

Euramet project 1075  
Bilateral comparison

Between the gas flow standards of the national Metrology  
Institutes of Bulgaria (BIM-NCM) and The Netherlands (VSL)

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Introduction and purpose of the bilateral comparison.

The purpose of this bilateral comparison of gas flow measurement standards is to support the Calibration and Measurement Capabilities (CMC) of the Bulgarian Institute of Metrology (BIM-NCM). This comparison has been performed under the framework of Euramet (known as project number 1075). The aim of the comparison was that the measurement errors at different flow rates between the three gas flow measurement standards found using three flow meters did not exceed the summed uncertainty claims of the two gas flow measurement standards according to the  $E_n$  value calculation for bilateral comparisons ( $E_n < 1$ ). VSL was the pilot laboratory for the bilateral comparison due to the fact that VSL has an entry in the International Bureau of Weights and Measures (BIPM) Mutual Recognition Arrangement (known as the CIPM MRA) for gas flow measurement. For this bilateral comparison VSL has used Euramet Guide no. 3 -Euramet Guidelines on Conducting Comparisons. In addition VSL has followed the technical aspects of ILAC guideline G13 -ILAC Guidelines for the Requirements for the Competence of Providers of Proficiency Testing Schemes.

Dordrecht,

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## 1 The reference value

To compare the two gas flow measurement standards three well known flow meters have been selected. For flow measurement standards it is impossible to have a direct reference value like a volume of a prover tank. Therefore the reference value is the measurement error of the quantity indication, in this case the error in volume of the flow meters at given flow-rates. The volumetric measurement error is defined as:

$$V_{\text{error}} = \frac{V_{\text{indication}} - V_{\text{reference}}}{V_{\text{reference}}} * 100\% \quad (1.1)$$

$V_{\text{error}}$  = The measurement error in the volume indication of the flow meter

$V_{\text{indication}}$  = The measurement indication as given by the flow meter under test

$V_{\text{reference}}$  = The volume that has passed through the reference flow meter

In this formula  $V_{\text{indication}}$  is the volumetric volume that is indicated by the flow meter under test during a test run and  $V_{\text{reference}}$  is the volume that passes through the reference flow meter during a test run. To determine this  $V_{\text{reference}}$  a calculation has to be made that determines the volume that has passed through the reference flow meter.

During the comparison all the flow rates that are mentioned in the protocol will be used in the evaluation of the results.

## 2 Specification of the measurement standards

### 2.1 Specification of the gas flow standard of BIM-NCM

The gas flow measurement standard used by BIM is a test rig that is based on venturi nozzles which are used at their critical flow. The flow rate through the nozzle depends on the geometry of the nozzle and the thermodynamic behavior of the gas upstream of the nozzle. The medium used is ambient temperature air. The test rig consist of 11 nozzles that can be individually selected or put parallel so that different flow rates can be selected [1]. A maximum of six different nozzles can be put parallel to achieve a defined flow rate. The maximum flow rate of the test rig is 70,7 m<sup>3</sup>/h and the minimum flow rate of the test rig is 0,025 m<sup>3</sup>/h.

The vacuum pump assures the necessary pressure difference over the nozzles in order to deliver the needed flow to calibrate the meter under test. As can be seen in the layout the calibration rig is supplied with pressure and temperature transmitters at the location of the meter under test and with pressure transmitters at the location of the nozzles. In total there are eight temperature transmitters, nine sensors for absolute pressure and a hygrometer to measure air humidity in the range of 10% to 90%. During a calibration relevant calibration parameters are recorded by data acquisition with PC and software. The nozzles are periodically calibrated at PTB and the temperature and pressure transmitters at the national center of metrology.

