intended use. For turbine meters, it is also recommended to perform the assessment on the same Reynolds number range (+/- 5%) since this technology is Reynolds number dependent."*

- EN 14236; *"The expert group recommends that for meters which are intended to operate with (partly) renewable test gases, then the relevant test gas from Table 1 is used. When using H2/natural gas blends, tests could be carried out at zero flow conditions only. This would minimise the volume of gas required to test and associated safety concerns, and provides a worst-case scenario test, where signal to noise ratio is expected to be poorest."*

- EN 17526; *"It is recommended that the appropriate test gases for (partly) renewable gases are used to ensure that the maximum and minimum ρ·cp values are tested for the meter. It is also suggested that manufacturers define a range of ρ·cp where the meter works within the expected uncertainty, with a series of limit gas compositions given as a reference for the final user."*

In the recommendation from nearly all EN standards the "Table 1" is mentioned. Table 1 is developed by the expert groups and is describing the suggested test gases which is recommended to be used when testing meters for use with a renewable gas.

Name	Composition	Note
Hydrogen injection 1	90 × 10-2 mol/mol CH_4 + 10 × 10-2 mol/molH_2 (CH_4 + 10% H_2) or 90 × 10-2 mol/mol NG + 10 × 10-2 mol/mol H_2 (NG + 10% H_2)	Natural Gas (NG) must comply with EN16726
Hydrogen injection 2	80 × 10-2 mol/mol CH_4 + 20 × 10-2 mol/mol H_2 (CH_4 + 20% H_2) or 80 × 10-2 mol/mol NG + 20 × 10-2 mol/mol H_2 (NG + 20% H_2)	Natural Gas (NG) must comply with EN16726
Hydrogen injection 3	70 × 10-2 mol/mol CH_4 + 30 × 10-2 mol/mol H_2 (CH_4 + 30% H_2) or 70 × 10-2 mol/mol NG + 30 × 10-2 mol/mol H_2 (NG + 30% H_2)	1. Natural Gas (NG) must comply with EN16726. 2. Metrological test not required if meter fails at the previous point (20 × 10^{-2} mol/mol H_2).
Hydrogen	pure* H_2	
Biomethane	From the field	The test gas shall be compliant with CEN/TR 17238 and EN 16723-1
Clean Biogas	60 × 10^{-2} mol/mol CH_4 + 40 × 10^{-2} mol/mol CO_2 (CH_4 + 40% CO_2)	Only dry, clean biogas is considered
Syngas	40 × 10^{-2} mol/mol CH_4 + 30 × 10^{-2} mol/mol H_2 + 30 × 10^{-2} mol/mol CO (CH_4 + 30% H_2 + 30% CO)	

Table 1: Renewable test gases defined by the NEWGASMET expert group

*Appropriate purity level and effects of contaminants need further study. Suggested purity level in the EASEE Common Business Practice '2022-001/01 Hydrogen Quality Specification' is at ≥ 98.0 × 10^{-2} mol/mol H_2. Changes in physical properties due to purity variability generically affect gas meter calibration results.

- *EN 16726: Gas infrastructure - Quality of gas - Group H*
- *EN 16723-1 Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network – Part 1: Specifications for biomethane for injection in the natural gas network*
- *CEN/TR 17238: Proposed limit values for contaminants in biomethane based on health assessment criteria*

When using a different or alternative test-gas than the one the meter are designed to measure, this can lead to another calibration result which have to be corrected for which again will lead to an increase in the uncertainty.
The results from the durability test in task 2.2 and described in report A2.2.6 indicate that current diaphragm and thermal mass flow gas meters, intended for use with natural gas, show shifts in measurement error when exposed to pure hydrogen which stay within the legal limits of the current documentary standards.

If air or natural gas is used and transferred to the gas the meter is intended to measure, then the air or natural gas test transferability to the renewable gas should be proven by traceable calibrations with uncertainties at 1/5 MPE.
Alternatively, this can also be done by evaluation of material composition of all parts of the gas meters, by long durability tests of the gas meters with gases from Table 1, etc.

3.2 Internal leakage especially when hydrogen blends or clean hydrogen is used.

Another common point from the recommendations is the internal leak, especially when hydrogen or hydrogen blends (with natural gas) are used. The following recommendations are found:

- EN 12480; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of rotary gas meters to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.3.3.3 may have to be modified to include pure hydrogen."*
- EN 1359; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of diaphragm gas meters in order to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.3.3.2 may have to be modified to include pure hydrogen."*

The leak has to be small enough that it doesn't affect the meter performance and doesn't affect the uncertainty of the measurement. This can only be established by long term experience with leakage tests and possibly redesign of meters internal construction.

