Coomet project No. 452/SK/09
COOMET.M.FF-S4

# Comparison of cold water flow calibration laboratories in a range of flow rates (3 - 20) $m^3/h$

## Final report

**Coordinator of the project**

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**Bratislava, March 2013**

# 1 Introduction

The aim of the project was to compare the performance of water flow calibration laboratories. The meters used for the comparison were two flow meters KROHNE Optiflux 2010 C/D DN 40 and Meistream Plus 40. Parameters were examined in a range of flow rates (3 -20) $m^3/h$.

# 2 Participants and a time schedule

The meters were calibrated in five laboratories as listed in Tab. 1 below. Each laboratory had several weeks for doing the measurements and for sending the meters to the following laboratory. Due to problems with customs documents the meters were delayed in some laboratories. The meters were calibrated twice at the beginning, at the end and twice during the travelling period at the pilot laboratory. The stability of meters were checked during these measurements. The calculation unit of flow meter KROHNE Optiflux 2010 C/D was out of order during a transport and it should be replaced with the other one. This change had influence on technical results and we cannot include these date.

*Tab.1 - Participants and the time schedule*

| Country | Laboratory | Address of the place of calibration | e-mail, Telephone, Fax | Date of calibration | Responsible person |
|---|---|---|---|---|---|
| Slovakia (PILOT LAB) | SMÚ | SMÚ Karloveská 63, 842 55 Bratislava 4, Slovakia | benkova@smu.gov.sk Tel. +421 2 60294 202 Fax. +421 2 60294 332 | August 2008 | Miroslava Benkova |
| Cuba | Inimet | Inimet, Consulado 206, Centro Habana CP.10200 Cludad de la Habana | franco@inimet.cu (53-7) 862 3041 | January 2009 | Dr. Ing. Jose Franco Fernández |
| Mexico | Cenam | Carretera a los Cués Municipio, El Marqués , C.P. 76246, Querétaro, México | aloza@cenam.mx +52 442211 3765 | March 2009 | Alejandro Loza |
| Slovakia (PILOT LAB) | SMÚ | SMÚ Karloveská 63, 842 55 Bratislava 4, Slovakia | benkova@smu.gov.sk Tel. +421 2 60294 202 Fax. +421 2 60294 332 | September - November 2009 | Miroslava Benkova |
| Lithuania | LEI | 3 Breslaujos str. LT-44403 Kaunas Lithuania | zygmanta@isag.lei.lt Tel. + 370 37 40 18 63 Fax. + 370 37 35 12 71 | January 2010 | Gediminas Zygmantas |

| Country | Laboratory | Address of the place of calibration | e-mail, Telephone, Fax | Date of calibration | Responsible person |
|---|---|---|---|---|---|
| Slovakia (PILOT LAB) | SMÚ | SMÚ Karloveská 63, 842 55 Bratislava 4, Slovakia | benkova@smu.gov.sk Tel. +421 2 60294 202 Fax. +421 2 60294 332 | January - February 2010 | Miroslava Benkova |
| Ukraine | UKRMETRTEST STANDART | Metrologichna St. 4, Kyiv, 03680, Ukraine | ukrcsm@ukrcsm.kiev.ua jkuzmenko@ukrcsm.kiev.ua Tel. +38 044 526 3436 | February 2010 | Jurij Kuzmenko |
| Slovakia (PILOT LAB) | SMÚ | SMÚ Karloveská 63, 842 55 Bratislava 4, Slovakia | benkova@smu.gov.sk Tel. +421 2 60294 202 Fax. +421 2 60294 332 | May 2010 | Miroslava Benkova |

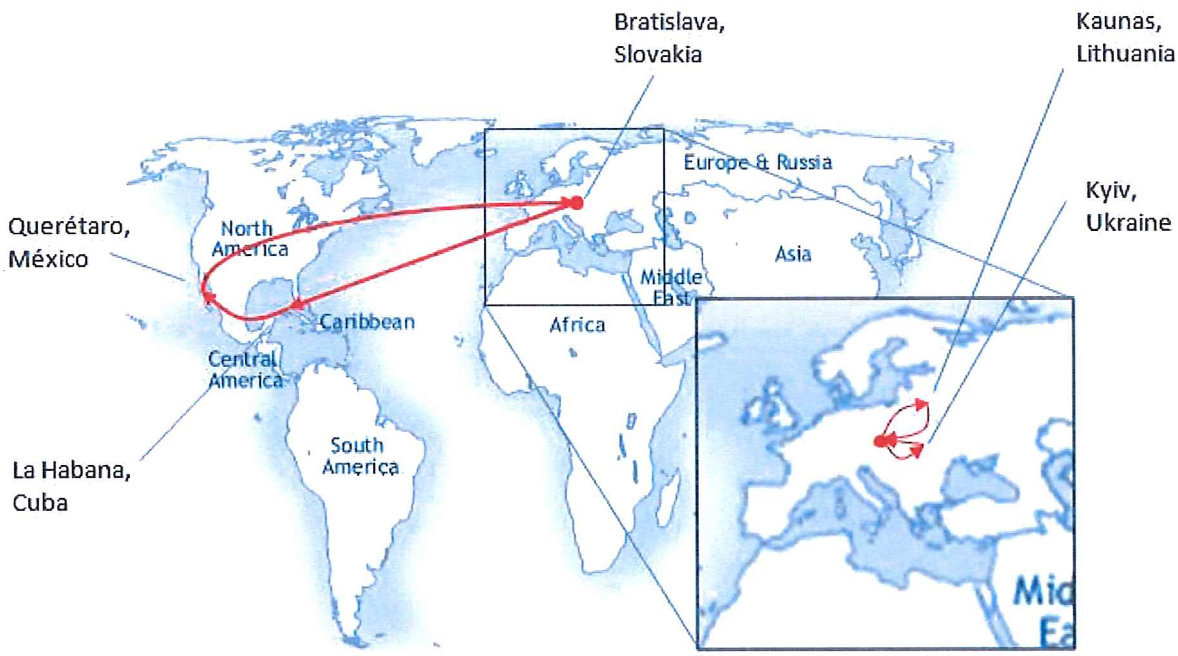



*Fig.1 Participants*

# 3 Transfer standards

Electromagnetic flowmeter KROHNE (Optiflux 2010 C/D) and Meistream Plus 40 were used as a transfer standard. The owner of the meters is SMU. The meter with serial number A08 02103 was denoted as No.1 and the meter with serial number 080049508 was denoted No.2 in the text. The inside diameter of the meters was DN 40. The meters were equipped with fixed inlet and outlet straight pipe sections (*Fig.2*). The sizes of pipes and the meter are shown in *Fig.3a and 3b.*

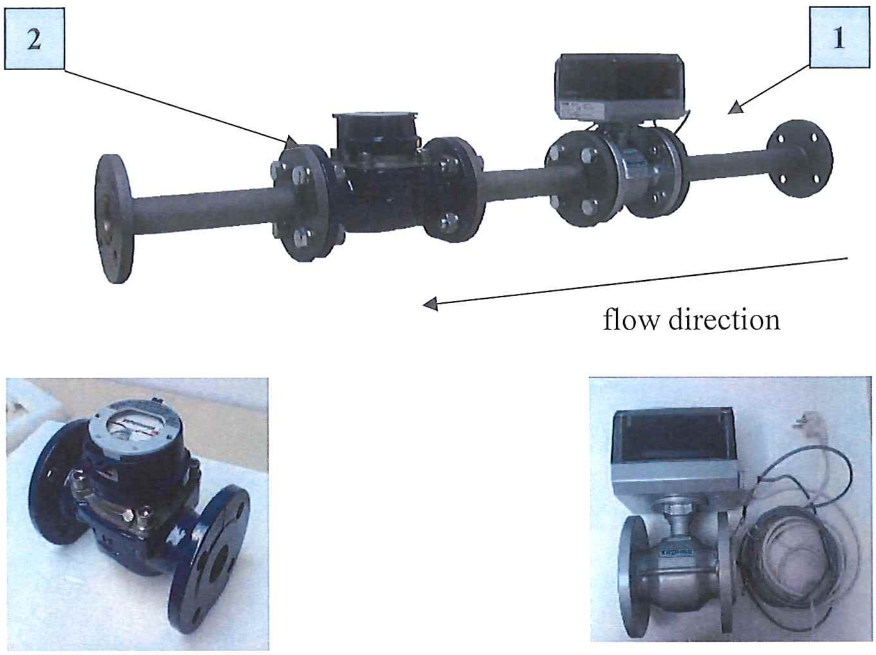



*Fig.2 – Electromagnetic flowmeter KROHNE* (1) *and flowmeter Meistream Plus* (2)

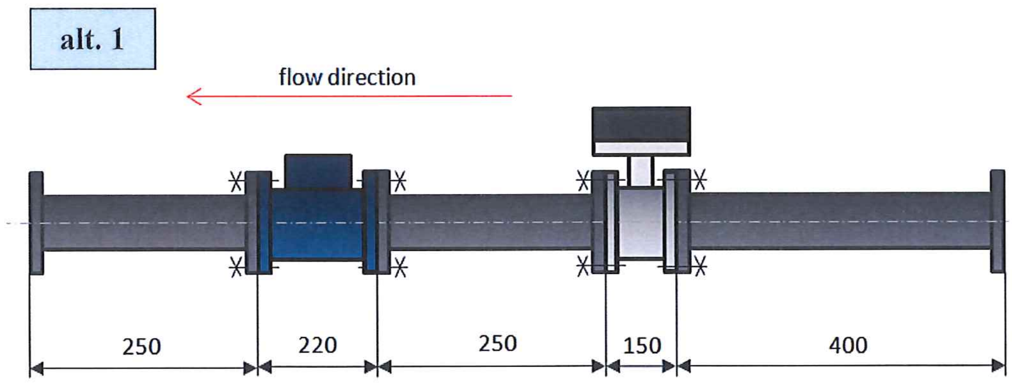



*Fig.3a – Dimensions of the meters in millimetres for alternative 1*

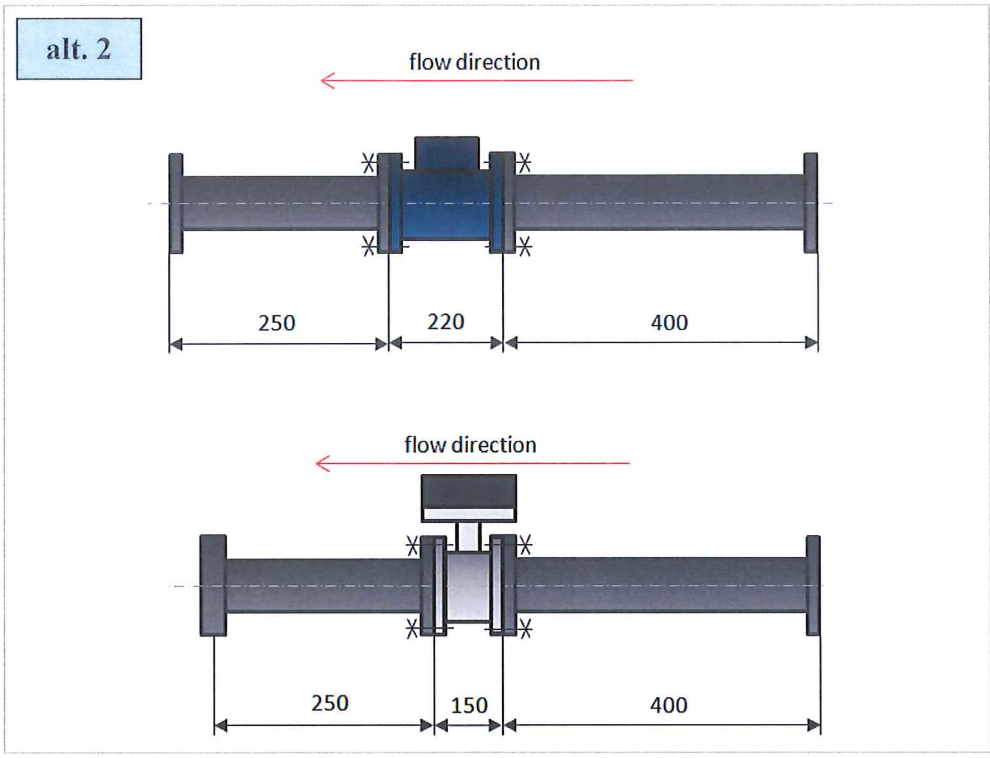
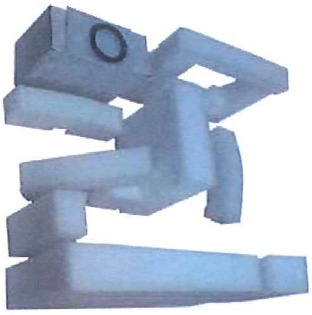
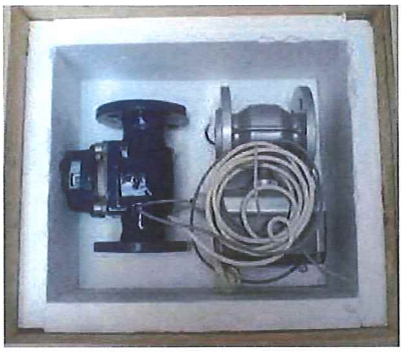



*Fig.3b – Dimensions of the meters in millimetres for alternative 2*

The meters were packed in wooden boxes depicted in *Fig. 4*. Dimensions of box are (560 x 470 x 522) mm. The weight of a complete box with a meter was approximately 43,2 kg.