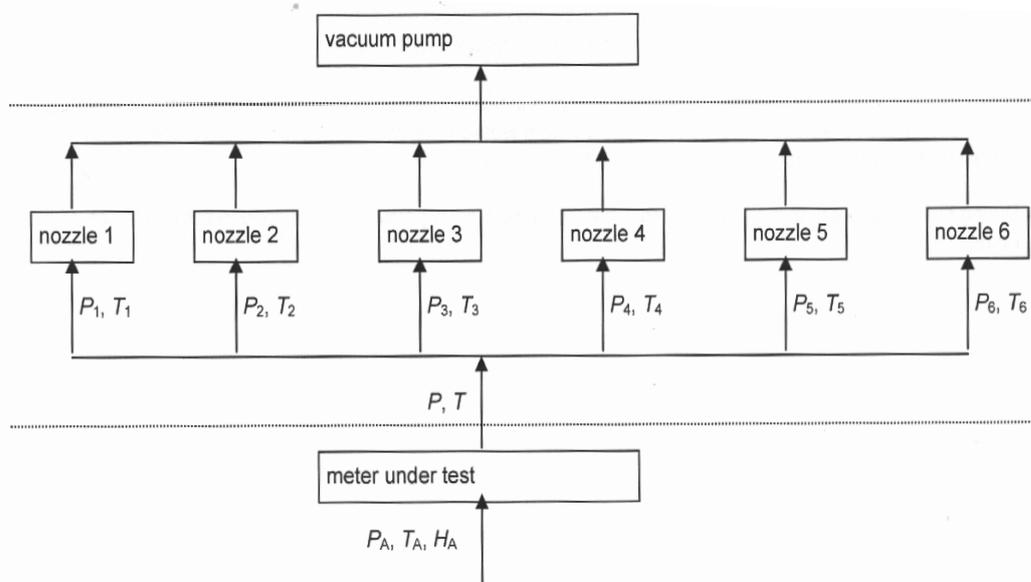


Figure 1: Layout of the calibration rig of BIM with the maximum number of nozzles that can be put parallel.

## 2.2 Specification of the gas flow standard of VSL

The gas flow travel standards that are used by VSL during the bilateral comparison are the following. A 1 liter wet gas travel meter and a 5 liter wet gas travel meter.

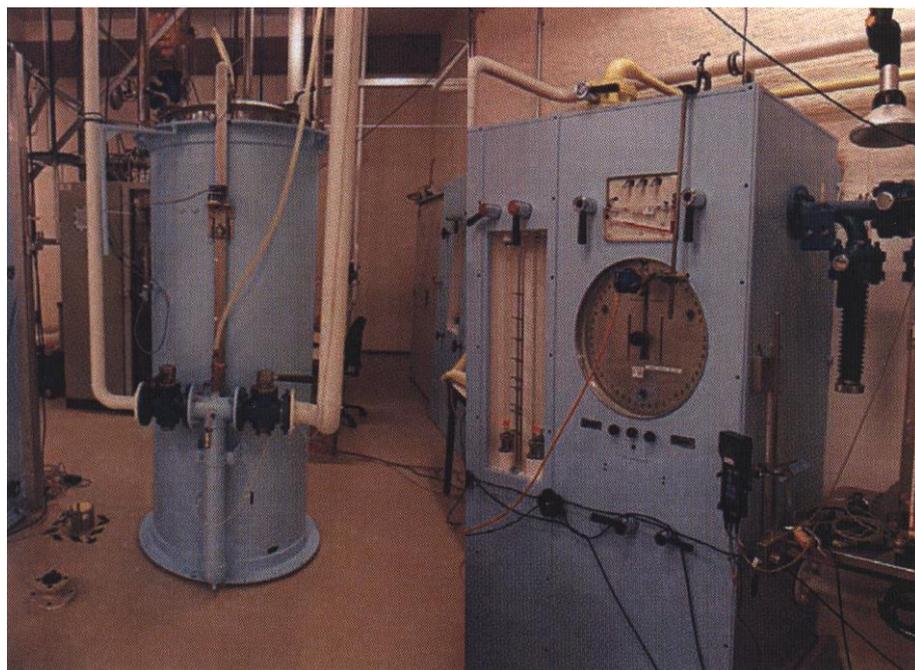
To calibrate the 1 liter wet gas travel meter a 5 liter wet gas master was used as a reference. For the 5 l wet gas travel meter the 5 l and a 50 l wet gas meter were used as a reference standard. The 5 and 50 liter wet gas reference meter are calibrated on a regular basis. The uncertainty of the 5 liter wet gas reference meter is 0.24% and the uncertainty of the 50 liter wet gas reference meter is 0.21%. The manufacturer of both wet gas meters is "Meterfabriek Dordrecht".