3.3 External leakage especially when hydrogen blends or clean hydrogen is used.

- EN 12480; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of rotary gas meters to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.3.3.3 may have to be modified to include pure hydrogen."*

- EN 1359; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of diaphragm gas meters in order to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.3.3.2 may have to be modified to include pure hydrogen."*
- EN 12261; *"The leak pressure test shall be done at the operating pressure with the closest fluid to the turbine meters intended use (hydrogen, blend, biogas)."*
- EN 14236; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of ultrasonic gas meters in order to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.2.4.2 may have to be modified to include pure hydrogen.*
  They concluded that existing leak test methods using alternative gases to hydrogen can still be applied, but the criteria of acceptance (CoA) should be 40% more strict if the meter is intended to be used with hydrogen rather than natural gas"
- EN17526; *"For H2NG and pure hydrogen, gas metering industry needs to build experience in leak tightness testing of thermal-mass flow-meter based gas meters in order to develop a representative and relevant leak tightness test. For pure hydrogen usage, the test medium prescribed in 6.3.3.2 may have to be modified to include pure hydrogen."*

As for the internal leakage the external leakage must be so small that it doesn't affect the meter performance and doesn't affect the uncertainty of the measurement. This can only be done by long term experience with leakage tests and possibly redesign of meters internal construction.
But most importantly, the leakage should not lead to any hazardous (explosive) situation.

4. Contributions to an uncertainty budget in general

From the NewGasMet work package 3 an Ishikawa diagram is developed to show which uncertainty parameters that have an influence in an uncertainty budget for gas meters in general.

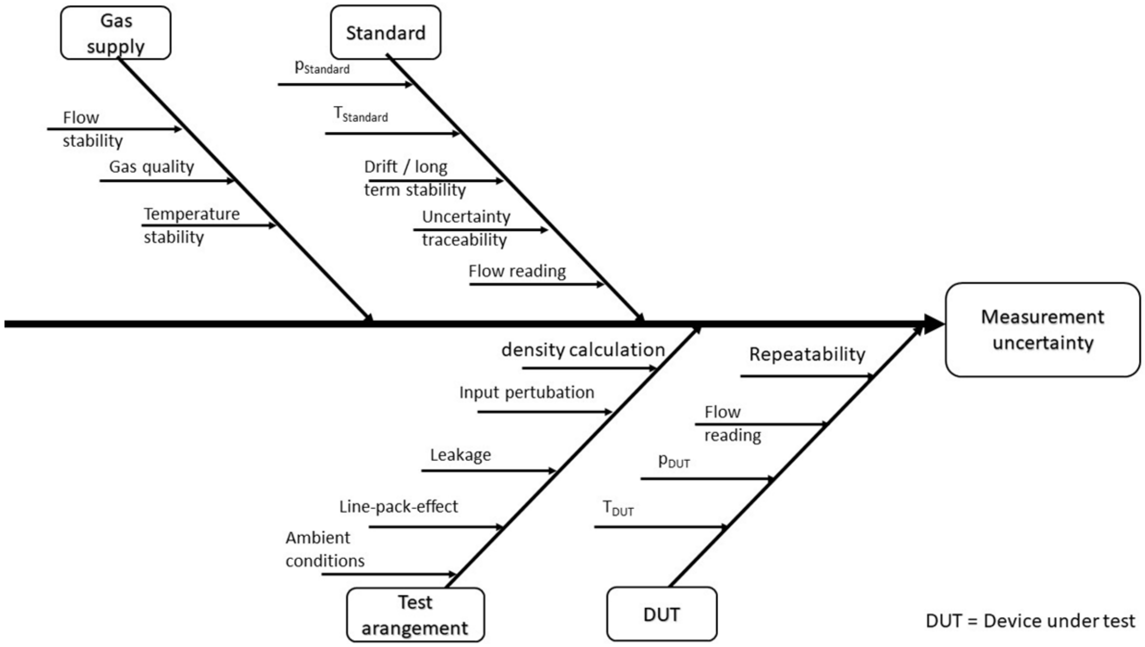

Figure 1, Ishikawa diagram

When using a renewable gas, the same parameters are still having an influence in the uncertainty budget.
But using a renewable gas does not exactly mean that this also will lead to an extended uncertainty than applicable to conventional natural gas. Each uncertainty parameter described in the Ishikawa diagram will be discussed in the text below in relation to using a renewable gas.