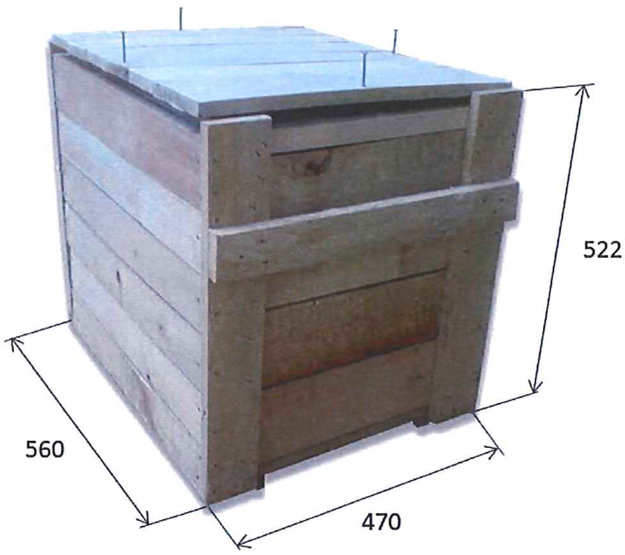



*Fig.4 – The wooden box for the transfer standards*

# 4 Test procedure

## 4.1 Method

The participating laboratories used their usual calibration procedure.

## 4.2 Reference conditions

- The calibration medium will be water with el. conductivity ≥ 20 μS/cm
- Water temperature: (20 ± 5)°C
- Water pressure downstream of the meter: optional
- Ambient temperature range: 15 °C to 25 °C
- Ambient relative humidity range: 30 % to 75 %
- Ambient atmospheric pressure range: 86 kPa to 106 kPa (0,86 bar to 1,06 bar)

### 4.3 Instructions for measurement

- Both flow-meters can be examined separatelly under the same conditions.
- Both flow-meters will be examined for the following 5 values of reference flow rate *Q*: (3; 5; 10; 15; 20) $m^3/h$.
- The standard value of flow rate has to be in an interval ± 3% of the reference value for each single measurement.
- The test in one flow rate should be repeated at least 10 times.
- The flow-meter has to be installed in the test rig such that possible disturbances of the flow velocity field in the meter due to imperfect smoothness of the connection of pipes are minimized.
- The flow-meters has to be switched on at least 30 min. before measurements.

# 5 Overview of participants' facilities and measurement methods

## 5.1 Slovakia – SMU

Establishment of the national standard of flow-rate and of delivered volume of water is constructed taking into consideration the requirements for quality system and requirements for possibility of measuring instruments tests. These tests are based on the different measuring principles with requirement to use different measuring methods (weighing or volumetric with flying or fixed starts with direct reading of impulses or a method of complete impulses). Also measuring instruments with mechanical counter, passive impulse output and active impulse output can be used. The device is composed of the following parts - source of flow-rate with a system of overflow tank, measuring lines – small and medium measuring lines, flow-meter branches, 3 different weighing systems and controlling system of measurement. The main parameters of equipment are:

| | |
|---|---|
| Measuring range of flow rate: | (0,006 - 250) $m^3/h$ |
| Connecting diameter: | DN 10 - DN 150 |
| Minimum of testing delivered volume: | 3 $dm^3$ |
| Maximum of testing delivered volume: | 5 000 $dm^3$ |
| Water temperature: | (10 - 85) °C |
| Expanded uncertainty of measurement ($k$=2): | (0,05 - 0,20)% |

The measurements were done on the Slovak national standard of flow-rate and delivered volume of water mentioned above. The volume of water delivered through the tested measuring instrument is evaluated at balances by a gravimetric method within the calculation for delivered volume. From the testing methods point of view we used the weighing method with method of complete impulses and flying starts. The conditions during measurements and the important data for each meter are in following table:

*Tab. 2 Installation parameters of SMU*

| | |
|---|---|
| Straight inlet pipe | 660 mm DN 25 + 436 mm DN 25 |
| Straight outlet pipe | 293 mm DN 25 + 300 mm DN 50 |
| Straightener | no |

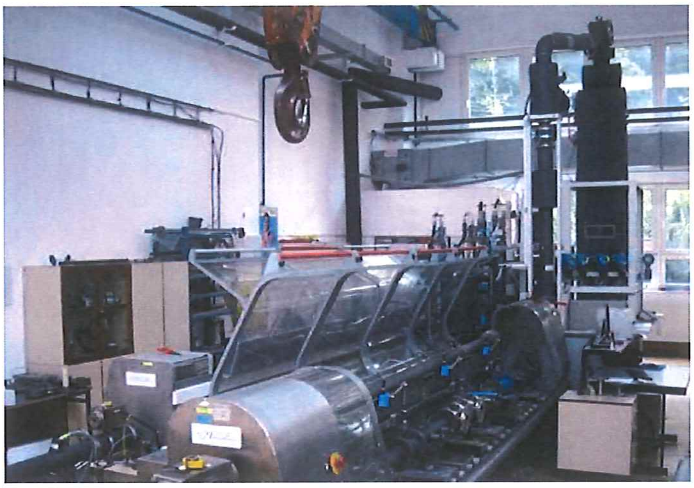


*Fig.5 View at the national standard of flow-rate and delivered volume of water*

## 5.2 Lithuania – VMT/LEI

*Tab.3 Technical parameters of flow facility of VMT/LEI*

<table>
<tr><td colspan="3">Parameter</td><td colspan="2">Specifications</td></tr>
<tr><td colspan="3">Mass flow (qm)</td><td colspan="2">0,01 - 100 000 kg/h</td></tr>
<tr><td colspan="3">Volume flow (qv)</td><td colspan="2">0,01 - 100 000 l/h</td></tr>
<tr><td colspan="3" rowspan="2">Pipe dimension (DN)</td><td>Line №1</td><td>max. 100 mm</td></tr>
<tr><td>Line №2</td><td>max. 50 mm</td></tr>
<tr><td colspan="3">Water temperature - medium</td><td colspan="2">18°C – 25 °C<br>(50°C)- not accredited</td></tr>
<tr><td colspan="3">Reservoir tank</td><td colspan="2">10 m³</td></tr>
<tr><td colspan="3" rowspan="2">Scales</td><td colspan="2">1500 kg + 60 kg (Line №1)</td></tr>
<tr><td colspan="2">600 kg + 60 kg (Line №2)</td></tr>
<tr><td colspan="3" rowspan="2">Straight pipe length upstream</td><td colspan="2">4,0 m (Line №1)</td></tr>
<tr><td colspan="2">1,0 m (Line №2)</td></tr>
<tr><td colspan="3">Length of working zone</td><td colspan="2">2,0 m (for bought lines)</td></tr>
<tr><td rowspan="4">Calibration principle</td><td rowspan="2">Calibration using mass and time (primary)</td><td>Flying start-stop with the use of a diverter</td><td colspan="2">YES</td></tr>
<tr><td>Standing start-stop</td><td colspan="2">YES</td></tr>
<tr><td rowspan="2">Calibration with a reference meter (secondary)</td><td>Flying start-stop with the use of a diverter</td><td colspan="2">YES</td></tr>
<tr><td>Standing start-stop</td><td colspan="2">YES</td></tr>
</table>

*Fig. 6 Water flow laboratory of VMT/LEI (Lithuania)*

## 5.3 Cuba - INIMET

The *Tab.4* filled for the meter No. 1 and for the meter No. 2
Water pressure downstream of the meter for each flow rate was not possible measuring
Ambient temperature, relative humidity and atmospheric pressure at the beginning and the end of measurement for each meter

*Tab. 4*

| Day | Flow | Start time | | | End time | | | Uncertainty | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | [m³/h] | *Ta* °C | *Hr* % | *Pa* hPa | *Ta* °C | *Hr* % | *Pa* hPa | $U_{TA}$ °C | $U_{Hr}$ % | $U_{Pa}$ hPa |
| 19-01-09 | 3 | 22,3 | 85 | 1017 | 23,2 | 85 | 1017 | ± 0,2 | ± 2 | ± 1 |
| 20-01-09 | 5 | 23,6 | 75 | 1011 | 23,4 | 75 | 1011 | | | |
| 20-01-09 | 10 | 23,5 | 75 | 1011 | 22,1 | 75 | 1011 | | | |
| 21-01-09 | 15 | 23,5 | 76 | 1021 | 23,4 | 76 | 1021 | | | |
| 21-01-09 | 20 | 23,5 | 76 | 1021 | 22,9 | 76 | 1021 | | | |

The facility is a volumetric one they have two provers tanks the first one capacity 100 L a second one 500 L, those have the level gauge glass tube type. The length of the calibrate meter section is about 2 m, the diameter is variable from 25 mm to 60 mm. The flow range is (1-50) m³/h.
The test procedure is a volumetric method by collection of liquid in the prover tank and compare it with meter reads.

*Fig. 7 Installation of the meters*

## 5.4 Mexico - CENAM

The water flow facility at Centro Nacional de Metrología (CENAM) constitutes México's primary standard for liquid flow measurement. The flow measurement system is based on the static weighing principle with weigh-bridges of 1 500 kg and 10 000 kg, each of them has a water diversion divice – diverter valve – to provide capabilities for flying start and stop and two volumetric standards of 500 L and 1 000 L for standing and start and stop.

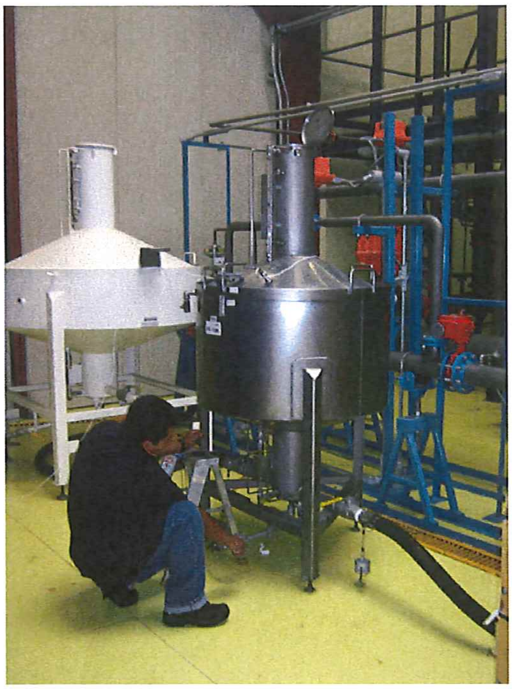


*Fig. 8 General view of the water flow facility, CENAM was used a 500 L volumetric standard*

## 5.5 Ukraine – UKRMETRTESTSTANDART (UMTS)

Calibration procedure is based on gravimetric measurement (Mettler-Toledo weighing scales). Buoyancy correction factor calculates in accordance to OIML D28 and OIML R 111-1 in respect to measurement of relative humidity, temperature and pressure of air. Density calculates in accordance to normalized formula (in Ukraine) of Governmental System of Standardized Reference Data in respect of water temperature measurements.