The calibration of the G40 travel meter was performed on a bell prover. The bell prover is divided in three different volumes. These volumes are 200, 100 and 30 liters. The uncertainties of the different volumes of the bell prover are 0.15 % for the 30 liter volume, 0.16 % for the 100 liter volume and 0.20% for the 30 liter volume.

Both calibration set ups are equipped with temperature and pressure transmitters. The data acquisition, recording of the readout of the flow meter, temperature and pressure is performed manually. The tests are performed under atmospheric pressure.

Type	ID code[-]	Manufacturer	CMC (%)
5 Liter wet gas meter	10V35/0608	"Meterfabriek Dordrecht"	0.24
50 Liter wet gas meter	10V35/0601	"Meterfabnek Dordrecht"	0.21
Bell prover (0.50 m <sup>3</sup> )	10V21/1601	"Wilson"	0.15; 0.16; 0.20

Table 2.1: References used at NM1-VSL in Delft in the comparison.



*Figure 2.1: On the left the bell prover make "Wilson" and on the right the 50 liter wet gas meter make "Meterfabriek Dordrecht".*

### 3 The test protocol

#### 3.1 Description of the travel standards

Three travel standards are used in the comparison. Two travel standards are of the type wet gas meter and one is of the type rotary piston meter. In the table below the specifications of the travel standards are mentioned further.

Description	Meter no. 1:	Meter no. 2:	Meter no. 3:
Principal	Wet gas meter	Wet gas meter	Duo rotor meter
Make	Schlumberger	Meterfabriek Dordrecht	Elster-Instromet B.V.
Model	1 liter	5 liter	G40
Serial number	26023/1986	21306/1972	20515215/2008
Minimum flow	16 l/h	60 l/h	0,5 m <sup>3</sup> /h
Maximum flow	300 l/h	1200 l/h	65 m <sup>3</sup> /h

Table 3.1: Description of the three travel standards used in the comparison.

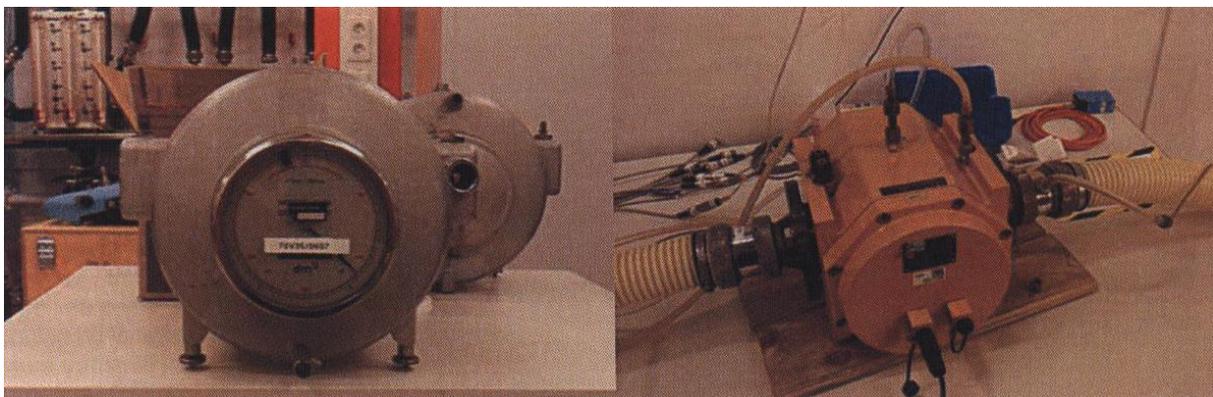


Figure 3.1: On the left the 5 liter wet gas meter, make "Meterfabriek Dordrecht", on the right G40 duo rotor meter, make "Elster-Instromet B. V."

