# Effect of hydrogen admixture on the accuracy of a rotary flow meter

By dr. Marcel Workamp* and dr. Menne Schakel**

VSL National Metrology Institute, Thijsseweg 11, 2629 JA Delft, The Netherlands

31st of August 2021

## Abstract

With the rise of hydrogen use in the natural gas grid a need exists for reliable measurements of the amount of energy being transported and traded for hydrogen admixtures. Using VSL's high-pressure Gas Oil Piston Prover (GOPP) primary standard, the effect of mixing hydrogen with natural gas on the performance of a high-pressure gas flow meter was investigated. The error of a rotary flow meter was determined using the best possible uncertainty, by calibration with the primary standard for high-pressure natural gas flow. The rotary flow meter was calibrated using both natural gas and hydrogen enriched natural gas (nominally 15% hydrogen), at two different pressures: 9 and 16 bar. Results indicate that, for the rotary flow meter and hydrogen admixtures used, the differences in the meter errors between high-pressure hydrogen-enriched natural gas calibration and high-pressure natural gas calibration are smaller than the corresponding differences between atmospheric pressure air calibration and high-pressure natural gas calibration.

## Introduction

As Europe moves towards renewable energy sources, the characteristics of energy gases being transported in European gas infrastructure will change significantly. It is expected that these changes will impact the accuracy of measuring instruments that are used for billing and custody transfer. For instance, the addition of hydrogen to natural gas grids may pose measurement challenges, as hydrogen has a lower density and viscosity than natural gas. There are still many unknowns with respect to how flow meters calibrated for natural gas (NG) perform when used with hydrogen-enriched natural gas (HENG). In this paper, the accuracy of a rotary flow meter with NG and HENG is investigated by comparison to a primary piston prover.

The assessment was carried out as part of the NEWGASMET project [1], which aims to increase knowledge about the accuracy and durability of currently installed gas meters. This should lead to the improvement of, e.g., existing meter designs and flow calibration standards.

## Methods

### Gas Oil Piston Prover

To investigate the effect of HENG on the performance of the flow meter, VSL's Gas Oil Piston Prover (GOPP) was used. The GOPP is the primary standard for high-pressure natural gas flow measurements in The Netherlands. Using the GOPP for traceability, VSL is part of EuReGa, a consortium of institutes aimed at harmonizing reference values for high-pressure gas flow measurements [2]. The GOPP has a direct relation to the SI-unit "meter": through measurement of its diameter and length. The prover contains a total of four well-known volumes. The piston acts as a separator between gas and oil. An oil pump is used to move the piston by drawing gas through the Meter-under-Test (MuT). For more information on the working principle of the GOPP, see [3].

The uncertainty in the determination of the error of the MuT has the following main components:

- Volume of the discrete prover sections
- Pressure and temperature measurement of the gas in the prover and at the MuT
- Line-pack effects
- Leakage across the piston (along the seals)
- Repeatability of the MuT

*E-mail: mworkamp@vsl.nl, **E-mail: mschakel@vsl.nl

*Figure 1. MuT mounted on VSL's GOPP, accompanied by hydrogen gas cylinders.*

No significant changes were observed in the readings of the GOPP's leak detection system when adding hydrogen to the natural gas.

## Meter-under-Test

The MuT is a rotary gas meter with the following specifications:

| | |
|---|---|
| Manufacturer: | Itron |
| Type: | Delta S1 Flow G100 |
| Body material: | Steel |
| Size: | G100 |
| Nominal diameter: | DN50 |
| $Q_{min}$ ($m^3/h$): | 0.8 |
| $Q_{max}$ ($m^3/h$): | 160 |
| $P_{max}$ (bar): | 101.2 |

Being a rotary gas meter, at low flow rates the meter tends to underreport flow as gas leaks along the rotating pistons. It can be expected that this effect becomes more pronounced when changing from NG to HENG, as the latter has lower viscosity, although this difference is very small for the used hydrogen concentrations [4] with respect to the difference between NG and pure hydrogen [5].

## Calibration protocol

The MuT was calibrated at 9 and 16 bar at 7 different flow rates from 5 to 160 $m^3/h$, with both NG and HENG.

## Gas composition

A sample of the gas in the prover was taken directly after calibration of the flow meter. All samples were analysed by VSL's gas analysis laboratory. As there is a certain solubility of gases in the oil of the GOPP, some changes of gas composition were observed when decreasing pressure from 16 bar to 9 bar HENG. The nominal amount fraction of hydrogen in the HENG was 15 %.

# Results & discussion

High-pressure calibration results of all four calibration conditions are shown in Figure 2. Error bars indicate the expanded measurement uncertainty ($k$ = 2). The curves show that the meter has similar behaviour at all calibration conditions used with the GOPP. The error curves for NG and HENG agree fairly well. Small differences between the two different pressure levels can be observed. A calibration curve with air from VSL's atmospheric air calibration facility reveals significant deviation from the NG and HENG-curves. This indicates that, for the best accuracy, a calibration at process conditions is required.