*Fig. 9 Installation of the meters*

Conditions by the measurements:

Meter 1:

Lengths of the straight inlet pipes – 1700 mm
Lengths of the straight outlet pipes – 950 mm
Inside diameter of pipes – 39,7 mm
No additional flow straightener.

Meter 2:
Lengths of the straight inlet pipes – 1700 mm
Lengths of the straight outlet pipes – 950 mm
Inside diameter of pipes – 39,7 mm
No additional flow straightener.

# 6 Measurement results

All the raw data collected from the participating laboratories are summarized in appendix A. Definitions of the quantities included in the tables of appendix A are listed below.

## 6.1 Definitions of the collected quantities

The particular repetitions of measurement for given reference flow rate and a given meter are labelled by an index $\alpha$. The values of this index can be $\alpha$ = 1,..., *n*, where *n* is the number of repetitions.

$Q_e$ ... The mean etalon value of flow rate, i.e. the mean of $Q_{e\alpha}$

$Q_{e\min}$ ...The minimal etalon value of flow rate, i.e. the minimum of $Q_{e\alpha}$

$Q_{e\max}$ ...The maximal etalon value of flow rate, i.e. the maximum of $Q_{e\alpha}$

*e*... The mean relative error of the meter, i.e. the mean of $e_\alpha$ given as

$$e_\alpha = \frac{V_{T\alpha} - V_{e\alpha}}{V_{e\alpha}} \cdot 100 \qquad (1)$$

where $V_{T\alpha}$ is the volume of water indicated by the transfer standard and $V_{e\alpha}$ is the volume of water indicated by the etalon

The uncertainties are calculated according to the following formulas (see *Guide to Expression of Uncertainty in Measurement* (ISO, Geneva, 1995))

Type A uncertainty type A based on statistical methods of measurement results is calculated using the following equation:

$$u_A^2 = \frac{1}{n(n-1)} \sum_{\alpha=1}^{n} (e_\alpha - \bar{e})^2 \qquad (2)$$

where *n* is the number of repetitions

Type B uncertainty is determined on the basis of non-statistical methods. It consists of square totals relevant sources of uncertainties from the mathematical model:

$$u_B = \frac{1}{V_e} \cdot \sqrt{\sum_{i=1}^{k} \left( \frac{\partial V_e}{\partial x_i} \right)^2 \cdot u^2(x_i)} \qquad (3)$$

Combined uncertainty is calculated according to the following formulas:

$$u_c = \sqrt{(u_A^2 + u_B^2)} \qquad (4)$$

The expanded uncertainty U is obtained by multiplying the combined standard uncertainty $u_c$ by expansion coefficient according to the formula:

$$U = k \cdot u_c \qquad (5)$$

The expansion coefficient used for flow rate area is *k*=2.

## 6.2 Deviations from the parameters prescribed

There are no significant deviations of the real measurement parameters from the ones prescribed in the instructions.
The deviations from the prescribed range of flow rates do not have any significant influence to the data evaluation and do not require any special corrections.
The deviations in ambient conditions also does not affect the measurement significantly as well as the water conductivity.
Measurement in series means that the flow profile in both meters will not be the same during the measurement. It does not affect the part of evaluation of the data where both of the meters are treated separately. It could have some influence on interpretation of correlations between the data from the two meters.
Any pressure corrections are not necessary for the data of the comparison since the pressure differences between labs are not greater than 6 bar.
Any temperature corrections are not necessary for the data of the comparison since the pressure differences between labs are not greater than 10°C.

## 6.3 Stability measurements at SMU

A calibration curve of both meters was obtained at SMU for times during the circulation of the meters. The results of the measurements are summarized in Tab. 5, 6 and in Fig. 10 and Fig. 11.

*Tab. 5 Errors of the meters obtained at various times at SMI. Expanded uncertainty was (0,11-0,16)%*

| Meter No. A0802103 | | | | | | | |
|---|---|---|---|---|---|---|---|
| date | *Q* | m³/h | 20 | 15 | 10 | 5 | 3 |
| 7.8.2008 | *e* | % | -0,47 | -0,52 | -0,57 | -0,65 | -0,58 |
| 26.11.2008 | *e* | % | -0,37 | -0,44 | -0,51 | -0,55 | -0,46 |
| 2.9.2009 | *e* | % | -0,26 | -0,27 | -0,29 | -0,32 | -0,40 |
| 2.2.2010 | *e* | % | -0,14 | -0,14 | -0,18 | -0,22 | -0,31 |
| 12.5.2010*) | *e* | % | -0,04 | -0,12 | -0,28 | -0,44 | -0,72 |

**) date excluded from the calculation due to changing of out of order calculation unit*

*Tab. 6 Errors of the meters obtained at various times at SMI. Expanded uncertainty was (0,11-0,16)%*

| Meter No. 080049508 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | *Q* | m³/h | 20 | 15 | 10 | 5 | 3 |
| 7.8.2008 | *e* | % | -0,32 | 0,16 | 0,49 | 0,18 | -0,19 |
| 26.11.2008 | *e* | % | -0,29 | 0,17 | 0,34 | -0,20 | -0,40 |
| 2.9.2009 | *e* | % | -0,37 | 0,09 | 0,43 | 0,38 | 0,04 |
| 2.2.2010 | *e* | % | 0,26 | 0,55 | 0,82 | 0,57 | 0,22 |
| 12.5.2010 | *e* | % | 0,30 | 0,47 | 0,37 | -0,12 | -0,48 |

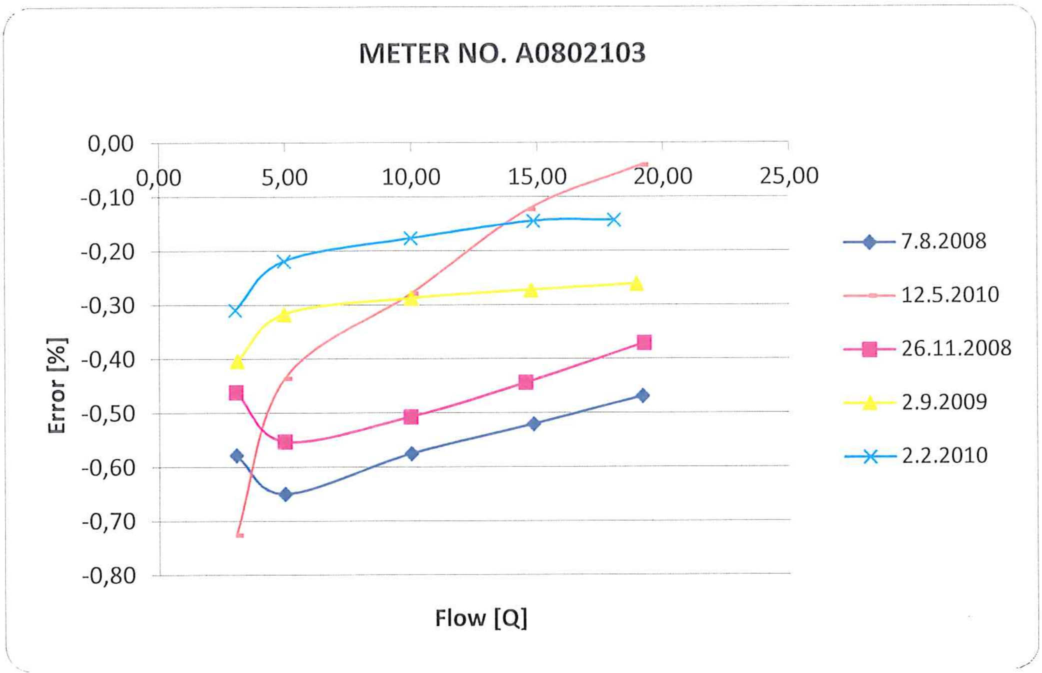



*Fig.10 Calibration curves – meter No.* A0802103, *various times*

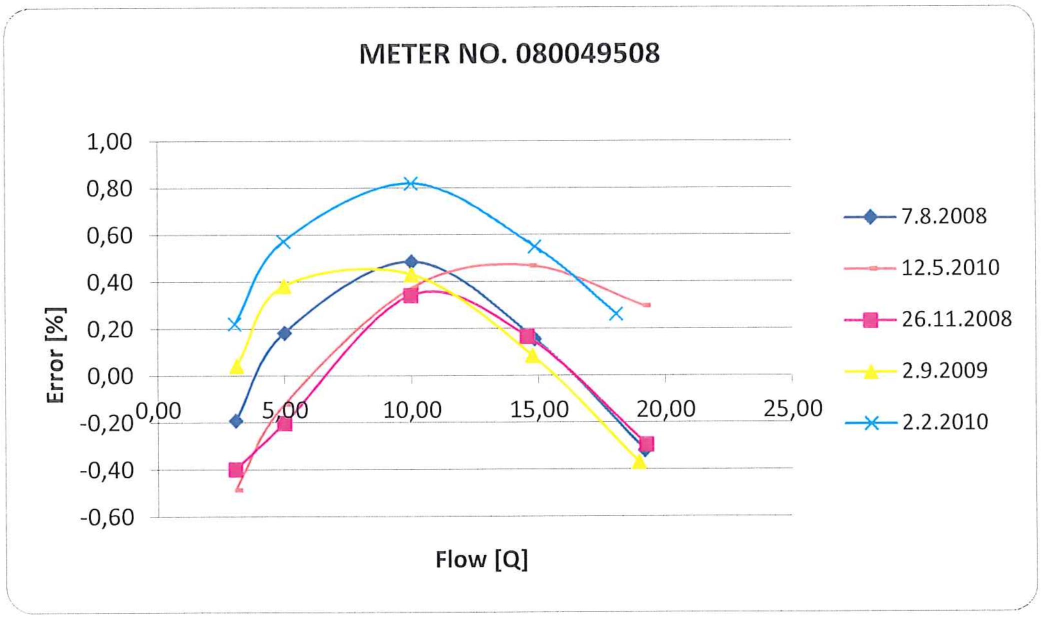



*Fig.11 Calibration curves – meter No.* 8004958, *various times*

# 7 Evaluation

The results are evaluated according to the procedure published by M.G.Cox [1]. The procedure is applied for each flow rate and for each meter separately.

## 7.1 The determination of the Comparison Reference Value (CRV) and its uncertainty

Using the notation of Cox, $x_i$ denotes the measured quantity provided by *i*-th laboratory, i.e. $x_i = e$ for *i-th* laboratory for the flow rate and the meter under considaration. The values of *i* are $i = 1,\ldots, n$ , where *n* is the number of laboratories.
The reference value *y* is calculated as weighted mean error:

$$y = \frac{\frac{x_1}{u_{x1}^2} + \frac{x_2}{u_{x2}^2} + \ldots\ldots\ldots \frac{x_n}{u_{xn}^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \ldots\ldots\ldots \frac{1}{u_{xn}^2}} \qquad (6)$$

where $u_{x1}, u_{x2},\ldots,u_{xn}$ are standard uncertainties of the error in laboratories *1,…,n* including the uncertainty caused by stability of the meter. These uncertainties are calculated as

$$u_{xi} = \sqrt{\left(\frac{U(x_i)}{2}\right)^2 + u_{st}^2} \qquad (7)$$

where $U(x_i)$ is the expanded combined uncertainty ($k=2$) determined by laboratory *i* and presented in results of laboratory *i* and $u_{st}$ is estimated standard uncertainty caused by the stability (reproducibility) of the flow-meter. The value of $u_{st}$ is obtained from the six measurements performed at the pilot institute. Uniform distribution of the data between minimal and maximal obtained value is supposed and the uncertainty is then given by the formula

$$u_{st} = \frac{(e_{\max} - e_{\min})}{2\sqrt{3}} \qquad (8)$$

In general this uncertainty includes influences of the test rig instability, meter instability and installation effects. In order to separate the test rig instability which should not be included in $u_{st}$ we check the correlation of the data from both meters. If the correlation is not significant then the uncertainty $u_{st}$ is considered to express the meter instability and installation effects only.
The standard uncertainty of the reference value $u_y$ is given by

$$\frac{1}{u_y^2} = \frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \ldots\ldots\ldots \frac{1}{u_{xn}^2} \qquad (9)$$

The expanded uncertainty of the reference value *U(y)* is

$$U(y) = 2 \cdot u_y \qquad (10)$$

The chi-square test for consistency check is performed using the values of errors of the meters for each flow rate. At first the chi-squared value $\chi^2_{obs}$ is calculated according to the formula

$$\chi^2_{obs} = \frac{(x_1 - y)^2}{u^2_{x1}} + \frac{(x_2 - y)^2}{u^2_{x2}} + .........+ \frac{(x_n - y)^2}{u^2_{xn}} \tag{11}$$

The degrees of freedom $\nu$ are calculated as $\nu = n - 1$. The consistency check fails if

$$\Pr\{\chi^2_\nu > \chi^2_{obs}\} < 0.05 \tag{12}$$

The uncertainty contribution $u_{st}$ due to the instability of the meters and installation effects was evaluated from the data in Tab. 5 and 6.