### 3.2 Measurement protocol, flow rates and flow points

To perform the comparison a number of flow rates were chosen. These flow rates were chosen in such a way that there would be overlap between the different flow standards. And also that the whole range of the calibration rig of BIM-NCM could be compared with the flow standards of NMI. In the table below the different flow rates and flow points can be seen. The tests are performed with ambient air at local conditions.

The readout of the G40 flow meter is a pulse output. The pulse can be connected at the center two pins of the six pins that are available. The readout of the wet gas meters is an analog readout.

The setup of the wet gas meters is especially important. The wet gas meters are filled with oil and the oil level should be set at such a level that the pin that is used to set oil level does not break the oil level. The flow meter should be level when filling the flow meter.

During the comparison relevant flow parameters are recorded and reported to NMI-VSL.

Flow meter [-]	Flow rates [m <sup>3</sup> /h]	Number of runs per flow rate [-]
Wet gas meter "Schlumberger"	0.025; 0.040; 0.060; 0.13; 0.27	5
Wet gas meter "Meterfabriek Dordrecht"	0.13; 0.27; 0.41; 0.83; 1.10	5
Duo rotor meter "Elster Instromet"	0.83; 1.10; 5.06; 20.0; 39.7; 64.6	5

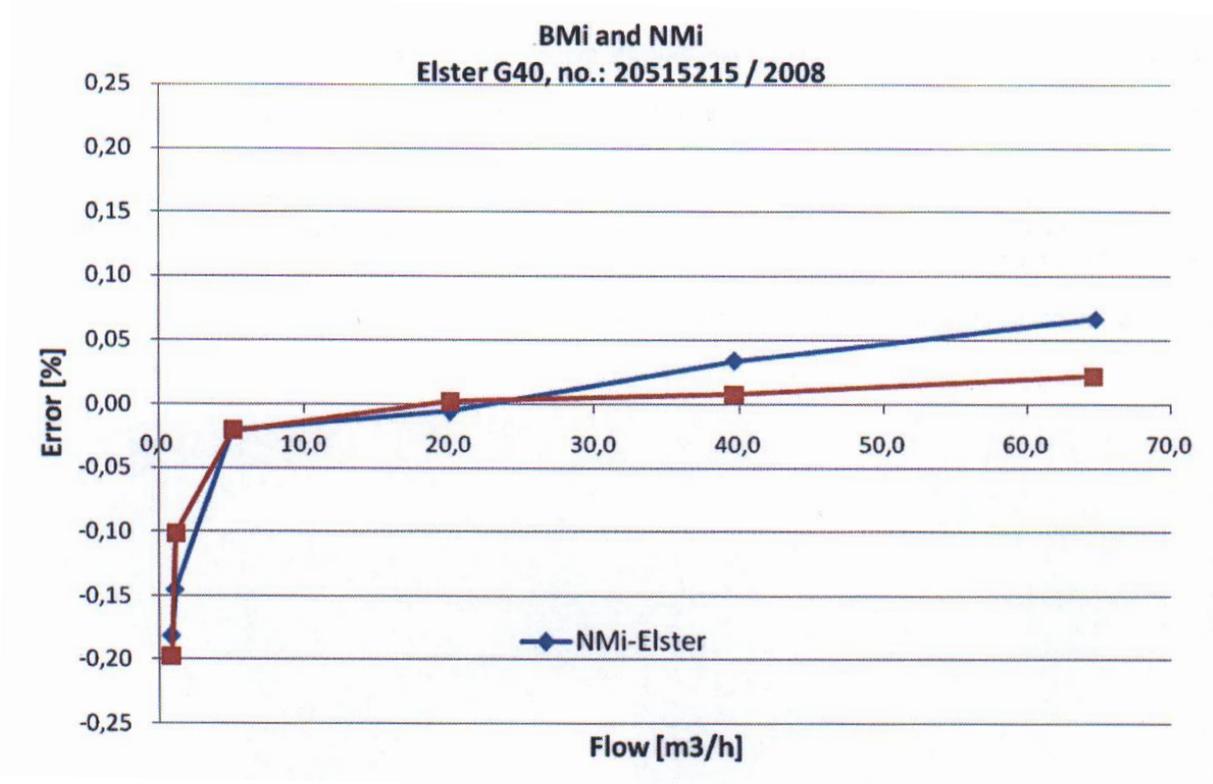
Table 3.2: The flow rates and number of runs per flow rate that have been used in the comparison.