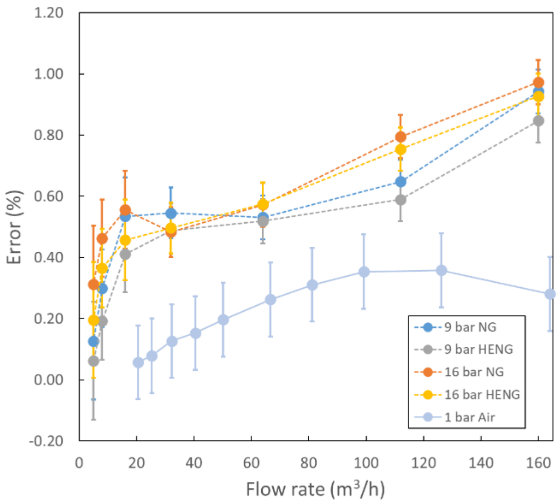


*Figure 2. Error of the MuT under the different conditions. Calibration data from VSL's atmospheric air flow facility is also included.*

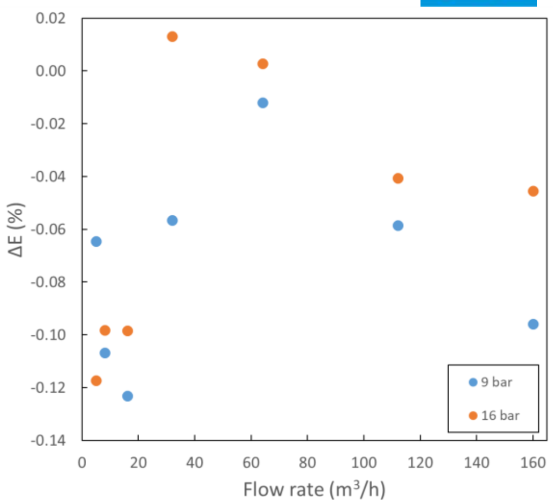


*Figure 3. Difference in meter error between the NG and HENG calibration results for the two pressure levels.*

To further investigate the difference between the NG- and HENG-curves, the difference between the two curves was calculated and plotted in Figure 3. Most differences are negative, indicating that the meter tends to underreport flow of HENG, as expected due to increased leakage along the rotors of the meter. One could interpret that the negative values are decreasing with decreasing flow, which would be expected from the fact that leakage effects of a rotary gas meter manifest stronger at low flow rates. However, the differences are smaller than the measurement uncertainty for all flow rates. Hence, from a metrological standpoint it is not possible to distinguish the performance of the meter between NG and HENG. Note that the lowest flow rate used is significantly higher than the $Q_{min}$ of the flow meter (0.8 $m^3/h$). Larger differences may occur at $Q_{min}$ of the meter as leakage through the meter will play a more dominant role there. Furthermore, for the HENG used (< 20 % hydrogen), dynamic viscosity changes between NG and HENG are very small compared to the differences between NG and pure hydrogen [5]. Consequently, one can expect larger (negative) differences between the meter response with NG and pure hydrogen.

## Conclusion

Using VSL's high-pressure Gas Oil Piston Prover primary standard (GOPP), the effect of mixing hydrogen with natural gas on the accuracy of a high-pressure flow meter was assessed for the first time. The accuracy of a G100 rotary flow meter was determined by direct calibration against primary reference values. The rotary flow meter was calibrated using both NG and HENG, at two different pressures: 9 bar and 16 bar. Although differences between errors with NG and HENG are mostly negative, these changes are insignificant from a metrological standpoint. Results indicate that, for the rotary flow meter and hydrogen admixtures (<20 % $H_2$) used, the meter error differences between high-pressure hydrogen admixture calibration and high-pressure natural gas calibration are smaller than the meter error differences between atmospheric pressure air calibration and high-pressure natural gas calibration.


## Acknowledgement

This project (NEWGASMET, 18NRM06) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. This project has received funding from the Ministry of Economic Affairs and Climate Policy of the Netherlands.

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

## Note

Results in this publication reflect the author's view. EURAMET is not responsible for any use that may be made of the information it contains.

Equipment, software and other resources identified in this whitepaper are not necessarily the best available for the purpose. Their mentioning does not constitute an endorsement.

## Author and review

This document is written by Marcel Workamp & Menne Schakel and reviewed by Adriaan van der Veen & Elvira Huizeling.

# Bibliography

[1] NEWGASMET project page, [Online]. Available: https://newgasmet.eu.

[2] EuReGa project page, [Online]. Available: https://www.euramet.org/technical-committees/tc-projects/details/project/eurega-1/.

[3] M. van der Beek and R. van den Brink, “Gas Oil Piston Prover, primary reference values for Gas-Volume,” *Flow Measurement and Instrumentation,* vol. 44, pp. 27-33, 2015.

[4] C. Zéberg-Mikkelsen, S. Quiñones-Cisneros and E. Stenby, “Viscosity prediction of hydrogen+ natural gas mixtures (hythane).,” *Industrial & engineering chemistry research,* vol. 40, no. 13, pp. 2966-2970, 2001.

[5] NIST Standard Reference Database 23, Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 9.1, DLL version number 9.1, Lemmon, E.W., Huber M.L., McLinden, M.O., Copyright 2013.

[6] NEWGASMET reports page, [Online]. Available: https://newgasmet.eu/reports.

[7] RvA scope VSL, [Online]. Available: https://www.rva.nl/scopes/details/K999.