*Tab.7 Contribution to an uncertainty due to the meter stability*

| | Krohne (Optiflux 2010 C/D), No. A0802103 | | | | | Meistream Plus 40 No. 080049508 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Q* (m³/h) | 3 | 5 | 10 | 15 | 20 | 3 | 5 | 10 | 15 | 20 |
| $u_{st}$ (%) | 0,15 | 0,25 | 0,23 | 0,22 | 0,19 | 0,40 | 0,44 | 0,28 | 0,27 | 0,39 |

The errors *e* (Tab. 8) of all the participants can be found together with their declared uncertainties *U(e)* and the uncertainty raised by the meter stability and installation effects contribution $U(e)_{st}$.
The results are in following table and also graphically in appendix C and also in Fig. 11 and 12.

*Tab. 8 Summary of the data and comparison reference*

| | | Krohne (Optiflux 2010 C/D), No. A0802103 | | | | | Meistream Plus 40 No. 080049508 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Q* (m³/h) | 3 | 5 | 10 | 15 | 20 | 3 | 5 | 10 | 15 | 20 |
| SMU | *e*(%) | -0,44 | -0,43 | -0,39 | -0,34 | -0,31 | -0,16 | 0,16 | 0,49 | 0,29 | -0,08 |
| | *U(e)* (%) | 0,11 | 0,11 | 0,11 | 0,11 | 0,11 | 0,13 | 0,12 | 0,12 | 0,12 | 0,16 |
| | $U(e)_{st}$ (%) | 0,25 | 0,25 | 0,25 | 0,25 | 0,25 | 0,45 | 0,45 | 0,45 | 0,45 | 0,45 |
| INIMET | *e* (%) | -0,11 | 0,01 | 0,06 | -0,04 | -0,18 | 0,12 | 0,42 | 0,48 | 0,31 | -0,15 |
| | *U(e)* (%) | 0,15 | 0,15 | 0,12 | 0,12 | 0,12 | 0,15 | 0,15 | 0,12 | 0,12 | 0,12 |
| | $U(e)_{st}$ (%) | 0,26 | 0,26 | 0,25 | 0,25 | 0,25 | 0,45 | 0,45 | 0,45 | 0,45 | 0,45 |
| LEI | *e* (%) | -0,41 | -0,30 | -0,21 | -0,19 | -0,16 | -0,04 | 0,17 | 0,63 | 0,54 | 0,12 |
| | *U(e)* (%) | 0,13 | 0,12 | 0,09 | 0,09 | 0,09 | 0,13 | 0,14 | 0,10 | 0,09 | 0,09 |
| | $U(e)_{st}$ (%) | 0,26 | 0,25 | 0,25 | 0,25 | 0,25 | 0,45 | 0,45 | 0,45 | 0,45 | 0,45 |
| UKRMETRTEST STANDART (in all charts as "UMTS") | *e* (%) | -0,26 | -0,19 | -0,17 | -0,11 | -0,10 | -0,29 | 0,24 | 0,41 | 0,30 | -0,28 |
| | *U(e)* (%) | 0,03 | 0,05 | 0,04 | 0,04 | 0,04 | 0,10 | 0,08 | 0,10 | 0,09 | 0,07 |
| | $U(e)_{st}$ (%) | 0,25 | 0,25 | 0,25 | 0,25 | 0,25 | 0,45 | 0,45 | 0,45 | 0,45 | 0,45 |
| CENAM 1 | *e* (%) | 0,00 | -0,18 | 0,01 | 0,09 | 0,19 | -0,49 | -0,04 | 0,37 | 0,03 | -0,66 |
| | *U(e)* (%) | 0,17 | 0,17 | 0,17 | 0,17 | 0,17 | 0,24 | 0,23 | 0,24 | 0,23 | 0,24 |
| | $U(e)_{st}$ (%) | 0,26 | 0,26 | 0,26 | 0,26 | 0,26 | 0,46 | 0,46 | 0,46 | 0,46 | 0,46 |
| CENAM 2 | *e* (%) | - | -0,27 | -0,23 | -0,18 | - | -0,34 | 0,17 | 0,34 | -0,04 | -0,72 |
| | *U(e)* (%) | - | 0,18 | 0,18 | 0,18 | - | 0,32 | 0,32 | 0,32 | 0,32 | 0,32 |
| | $U(e)_{st}$ (%) | - | 0,26 | 0,26 | 0,26 | - | 0,47 | 0,47 | 0,47 | 0,47 | 0,47 |
| **CRV*)** | *y* (%) | -0,25 | -0,22 | -0,14 | -0,12 | -0,12 | -0,17 | 0,16 | 0,41 | 0,25 | -0,21 |
| | *U(y)* (%) | 0,23 | 0,23 | 0,23 | 0,23 | 0,23 | 0,4 | 0,37 | 0,37 | 0,37 | 0,40 |

**) comparison reference value*

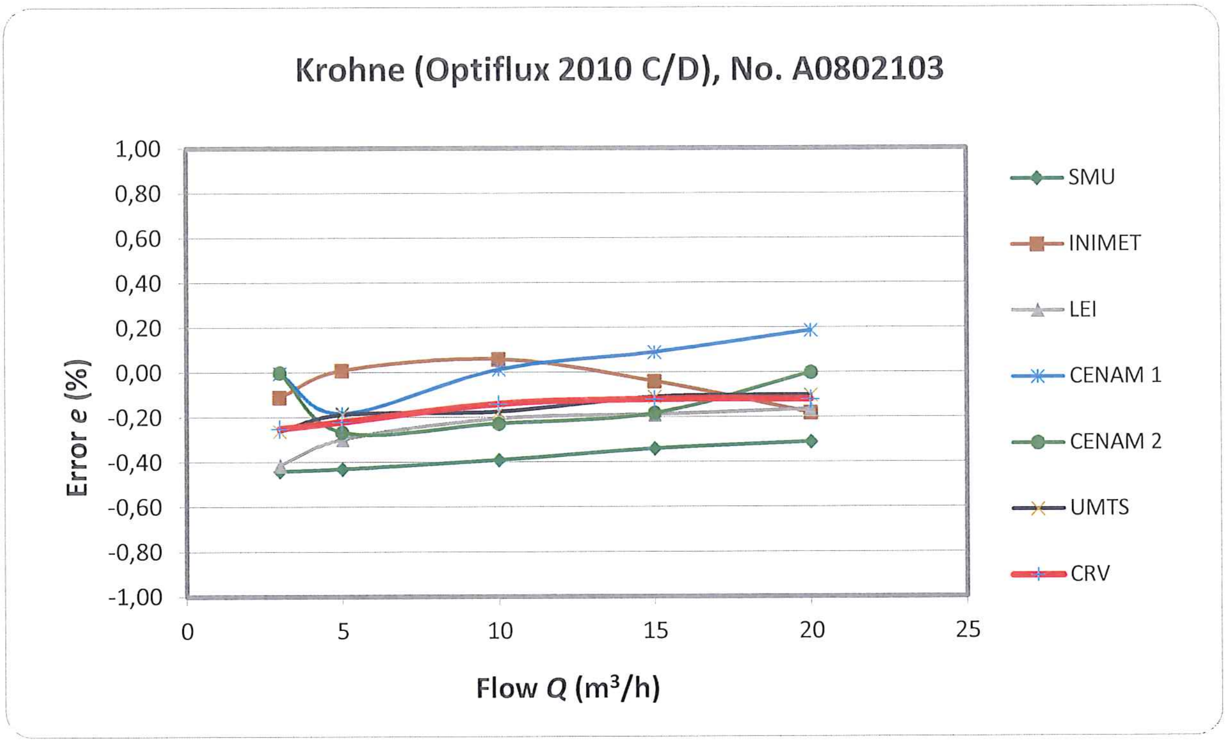



*Fig. 11 Calibration curves for various laboratories – meter No. A0802103*

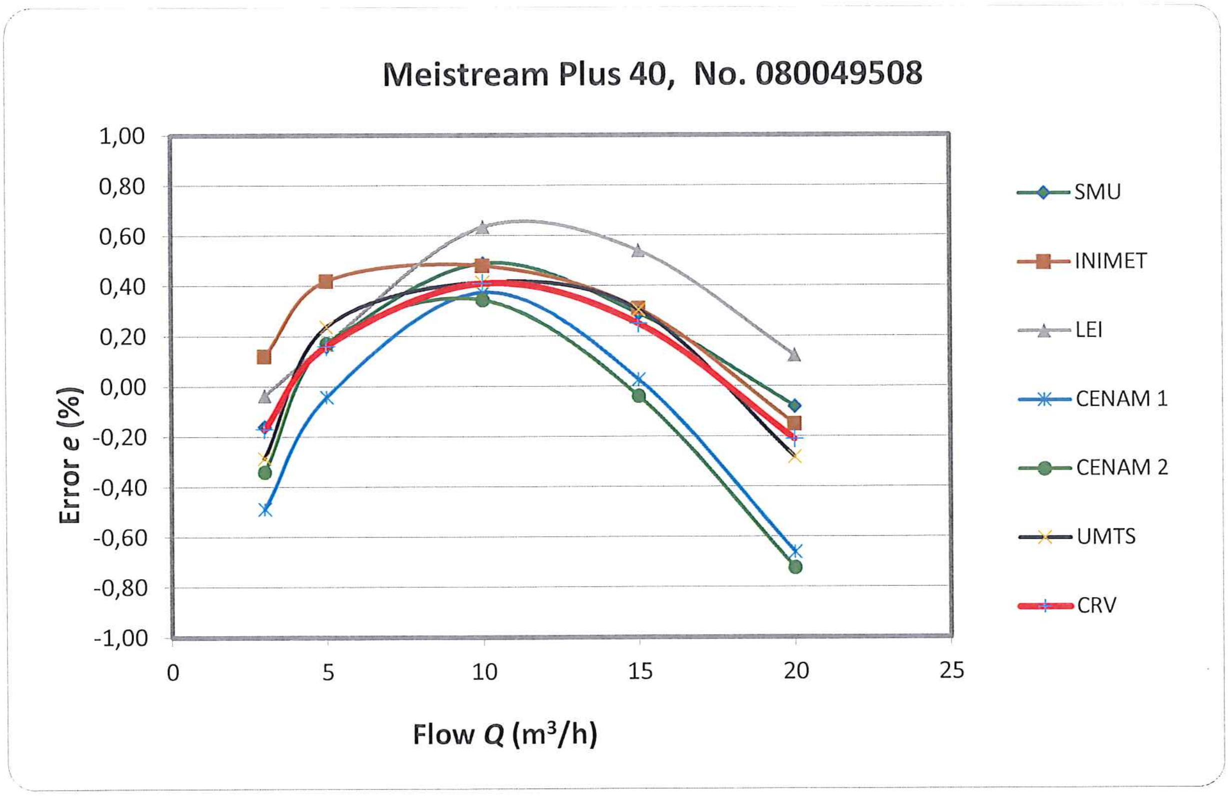



*Fig.12 Calibration curves for various laboratories – meter No.080049508*

## 7.2 The determination of the differences "Lab to CRV", "Lab to Lab" and degrees of equivalence

When the CRV is determined, the differences between the participating laboratories and the CRV is calculated according to

$$d_i = x_i - y \tag{13}$$

$$d_{ij} = x_i - x_j \tag{14}$$

In case of the CRV obtained as the weighted mean of errors of a reduced set of laboratories, the *degrees of equivalence* are calculated according to:

$$E_i = \left| \frac{d_i}{2u(d_i)} \right| \tag{15}$$

$$E_{ij} = \left| \frac{d_{ij}}{2u(d_{ij})} \right| \tag{16}$$

where

$$u(d_i)^2 = u_{xi}{}^2 - u_y{}^2 \tag{17}$$

in case when the $i$ – th laboratory is a part of the reduced set,

$$u(d_i)^2 = u_{xi}{}^2 + u_y{}^2 \tag{18}$$

in case when the $i$ – th laboratory is excluded from the set determining the reference value and

$$u(d_{ij})^2 = u_{xi}^2 + u_{xj}^2 \tag{19}$$

The *degree of equivalence* is a measure for the equivalence of the results of any laboratory with the CRV or with any other laboratory, respectively. $Ei \leq 1$ means that $i$-th laboratory is in good agreement with CRV and $Eij \leq 1$ means that $i$-th and $j$-th laboratory are in good agreement.