## 4 Summarized results of the flow meters

To be able to compare the results of the comparison the measurement results were put into graphs. The numerical overview of the results can be found in chapter 5 and 6. The first graph shows the results of the Elster Duo Rotor meter, the second graph shows the results of the 5 liter wet gas meter and the third graph shows the results of the 1 liter wet gas meter.

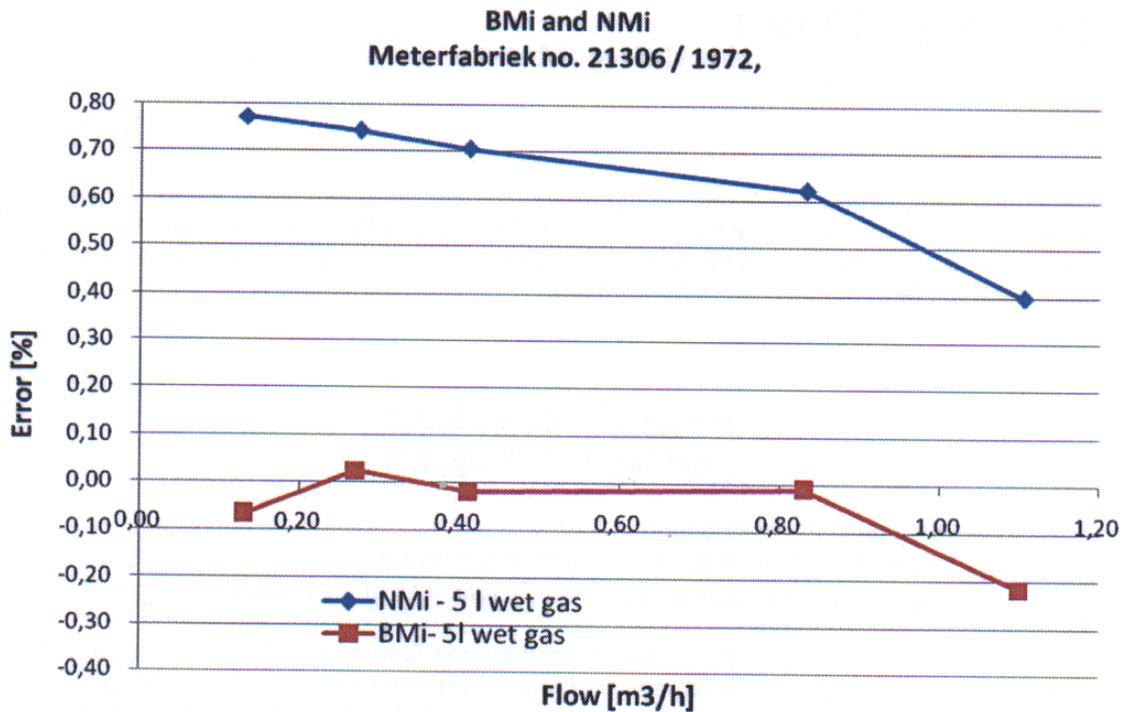
### 4.1 Results overview

#### 4.1.1 Elster IRM-A-DUO / G40, no.: 20515215 / 2008



Graph 4.1.: The graphical results of the found errors of BIM and NMI-VSL.