Gas supply:
Flow stability: The stability of the flow is very important for the measurement uncertainty, but the stability of the flow is more related to mechanical issues and not directly related to the gas measured.

Gas quality: Some meter types are sensitive to the quality of the gas and therefore this can lead to a larger uncertainty of the measurement.

Temperature stability: The stability of the temperature is of course very important and can be a challenge to control depending on which gas is measured. But again, this is more related to mechanical issues and not directly related to the gas measured.

Standard (reference meter):
$P_{standard}$: The pressure at the standard and the measurement of the pressure is depending on the equipment measuring the pressure, which have to be designed to measure in the specified gas. If a correct pressure transducer is used, then this will not lead to a larger uncertainty.

$T_{standard}$: The measurement of the temperature at the standard will not lead to a larger uncertainty when measuring renewable gas.

Long-term stability: The long-term stability of the standard is one of the key factors when selecting a reference meter. This is directly related to the meter and meter type and when selecting a meter which is designed for measuring the actual renewable gas, then this should not be an issue and should not lead to a larger uncertainty.

Traceablity: The traceability is at the moment rather difficult for some renewable gases like hydrogen and blends with hydrogen and natural gas since there is no primary facilities operating on hydrogen or hydrogen enriched natural gas. There are some facilities that are traceable to a primary facility which is operating on air and then by modelling traceable to hydrogen. By using an alternative gas in the traceability chain will lead to a larger uncertainty.

Flow reading: The reading of the standard will not lead to an extended uncertainty.

Test arrangement:
Ambient conditions: When testing on renewable gases the environment and ambient conditions has to be as stable similar to testing on conventional gases and will therefore not lead to a larger uncertainty.

Line-pack effect: When measuring on renewable gases the line-pack effect is not expected to lead to any extended influence compared to conventional gases and is therefore not expected to lead to an extended uncertainty.

Leakage: The leak is small enough that it doesn't affect the meter performance and doesn't affect the uncertainty of the measurement. Especially when testing on hydrogen a leak tightness test must be performed very carefully to ensure no leakage or so small that it doesn't affect the testing of the meter or contribute significantly to the total uncertainty.

Input perturbation: effect: When measuring on renewable gases the input perturbation will not lead to any extended influence compared to conventional gases and does not lead to a larger uncertainty.

Density calculation: The calculation of the density can lead to an increased uncertainty, but is only an issue when measuring in mass flow etc. kg/h.

DUT (Device-Under-Test):
T_{DUT}: The measurement of the temperature at the DUT (i.e., the gas meter being calibrated by the standard) will not lead to a larger uncertainty when measuring renewable gas.

p_{DUT}: The pressure at the DUT and the measurement of the pressure is depending on the equipment measuring the pressure, which have to be designed to measure in the specified gas. If a correct pressure transducer is used, then this will not lead to a larger uncertainty.

Flow reading: The reading of the output from the DUT will not lead to an extended uncertainty.

Repeatability: The repeatability of the gas meter is a key factor of the uncertainty budget and according to the durability tests results in D5 of the NewGasMet project it seems that the repeatability is close to the repeatability of natural gas. So based on these tests results it cannot be concluded whether the repeatability will be affected or not.

5. Conclusions

The testing on renewable gases will for some points contribute to the total uncertainty. From the above it can be concluded that especially when measuring on an alternative gas, this can lead to a larger uncertainty since the behavior and specifications of the gas is not the same. Therefore, this has to be determined before using an alternative gas.

Also, the leakage of the meter both internally and externally has to be detected and possible corrected for especially when measuring hydrogen and blends with hydrogen.

When looking at the uncertainty budget in general the inputs to the budget are mostly not related to the type of gas, but one has to make some considerations especially when measuring hydrogen but also converting calibrations from an alternative gas to the application gas.

6. References

1. *EN 12480:2018 Gas meters – Rotary displacement gas meters*
2. *EN 1359:2017 Gas Meters - Diaphragm gas meters*
3. *EN 12261:2018 Gas Meters - Turbine gas meters*
4. *EN 14236:2018 Ultrasonic domestic gas meters*
5. *EN 17526:2021 Gas meter – Thermal-mass flow-meter based gas meter*
6. *EN 16723-1 Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network – Part 1: Specifications for biomethane for injection in the natural gas network*
7. *EN16726 Gas infrastructure - Quality of gas - Group H*
8. *CEN/TR 17238 Proposed limit values for contaminants in biomethane based on health assessment criteria*
9. *NEWGASMET A3.1.2 Ishikawa diagram uncertainty budget*