The "lab to CRV" equivalence degrees $E_i$ are summarized in Tab.9. The tables with "lab to lab" equivalence degrees $E_{ij}$ are summarized in appendix B.

# 8 References

[1] Cox M.G., *Evaluation of key comparison data*, Metrologia, 2002, **39**, 589-595

[2] Cox M.G., *The evaluation of key comparison data: determining the largest consistent subset*, Metrologia, 2007, **44**, 187-200

[3] Gersl, Lojek., *Intercomparison of two electromagnetic meters*, Euromet project No. 1046 – report, 2011

# 9 Conclusions

There are no significant deviations of the real measurement parameters from the ones prescribed in the instructions. Any corrections are not necessary for the data of the comparison.
The stability of the meters was check several times at pilot laboratory.

Due to problems with customs documents the meters were delayed in some laboratories. The calculation unit of flow meter KROHNE Optiflux 2010 C/D, No. A0802103 was out of order during a transport and it should be replaced with the other one. This change had influence on technical results and we cannot include these date.

Stability measurements were calculated according to the formulas in chapter 6.3. These contribution were calculated in the uncertainty of each laboratory according to the [1].

All "lab to CRV" equivalence degrees were $Ei \leq 1$ , it means laboratories are in good agreement with CRV.

*Tab. 9 Summary of "lab to CRV" equivalence degrees*

| Meter No. | Krohne (Optiflux 2010 C/D), No. A0802103 | | | | | Meistream Plus 40 No. 080049508 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Q* (m³/h) | 3 | 5 | 10 | 15 | 20 | 3 | 5 | 10 | 15 | 20 |
| SMU | 0,39 | 0,47 | 0,80 | 0,70 | 0,42 | 0,01 | 0,00 | 0,10 | 0,04 | 0,15 |
| INIMET | 0,28 | 0,50 | 0,12 | 0,13 | 0,14 | 0,36 | 0,31 | 0,09 | 0,07 | 0,07 |
| LEI | 0,34 | 0,17 | 0,43 | 0,38 | 0,10 | 0,16 | 0,01 | 0,28 | 0,35 | 0,41 |
| UKRMETRTESTSTANDART | 0,03 | 0,07 | 0,37 | 0,23 | 0,04 | 0,15 | 0,09 | 0,01 | 0,07 | 0,10 |
| CENAM 1 | 0,49 | 0,08 | 0,03 | 0,18 | 0,64 | 0,39 | 0,24 | 0,04 | 0,26 | 0,55 |
| CENAM 2 | - | 0,10 | 0,45 | 0,35 | - | 0,20 | 0,01 | 0,07 | 0,34 | 0,60 |

# Appendix A – tables with full measurement results

## Slovakia - SMU

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature | 22°C | 22°C |
| Ambient humidity | 33 % | 33 % |
| Atmospheric pressure | 98,2 kPa | 98,2 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,07 | 3,02 | 3,11 | -0,44 | - | 254,68 | 22,23 | 4,6 | 0,021 | 0,05 | 0,11 |
| 5 | 4,99 | 4,97 | 5 | -0,43 | - | 340,59 | 22,41 | 4,6 | 0,022 | 0,05 | 0,11 |
| 10 | 9,99 | 9,98 | 10,01 | -0,39 | - | 401,97 | 22,47 | 4,6 | 0,021 | 0,05 | 0,11 |
| 15 | 14,72 | 14,46 | 14,84 | -0,34 | - | 502,72 | 22,46 | 4,6 | 0,017 | 0,05 | 0,11 |
| 20 | 18,93 | 18,1 | 19,26 | -0,31 | - | 503,39 | 22,45 | 4,6 | 0,020 | 0,05 | 0,11 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature | 22°C | 22°C |
| Ambient humidity | 33 % | 33 % |
| Atmospheric pressure | 98,2 kPa | 98,2 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,05 | 3,02 | 3,07 | -0,16 | - | 272,85 | 21,85 | 4,6 | 0,031 | 0,05 | 0,13 |
| 5 | 4,98 | 4,95 | 5,00 | 0,16 | - | 362,96 | 21,00 | 4,6 | 0,029 | 0,05 | 0,12 |
| 10 | 9,99 | 9,98 | 10,01 | 0,49 | - | 395,09 | 22,38 | 4,6 | 0,032 | 0,05 | 0,12 |
| 15 | 14,71 | 14,46 | 14,84 | 0,29 | - | 500,91 | 22,47 | 4,6 | 0,028 | 0,05 | 0,13 |
| 20 | 18,93 | 18,10 | 19,26 | -0,08 | - | 495,29 | 22,47 | 4,6 | 0,058 | 0,05 | 0,16 |

## Cuba - INIMET

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature | 19 °C | 21 °C |
| Ambient humidity | 47 % | 50 % |
| Atmospheric pressure | 94,5 kPa | 95,1 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,11 | 3,11 | 3,14 | -0,11 | 10 | 0,20024 | 27,7 | 0,5 | 0,07 | 0,07 | 0,15 |
| 5 | 5,03 | 4,93 | 5,06 | 0,01 | 10 | 0,20089 | 27,5 | 0,9 | 0,08 | 0,07 | 0,15 |
| 10 | 9,97 | 9,92 | 10,11 | 0,06 | 10 | 0,50148 | 28,5 | 1,8 | 0,06 | 0,06 | 0,12 |
| 15 | 14,80 | 14,75 | 14,88 | -0,04 | 10 | 0,50021 | 27,8 | 2,7 | 0,06 | 0,06 | 0,12 |
| 20 | 20,05 | 20,00 | 20,09 | -0,18 | 10 | 0,50014 | 27,2 | 5,5 | 0,06 | 0,06 | 0,12 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature | 19 °C | 21 °C |
| Ambient humidity | 47 % | 50 % |
| Atmospheric pressure | 94,5 kPa | 95,1 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,11 | 3,11 | 3,14 | 0,12 | 10 | 0,20024 | 27,7 | 0,5 | 0,07 | 0,07 | 0,15 |
| 5 | 5,03 | 4,93 | 5,06 | 0,42 | 10 | 0,20089 | 27,5 | 0,9 | 0,07 | 0,07 | 0,15 |
| 10 | 9,97 | 9,92 | 10,11 | 0,48 | 10 | 0,50148 | 28,5 | 1,8 | 0,06 | 0,06 | 0,12 |
| 15 | 14,80 | 14,75 | 14,88 | 0,31 | 10 | 0,50021 | 27,8 | 2,7 | 0,06 | 0,06 | 0,12 |
| 20 | 20,05 | 20,00 | 20,09 | -0,15 | 10 | 0,50014 | 27,2 | 5,5 | 0,06 | 0,06 | 0,12 |

## Lithuania - LEI

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature | 21 °C | 22 °C |
| Ambient humidity | 56 % | 50 % |
| Atmospheric pressure | 987,6 hPa | 984,6 hPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,06 | 3,055 | 3,057 | -0,413 | 10 | 21,877 | 20,54 | 1,27 | - | - | 0,13 |
| 5 | 4,99 | 4,986 | 4,996 | -0,298 | 10 | 25,533 | 20,55 | 1,32 | - | - | 0,12 |
| 10 | 10,15 | 10,150 | 10,157 | -0,206 | 10 | 31,519 | 20,59 | 1,17 | - | - | 0,093 |
| 15 | 15,23 | 15,231 | 15,236 | -0,188 | 10 | 22,228 | 20,48 | 1,07 | - | - | 0,088 |
| 20 | 19,82 | 19,815 | 19,825 | -0,164 | 10 | 22,710 | 20,31 | 0,92 | - | - | 0,085 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature | 22 °C | 23 °C |
| Ambient humidity | 51 % | 48 % |
| Atmospheric pressure | 983,4 hPa | 992,2 hPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3,03 | 3,02 | 3,05 | -0,036 | 10 | 10,193 | 20,14 | 1,40 | - | - | 0,13 |
| 5 | 4,96 | 4,93 | 4,98 | 0,169 | 10 | 23,407 | 20,22 | 1,33 | - | - | 0,14 |
| 10 | 9,90 | 9,85 | 9,96 | 0,634 | 10 | 26,818 | 20,28 | 1,13 | - | - | 0,10 |
| 15 | 14,87 | 14,80 | 14,94 | 0,540 | 10 | 21,362 | 20,58 | 1,04 | - | - | 0,092 |
| 20 | 19,77 | 19,67 | 19,93 | 0,123 | 10 | 22,791 | 20,45 | 0,93 | - | - | 0,088 |

## Ukraine – UKRMETRTESTSTANDART (UMTS)

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature [°C] | 19,10 | 21,21 |
| Ambient humidity [%] | 33,73 | 34,49 |
| Atmospheric pressure [bar] | 0,98389 | 0,99891 |

| $Q$ [m³/h] | $n$ | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $p$ [bar] | $T$ [°C] | $V_e$ [m³] | $e$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 10 | 3,0401 | 3,037 | 3,045 | 2,05 | 18,01 | 0,290138 | -0,261 | 0,027 |
| 5 | 10 | 5,0718 | 5,058 | 5,079 | 1,80 | 20,50 | 0,290484 | -0,1874 | 0,048 |
| 10 | 10 | 10,1381 | 10,132 | 10,142 | 2,96 | 24,53 | 2,000960 | -0,1739 | 0,037 |
| 15 | 10 | 15,1947 | 15,188 | 15,203 | 3,36 | 20,81 | 2,900383 | -0,1097 | 0,039 |
| 20 | 10 | 20,2194 | 20,209 | 20,229 | 2,94 | 21,55 | 2,899655 | -0,1009 | 0,039 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature [°C] | 21,15 | 20,54 |
| Ambient humidity [%] | 34,19 | 40,72 |
| Atmospheric pressure [bar] | 1,002140 | 0,99013 |

| $Q$ [m³/h] | $n$ | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $p$ [bar] | $T$ [°C] | $V_e$ [m³] | $e$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 10 | 3,0405 | 3,038 | 3,043 | 2,91 | 21,08 | 0,292476 | -0,2858 | 0,099 |
| 5 | 10 | 5,0585 | 5,054 | 5,065 | 2,11 | 21,75 | 0,293583 | 0,2375 | 0,083 |
| 10 | 10 | 10,1416 | 10,138 | 10,147 | 2,93 | 20,52 | 2,010906 | 0,4139 | 0,095 |
| 15 | 10 | 15,2059 | 15,195 | 15,214 | 3,20 | 21,45 | 2,911889 | 0,3046 | 0,093 |
| 20 | 10 | 20,1630 | 20,158 | 20,168 | 2,81 | 22,44 | 2,918576 | -0,2818 | 0,074 |