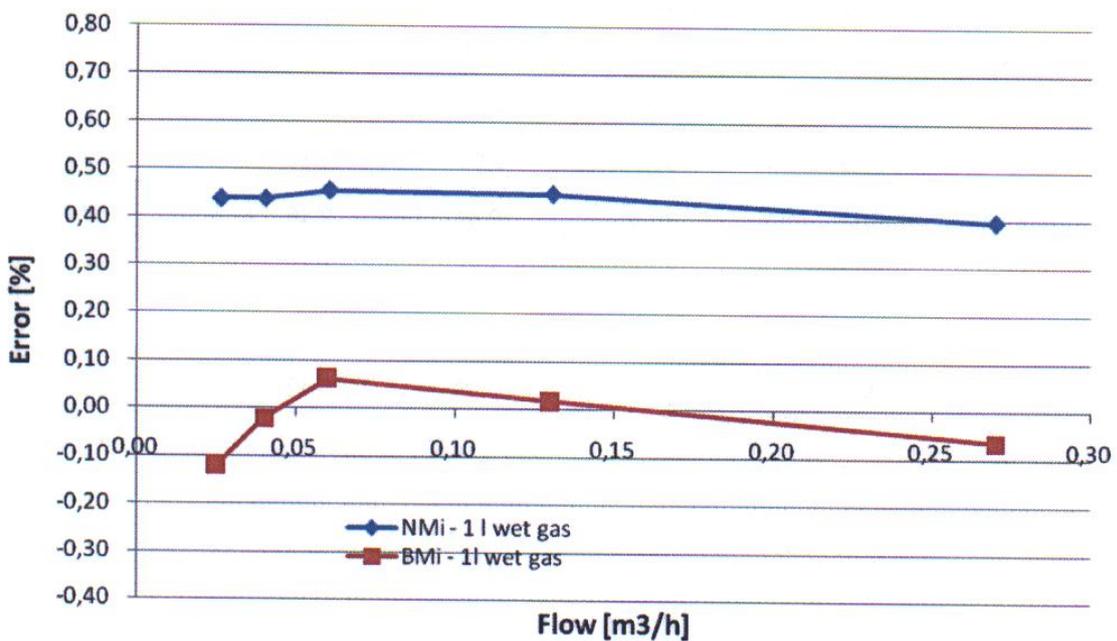
4.1.2 5-dm3 wet gas, Meterfabriek no. 21306 / 1972



Graph 4.2.: The graphical results of the found errors of BIM and NMi-VSL.

4.1.3 1-dm3 wet gas, Schlumberger no. 26023 /1986

BMi and NMi  
Schlumberger no. 26023 / 1986



Graph 4.3.: The graphical results of the found errors of BIM and NM1-VSL.

## 5 Calculation of the $E_n$ values based upon the uncertainty claims

To evaluate the bilateral comparison the so called  $E_n$  value should be calculated. An  $E_n$  value of 1 and smaller indicates measurement results that overlap.  $E_n$  values of 1 and larger indicate measurement results that do not overlap. For each flow rate this calculation is performed.

The formula for the  $E_n$  is:

$$E_n = \frac{X_{lab} - X_{pilot}}{\text{Sqrt}(U_{exp lab}^2 + U_{exp pilot}^2)} \quad (5.1)$$

In this formula

$E_n$  = the  $E_n$  value in the comparison

$X_{lab}$ ,  $X_{pilot}$  = the reported errors in the measurement results

$U_{exp lab}$ ,  $U_{exp pilot}$  = The calculated expanded uncertainties of the measurement results

In the tables below the results can be seen of the calibration of the three flow meters. The table indicates the flow rates at which the error was determined. The mean error of the five calibration runs and the expanded uncertainty of the reported error. Finally at the end of the table the  $E_n$  values are indicated as they are calculated from the reported errors and uncertainties.

### 5.1 $E_n$ values of Elster IRM-A-DUO / G40, no.: 20515215 / 2008

BIM			NMI			BIM-NMI
Flow rate (m <sup>3</sup> /h)	Mean error (%)	$U_{exp}$ (%)	Flow rate [m <sup>3</sup> /h]	Mean error [%]	$U_{exp}$ (%)	$E_n$ (-)
64.6	0.02	0.17	64.8	0.07	0.16	-0.19
39.7	0.01	0.15	39.7	0.03	0.16	-0.12
20.0	0.00	0.16	20.0	-0.01	0.16	0.03
5.06	-0.02	0.14	5.07	-0.02	0.16	0.00
1.10	-0.10	0.17	1.10	-0.14	0.16	0.18
0.83	-0.20	0.17	0.83	-0.18	0.17	-0.06

Table 5.1.: Flow rates, found errors and  $E_n$  results of the Elster IRM-A -DUO / G40

### 5.2 $E_n$ values of 5-dm<sup>3</sup> wet gas, Meterfabriek no. 21306 / 1972

BIM			NMI			BIM-NMi
Flow rate	Mean error	$U_{exp}$	Flow rate	Mean error	$U_{exp}$	$E_n$
[m <sup>3</sup> /h]	[%]	[%]	[m <sup>3</sup> /h]	[%]	[%]	[-]
1.1	-0.22	0.18	1.11	0.40	0.23	-2.12
0.83	-0.01	0.17	0.83	0.62	0.22	-2.31
0.41	-0.02	0.18	0.41	0.71	0.21	-2.60
0.27	0.02	0.18	0.27	0.75	0.21	-2.62
0.13	-0.07	0.21	0.13	0.77	0.21	-2.81

Table 5.2.: Flow rates, found errors en  $E_n$  results of the 5 liter wet gas meter Meterfabriek

### 5.3 $E_n$ values of 1-dm<sup>3</sup> wet gas, Schiumberger no. 26023 11986

BIM			NMI			BIM-NMi
Flow rate	Mean error	$U_{exp}$	Flow rate	Mean error	$U_{exp}$	$E_n$
[m <sup>3</sup> /h]	[%]	[%]	[m <sup>3</sup> /h]	[%]	[%]	[-]
0.27	-0.06	0.16	0.27	0.40	0.29	-1.39
0.13	0.02	0.18	0.13	0.45	0.24	-1.43
0.06	0.06	0.16	0.06	0.46	0.27	-1.27
0.04	-0.02	0.21	0.04	0.44	0.26	-1.38
0.03	-0.12	0.21	0.03	0.44	0.25	-1.72

Table 5.3.: Flow rates, found errors en  $E_n$  results of the 1 liter wet gas meter Schlumberger

## 6 Conclusion

The purpose of the bilateral comparison of gas flow standards was to support the Calibration and Measurement Capabilities (CMC) of the Bulgarian Institute of Metrology (BIM-NCM). Since the results of only one of the flow meters falls within the  $E_n$  value of 1 it is not possible to determine that the entire flow range falls within the uncertainty claims.

The results of BIM-NCM of the two wet gas meters show an offset when compared to the results from NMI-VSL.

However the results of the Elster duo rotor flow meter in the range of 0,8 to 64 m<sup>3</sup>/h are well within the  $E_n$  value of 1.

The results of the wet gas meters are more easily influenced by flow meter setup. Setting the oil level correctly is essential to be able to achieve accurate results. The handling of the G40 duo rotor flow meter is more straight forward. After interviewing and discussions with and between BIM and NMI it was established that the procedure for setting up the wet gas meter was not consistent between BIM and NMI. For this reason the measurement results for both wet gas meters are not useful for the comparison between the gas calibration standards of BIM and BIM. This indicates that the calibration daims for the higher flow rates can be verified. But it is not possible to demonstrate this, at the present moment, for flows lower than 0.83m<sup>3</sup>/h.

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## 7 Measurement results of BIM-NCM and NMi-VSL

### 7.1 Measurements results as reported from BIM-NCM

Measuring instrument: Duo rotor meter

Manufacturer: Elster

Serial number: 20515215 / 2008

Flow rate m <sup>3</sup> /h	mean error %	Unc. type A %	Unc. typeB %	Unc. A+B %	Number of runs	Degree of freedom	Coefficient of expansion	Expanded uncertainty %
0.830	-0.1973	0.0331	0.0762	0.0831	5	158.7	2.02	0.1675
1.100	-0.1014	0.0352	0.0771	0.0848	5	134.1	2.02	0.1711
5.060	-0.0209	0.0072	0.0690	0.0694	5	INF	2.00	0.1390
20.000	0.0022	0.0393	0.0688	0.0792	5	66.3	2.04	0.1615
39.700	0.0080	0.0229	0.0707	0.0743	5	444.6	2.01	0.1490
64.600	0.0222	0.0443	0.0717	0.0843	5	52.4	2.05	0.1727