## Mexico – CENAM 1

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature | 20,5 °C | 20,1 °C |
| Ambient humidity | 32,2 % | 32,7 % |
| Atmospheric pressure | 99,74 kPa | 99,85 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 20,00 | 19,71 | 20,15 | 0,19 | - | - | 23,89 | 2,943 | - | - | 0,17 |
| 15 | 15,09 | 15,02 | 15,17 | 0,09 | - | - | 24,00 | 3,081 | - | - | 0,17 |
| 10 | 10,10 | 9,97 | 10,27 | 0,01 | - | - | 23,85 | 3,105 | - | - | 0,17 |
| 5 | 5,09 | 5,02 | 5,19 | -0,18 | - | - | 23,60 | 3,131 | - | - | 0,17 |
| 3 | 3,07 | 3,00 | 3,15 | 0,00 | - | - | 24,41 | 3,156 | - | - | 0,17 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature | 21,2 °C | 20,5 °C |
| Ambient humidity | 44,0 % | 39,1 % |
| Atmospheric pressure | 99,13 kPa | 98,84 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 20,00 | 19,71 | 20,15 | -0,66 | 12 | 762.78 | 23,89 | 2,943 | 0.0284 | 0.0044 | 0,24 |
| 15 | 15,09 | 15,02 | 15,17 | 0,03 | 12 | 745.94 | 24,00 | 3,081 | 0.0067 | 0.0053 | 0,23 |
| 10 | 10,11 | 9,97 | 10,27 | 0,37 | 12 | 742.60 | 23,86 | 3,103 | 0.0061 | 0.0043 | 0,24 |
| 5 | 5,09 | 5,02 | 5,19 | -0,04 | 12 | 742.05 | 23,60 | 3,131 | 0.0073 | 0.0050 | 0,23 |
| 3 | 3,07 | 3,00 | 3,15 | -0,49 | 11 | 738.53 | 24,41 | 3,156 | 0.0088 | 0.0042 | 0,24 |

## Mexico – CENAM 2

| Meter No. A0802103 | start | end |
|---|---|---|
| Ambient temperature | 20,5 °C | 20,1 °C |
| Ambient humidity | 32,2 % | 32,7 % |
| Atmospheric pressure | 99,74 kPa | 99,85 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 15,10 | 15,10 | 15,10 | -0,18 | - | - | 25,95 | 3,776 | - | - | 0,18 |
| 10 | 10,19 | 10,16 | 10,20 | -0,23 | - | - | 24,57 | 2,445 | - | - | 0,18 |
| 5 | 4,95 | 4,93 | 4,96 | -0,27 | - | - | 24,78 | 2,564 | - | - | 0,18 |

| Meter No. 080049508 | start | end |
|---|---|---|
| Ambient temperature | 21,2 °C | 20,5 °C |
| Ambient humidity | 44,0 % | 39,1 % |
| Atmospheric pressure | 99,13 kPa | 98,84 kPa |

| $Q$ [m³/h] | $Q_e$ [m³/h] | $Q_{emin}$ [m³/h] | $Q_{emax}$ [m³/h] | $e$ [%] | $n$ | $V_e$ [dm³] | $T$ [°C] | $p$ [bar] | $u_A$ [%] | $u_B$ [%] | $U$ [%] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 20,08 | 20,03 | 20,12 | -0,72 | 12 | 762,78 | 27,48 | 2,058 | 0,0284 | 0,0044 | 0,32 |
| 15 | 15,05 | 15,02 | 15,09 | -0,04 | 12 | 745,94 | 27,53 | 2,497 | 0,0067 | 0,0053 | 0,32 |
| 10 | 10,10 | 10,07 | 10,14 | 0,34 | 12 | 742,60 | 27,64 | 2,813 | 0,0061 | 0,0043 | 0,32 |
| 5 | 5,08 | 5,05 | 5,13 | 0,17 | 12 | 742,05 | 27,69 | 3,021 | 0,0073 | 0,0050 | 0,32 |
| 3 | 3,09 | 3,06 | 3,13 | -0,34 | 11 | 738,53 | 27,73 | 3,069 | 0,0088 | 0,0042 | 0,32 |

# Appendix B – lab to lab equivalence degrees

### Krohne Optiflux 2010 C/D - No A0802103, flow 3 $m^3/h$

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,15 | - | - | - | - | - |
| CENAM 2 | - | - | - | - | - | - |
| LEI | 0,42 | 0,56 | - | - | - | - |
| UMTS | 0,21 | 0,36 | - | 0,21 | - | - |
| SMU | 0,45 | 0,60 | - | 0,03 | 0,25 | - |

### Krohne Optiflux 2010 C/D - No A0802103, flow 5 $m^3/h$

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,26 | - | - | - | - | - |
| CENAM 2 | 0,37 | 0,11 | - | - | - | - |
| LEI | 0,42 | 0,16 | 0,04 | - | - | - |
| UMTS | 0,27 | 0,01 | 0,11 | 0,16 | - | - |
| SMU | 0,61 | 0,35 | 0,23 | 0,19 | 0,35 | - |

### Krohne Optiflux 2010 C/D - No A0802103, flow 10 $m^3/h$

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,06 | - | - | - | - | - |
| CENAM 2 | 0,39 | 0,32 | - | - | - | - |
| LEI | 0,37 | 0,30 | 0,03 | - | - | - |
| UMTS | 0,33 | 0,26 | 0,07 | 0,05 | - | - |
| SMU | 0,62 | 0,55 | 0,22 | 0,26 | 0,30 | - |

### Krohne Optiflux 2010 C/D - No A0802103, flow 15 $m^3/h$

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,37 | - | - | - | - | - |
| CENAM 2 | 0,00 | 0,37 | - | - | - | - |
| LEI | 0,01 | 0,38 | 0,01 | - | - | - |
| UMTS | 0,10 | 0,28 | 0,10 | 0,11 | - | - |
| SMU | 0,23 | 0,59 | 0,22 | 0,22 | 0,33 | - |

### Krohne Optiflux 2010 C/D - No A0802103, flow 20 $m^3/h$

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,50 | - | - | - | - | - |
| CENAM 2 | - | - | - | - | - | - |
| LEI | 0,02 | 0,48 | - | - | - | - |
| UMTS | 0,11 | 0,40 | - | 0,09 | - | - |
| SMU | 0,18 | 0,68 | - | 0,20 | 0,29 | - |

**Meistream Plus 40 – No 080049508, flow 3 m³/h**

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,47 | - | - | - | - | - |
| CENAM 2 | 0,35 | 0,11 | - | - | - | - |
| LEI | 0,12 | 0,35 | 0,23 | - | - | - |
| UMTS | 0,32 | 0,16 | 0,04 | 0,20 | - | - |
| SMU | 0,22 | 0,25 | 0,14 | 0,10 | 0,10 | - |

**Meistream Plus 40 – No 080049508, flow 5 m³/h**

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,36 | - | - | - | - | - |
| CENAM 2 | 0,19 | 0,16 | - | - | - | - |
| LEI | 0,20 | 0,16 | 0,00 | - | - | - |
| UMTS | 0,14 | 0,22 | 0,05 | 0,05 | - | - |
| SMU | 0,20 | 0,16 | 0,01 | 0,01 | 0,06 | - |

**Meistream Plus 40 – No 080049508, flow 10 m³/h**

| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,09 | - | - | - | - | - |
| CENAM 2 | 0,11 | 0,02 | - | - | - | - |
| LEI | 0,12 | 0,21 | 0,23 | - | - | - |
| UMTS | 0,05 | 0,03 | 0,06 | 0,17 | - | - |
| SMU | 0,01 | 0,09 | 0,12 | 0,11 | 0,06 | - |

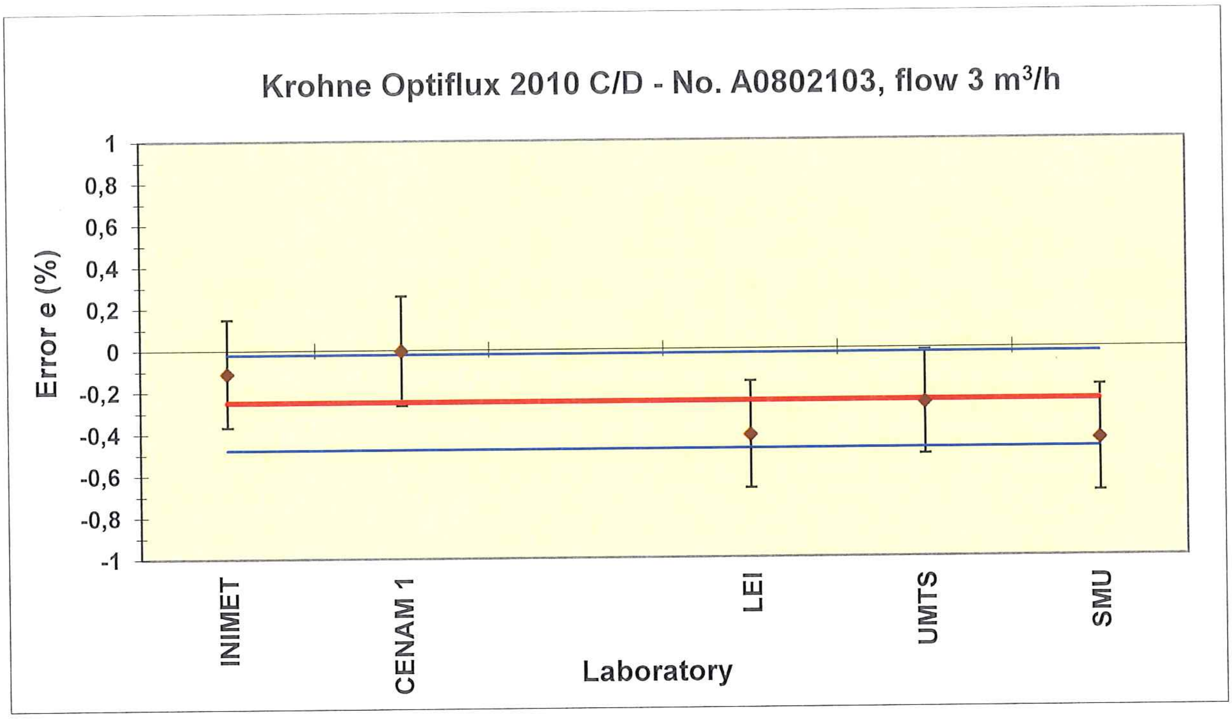
**Meistream Plus 40 – No 080049508, flow 15 m³/h**

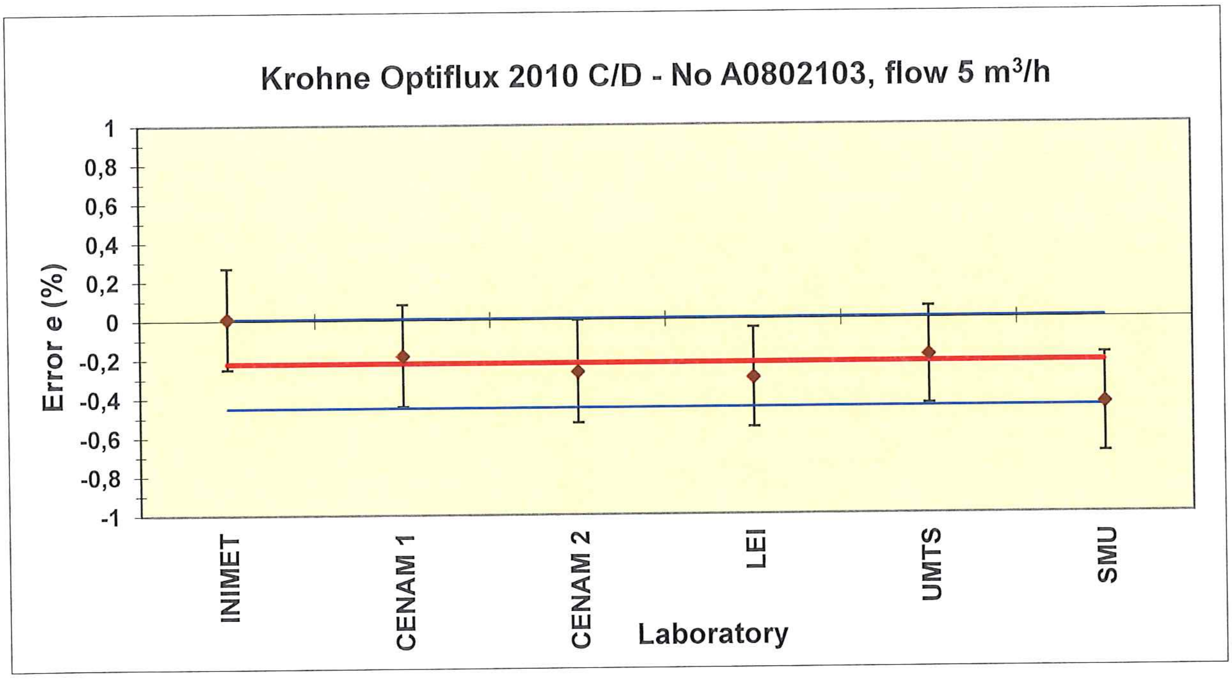
| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,22 | - | - | - | - | - |
| CENAM 2 | 0,27 | 0,05 | - | - | - | - |
| LEI | 0,18 | 0,40 | 0,45 | - | - | - |
| UMTS | 0,00 | 0,21 | 0,26 | 0,19 | - | - |
| SMU | 0,02 | 0,20 | 0,25 | 0,20 | 0,01 | - |

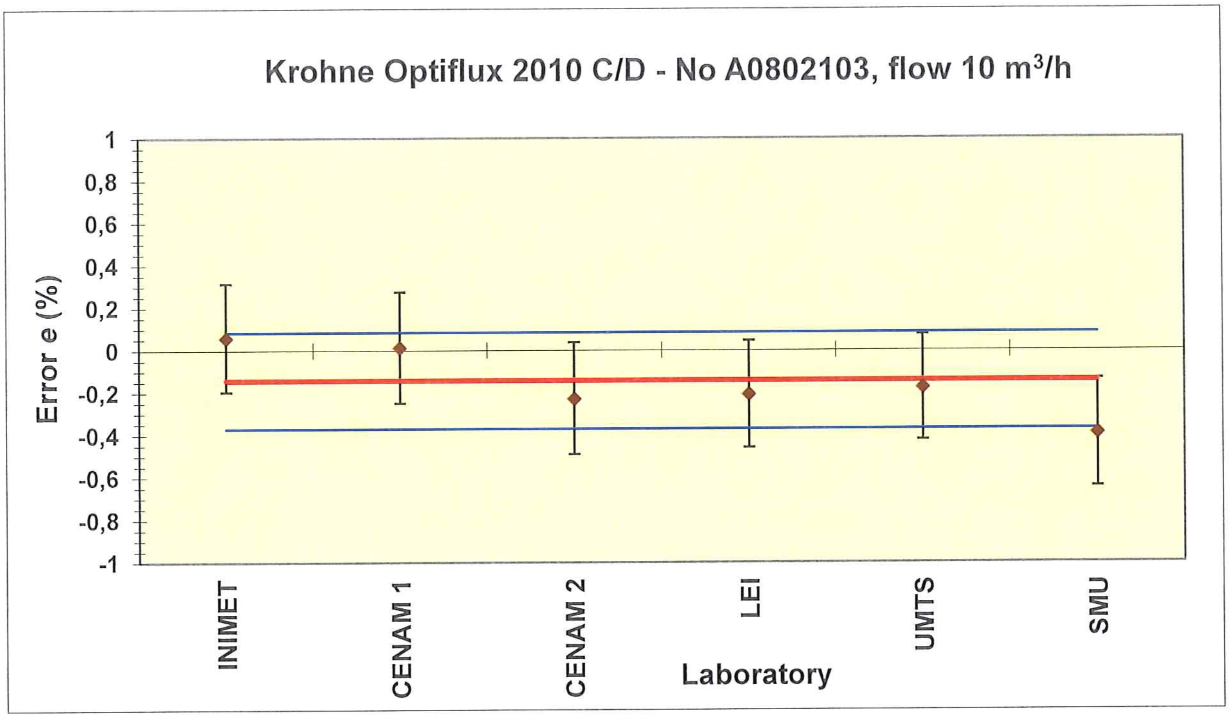
**Meistream Plus 40 – No 080049508, flow 20 m³/h**

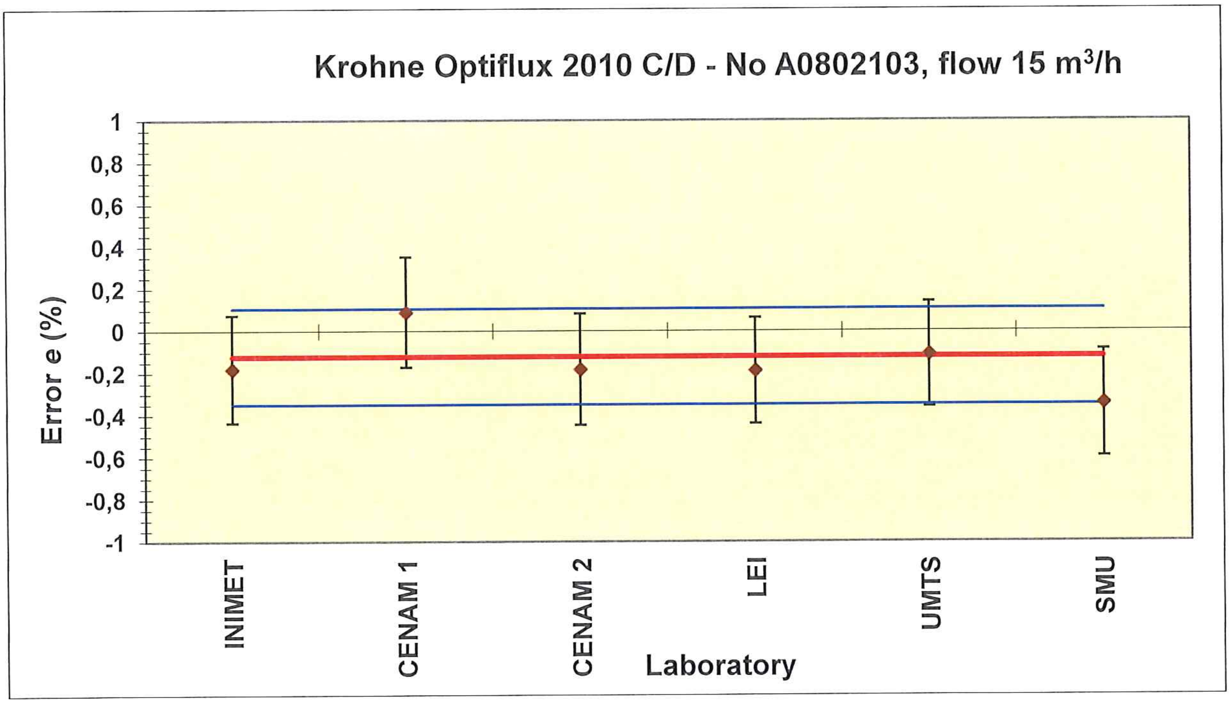
| | INIMET | CENAM 1 | CENAM 2 | LEI | UMTS | SMU |
|---|---|---|---|---|---|---|
| INIMET | - | - | - | - | - | - |
| CENAM 1 | 0,40 | - | - | - | - | - |
| CENAM 2 | 0,44 | 0,05 | - | - | - | - |
| LEI | 0,22 | 0,61 | 0,65 | - | - | - |
| UMTS | 0,10 | 0,29 | 0,34 | 0,32 | - | - |
| SMU | 0,05 | 0,45 | 0,49 | 0,16 | 0,16 | - |

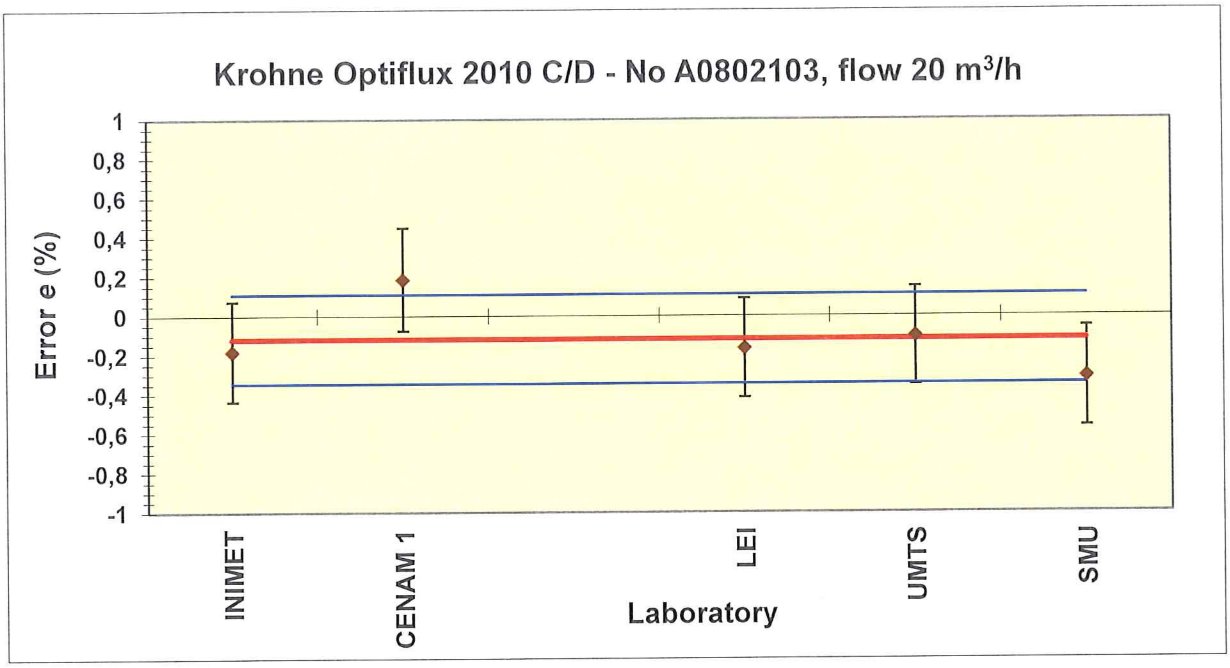
## Appendix C – graphical representation of errors $e$ and ucertainties $U(e)_{st}$