Measuring instrument: Wet gas meter

Manufacturer: Meterfabriek

Serial number: 21306/1972

Flow rate m <sup>3</sup> /h	mean error %	Unc. type A %	Unc. type B %	Unc. A+B %	number of runs	degree of freedom	coefficient of expansion	expanded uncertainty %
0.130	-0.0680	0.0487	0.0935	0.1055	5	87.8	2.03	0.2140
0.270	0.0247	0.0286	0.0833	0.0881	5	360.9	2.01	0.1768
0.410	-0.0191	0.0374	0.0803	0.0886	5	125.6	2.02	0.1791
0.830	-0.0093	0.0275	0.0775	0.0822	5	320.0	2.01	0.1651
1.100	-0.2164	0.0428	0.0786	0.0895	5	76.4	2.03	0.1820

Measuring instrument: Wet gas meter

Manufacturer: Schlumberger

Serial number: 26023/1986

Flow rate m <sup>3</sup> /h	mean error %	Unc. type A %	Unc. type B %	Unc. A+B %	number of runs	degree of freedom	coefficient of expansion	expanded uncertainty %
0.025	-0.1220	0.0199	0.1042	0.1061	5	INF	2.00	0.2125
0.040	-0.0213	0.0221	0.1043	0.1066	5	INF	2.00	0.2135
0.060	0.0617	0.0176	0.0761	0.0781	5	INF	2.00	0.1564
0.130	0.0163	0.0135	0.0904	0.0914	5	INF	2.00	0.1830
0.270	-0.0642	0.0123	0.0799	0.0809	5	INF	2.00	0.1620

## 7.2 Measurement results from NMI-VSL

Measuring instrument: Duo rotor meter

Manufacturer: Elster

Serial number: 20515215/2008

Flow-rate [m <sup>3</sup> /h]	Mean error [%]	U <sub>b</sub> [%J]	U <sub>a</sub> [%]	U <sub>exp</sub> [%]
64.8	0.07	0.16	0.02	0.16
39.7	0.03	0.16	0.02	0.16
20.0	-0.01	0.16	0.01	0.16
5.07	-0.02	0.16	0.02	0.16
1.10	-0.14	0.16	0.03	0.16
0.83	-0.18	0.16	0.07	0.17

Measuring instrument: Wet gas meter

Manufacturer Meterfabriek

Serial number: 21306/1972

Flow-rate [m <sup>3</sup> /h]	Mean error [%]	U <sub>b</sub> [%J]	U <sub>a</sub> [%]	U <sub>exp</sub> [%]
1.11	0.40	0.21	0.09	0.23
0.83	0.62	0.21	0.06	0.22
0.41	0.71	0.21	0.04	0.21
0.27	0.75	0.21	0.01	0.21
0.13	0.77	0.21	0.01	0.21

Measuring instrument: Wet gas meter

Manufacturer Schlumberger

Serial number: 26023/1986

Flow-rate [m <sup>3</sup> /h]	Mean error [%]	U <sub>b</sub> [%J]	U <sub>a</sub> [%]	U <sub>exp</sub> [%]
0.27	0.40	0.24	0.16	0.29
0.13	0.45	0.24	0.03	0.24
0.06	0.46	0.24	0.12	0.27
0.041	0.44	0.24	0.09	0.26
0.027	0.44	0.24	0.05	0.25

## **8 Reference documents**

- 1 Euramet Guide no. 3 "Euramet Guidelines on Conducting Comparisons".
- 2 ILAC guideline G13 "ILAC Guidelines for the Requirements for the Competence of Providers of Proficiency Testing Schemes"
- 3 JCGM 100:2008 "Evaluation of measurement data — Guide to the expression of uncertainty in measurement"
- 4 EA 4/02 Expression of the Uncertainty of Measurement in Calibration