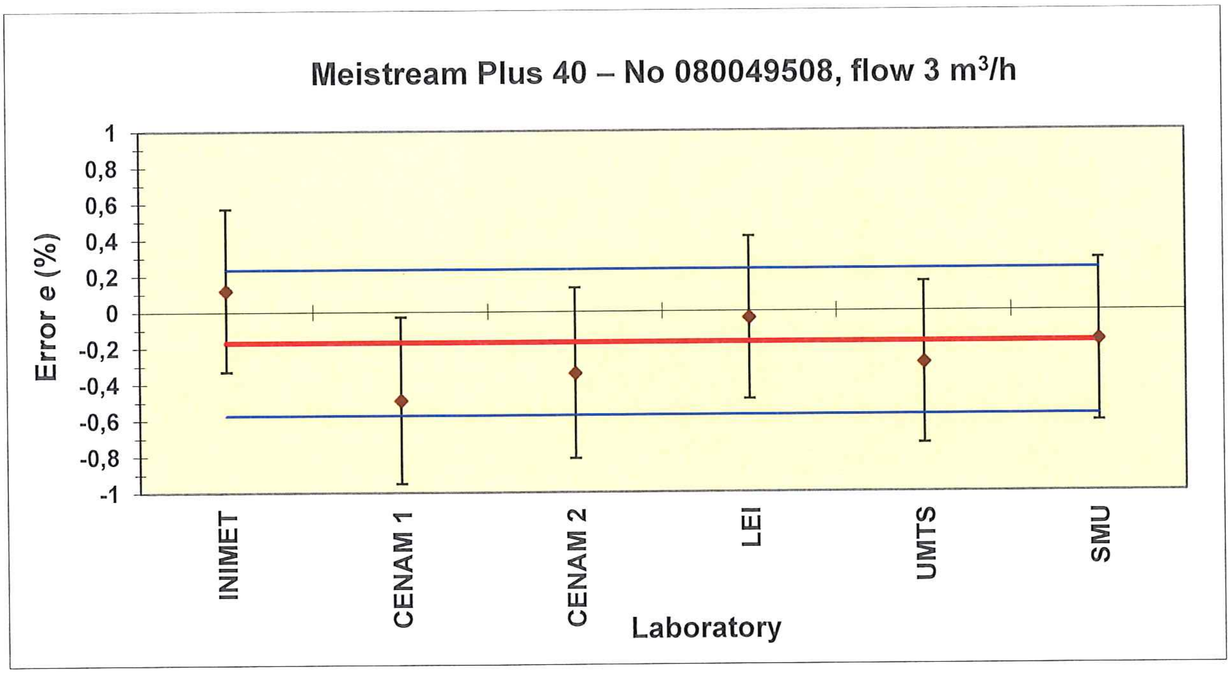


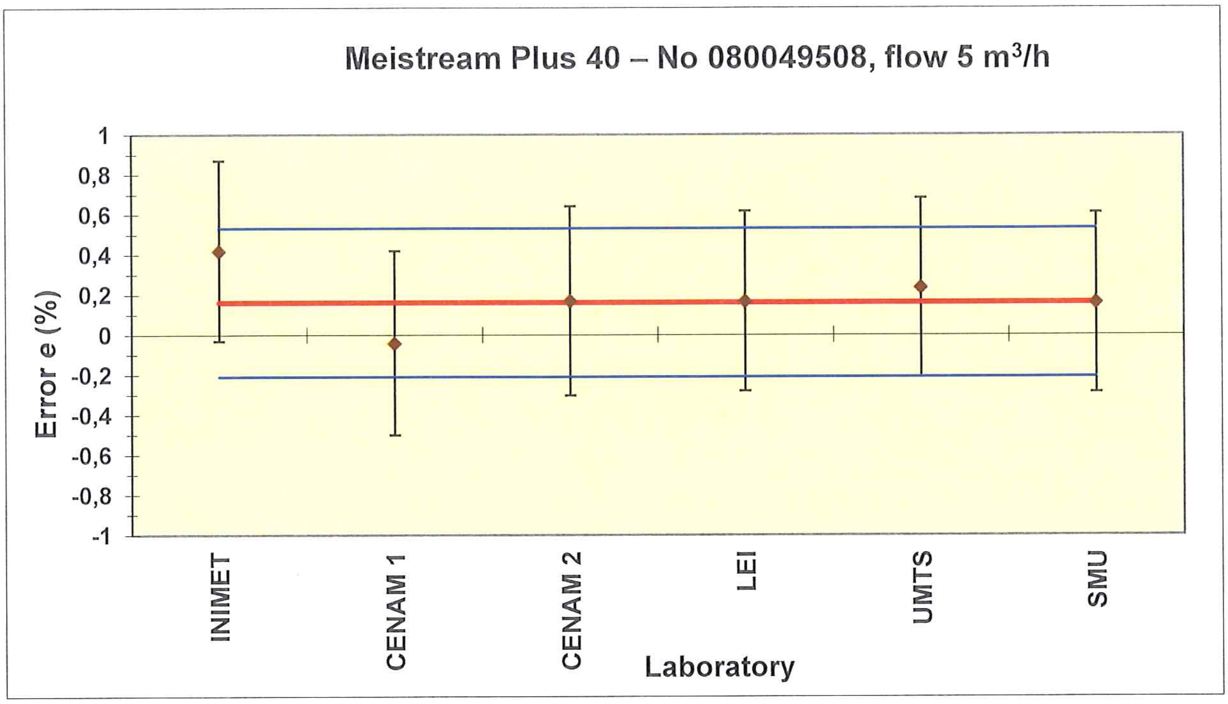



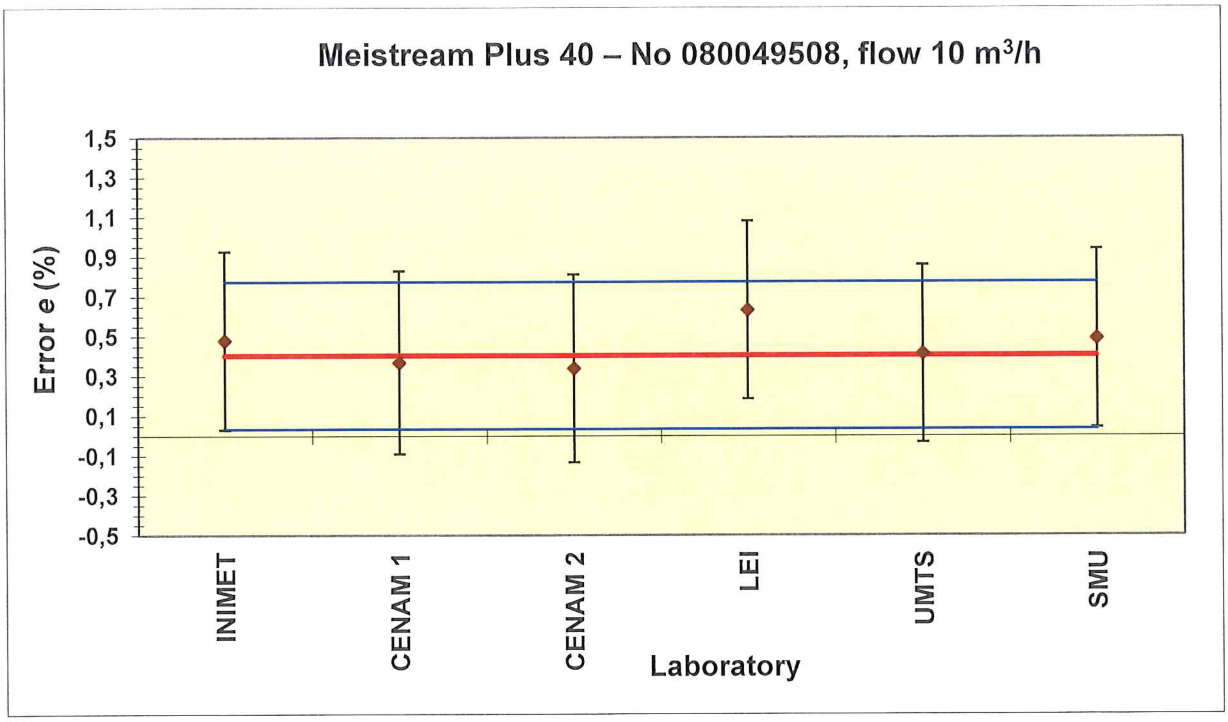

Krohne Optiflux 2010 C/D - No A0802103, flow 10 m³/h
Error e (%)
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory

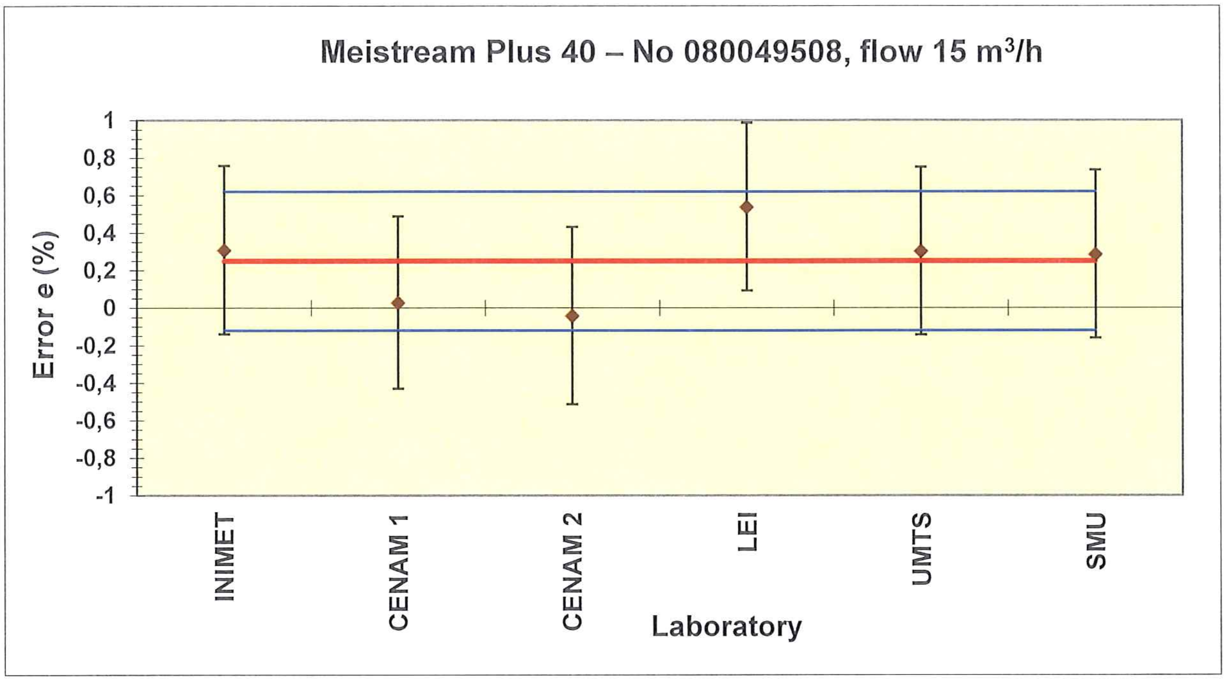

Krohne Optiflux 2010 C/D - No A0802103, flow 15 m³/h
Error e (%)
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory

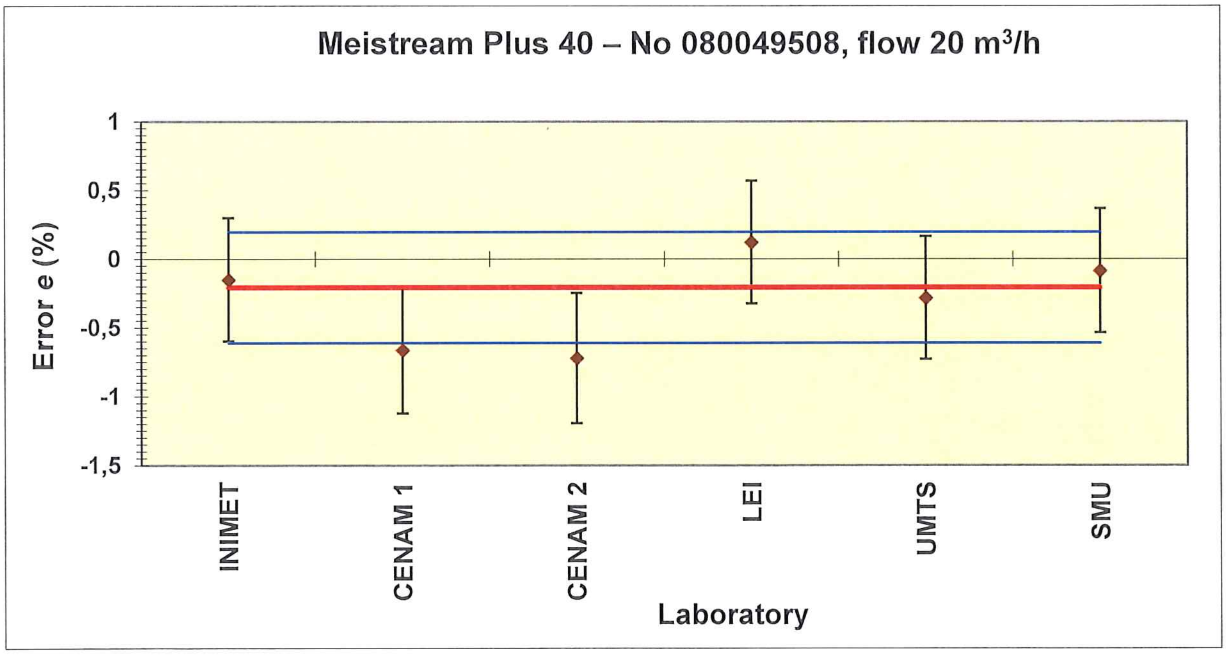

Krohne Optiflux 2010 C/D - No A0802103, flow 20 m³/h
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
Error e (%)
INIMET
CENAM 1
LEI
UMTS
SMU
Laboratory


Meistream Plus 40 – No 080049508, flow 3 m³/h
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
Error e (%)
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory


Meistream Plus 40 – No 080049508, flow 5 m³/h
Error e (%)
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory


Meistream Plus 40 – No 080049508, flow 10 m³/h
Error e (%)
1,5
1,3
1,1
0,9
0,7
0,5
0,3
0,1
-0,1
-0,3
-0,5
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory


Meistream Plus 40 – No 080049508, flow 15 m³/h
Error e (%)
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory


Meistream Plus 40 – No 080049508, flow 20 m³/h
Error e (%)
1
0,5
0
-0,5
-1
-1,5
INIMET
CENAM 1
CENAM 2
LEI
UMTS
SMU
Laboratory