EURAMET project No. 1180
EURAMET Regional Key Comparison
EURAMET.M.FF-K6

Comparison of the Primary (National) Standards of low-pressure Gas Flow

Final Report

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1 Introduction

A comparison was organised for the purpose of determination of the degree of equivalence of the primary (national) standards for low-pressure gas flow measurement over the range (2 to 100) m^3/h. A rotary gas meter G65 donated by LNE-LADG France was used as a transfer standard.

This comparison was initialised as a Regional Key Comparison with linking to the CCM Key Comparison CCM.FF-K6.2011 for low-pressure gas flow. The results of this comparison can be used for review of CMC tables.

2 Participants

The 15 participants and the time schedule are shown in Table 1. The comparison measurements started in February 2010 and finished in May 2011. The CCM.FF-K6.2011 using the same transfer standard started in August 2010 and finished in December 2012.

Each laboratory had several weeks for providing the measurements and for sending the transfer standard to the next laboratory. Due to some problems with customs documents the transfer standard shipment was delayed several times. The transfer standard was calibrated 7 times by the pilot laboratory before, during and after the comparison to assess its calibration stability.

Tab.1 - Participants and the time schedule

Country	NMI	Contact	Date of calibration
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	15.2. to 28.2.2010
Germany	PTB Physikalisch-Technische Bundesanstalt	Bodo Mickan	1.3.to 20.3.2010
Spain	CEM (Centro Español de Metrología) Enagas S.A.	Nieves Medina	20.3. to 30.4.2010
France	LNE-LADG Laboratoire Associé de Débitmétrie Gazeuse	Christophe Windenberg	5.5. to 12.5.2010
Netherlands	VSL National Metrology Institute of the Netherlands	Mijndert P. van der Beek	18.5. to 28.5.2010
Czech Republic	CMI Czech Metrology Institute Regional Inspectorate Pardubice	Tomas Valenta	31.5. to 9.6.2010
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	9.6. to 14.6.2010

Austria	BEV Bundesamt für Eich- und Vermessungswesen	Manfred Macek	14.6. to 20.6.2010
Poland	GUM Główny Urząd Miar (Central Office of Measures)	Monika Kusyk	24.6. to 30.6.2010
Hungary	MKEH Hungarian Trade Licensing Office. Section of Flow Measurement	Csaba Czibulka	2.7. to 6.7.2010
Sweden	SP Technical Research Institute of Sweden	Per Jacobsson	10.7. to 23.7.2010
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	3.8. to 23.8.2010
Switzerland	METAS Federal Office of Metrology	Hugo Bissig	24.8. to 9.9.2010
Republic of Serbia DMDM	Bureau of Measurements and Precious Metals of Serbia	Branislav Tanasić	17.9. to 30.9.2010
Turkey	TUBITAK - UME National Metrology Institute of Turkey	Vahit Ciftci	15.10. to 22.10.2010
Greece	EIM Hellenic Institute of Metrology	Zoe Metaxiotou	1.11. to 1.12.2010
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	1.12. to 23.12.2011
Bosnia-Herzegovina IMBH	Institute of Metrology of Bosnia&Herzegovina	Zijad Dzemic	29.3. to 9.5.2011
Slovak Republic (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	12.5.2011

3 The transfer standard

The transfer standard was a rotary gas meter, a new model of S-Flow meter inside the body Actaris Delta 2050. The transfer standard, a pulse transmitter connector and a filter were shipped in one transfer box.

3.1 Basic technical specification

Type:	Delta 2050 S-Flow
Manufacturer:	Actaris Gaszählerbau GmbH. Germany
Size:	G65
Serial number:	GN-HD-001
Flow range:	(2 to 100) m^3/h
P_{max} :	40 bar

Inside diameter: DN 50


Figure 1 – Rotary gas meter Actaris Delta S-Flow

4 The measurement procedure

4.1 Method of measurement

The participating NMIs used their usual calibration procedure, that was described in their reports, as well as the traceability to the SI and to the independent realisation of the quantity.

The Relative error of the transfer standard x in (%) was the quantity used to compare the participants results. It is defined as the difference between the volume indicated by the transfer standard and the volume measured by the reference (national) standard:

$$x = \frac{V_t - V_s}{V_s}.100, \qquad (1)$$

where x is the relative error of the transfer standard (%),
V_t is the volume indicated by the transfer standard (m^3),
V_s is the volume measured by the reference (national) standard (m^3).

4.2 Equipment

Each laboratory described the equipment used in the calibration and sent the information about whether or not their traceability is independent of other laboratories or of laboratories creating KCRV from CCM.FF-K6.2011 (EURAMET: PTB, Germany; SMU, Slovakia; LNE-LADG, France; SIM: NIST, USA; CENAM, Mexico; APMP: NMIJ AIST Japan; KRISS, Korea; NMI, Australia; NIM, China; CMS, Chinese Taipei; COOMET: GP GP Ivano-Frankivs'kstandart-metrologia, Republic of Ukraine). A summary of used equipment, range of flow tested and traceability can be found in Table 2.

Table 2 – Method of measurement

Country NMI	NMI standard	Flow range of comparison	Traceability
Slovakia SMU	Bell prover	(2 - 100) m^3/h	Independent laboratory with contribution to KCRV
Germany PTB	Bell prover	(2 - 100) m^3/h	Independent laboratory with contribution to KCRV
Spain CEM	Test facility with rotary gas meter G65 and Turbine gas meter G 650	(6.6 - 100) m^3/h	Traceability to PTB contributing to KCRV
France LNE-LADG	Set of Venturi nozzles	(13 - 100) m^3/h	Independent laboratory with contribution to KCRV
Netherlands VSL	Bell prover	(2 - 100) m^3/h	Independent laboratory
Czech Republic CMI	Static weighing system	(2 - 16) m^3/h	Independent laboratory
	Bell prover	(24 - 100) m^3/h	
Austria BEV	Wet drum meter, rotary piston meter	(2 - 25) m^3/h	Independent laboratory, own bell prover
	Rotary piston meter (DUO)	(25 - 100) m3/h	Traceability to VSL
Poland GUM	Bell prover	(2 - 100) m^3/h	Independent laboratory
Hungary MKEH	Bell prover	(2 - 50) m^3/h	Independent laboratory
Sweden SP	Laminar flow element	(2 - 100) m^3/h	Traceability to NIST, USA contributing to KCRV
Switzerland METAS	Test facility with Turbine gas meters	(2 - 100) m^3/h	Independent laboratory
Republic of Serbia DMDM	Rotary gas meter G 40	(2 - 65) m^3/h	Traceability to VSL
	Rotary gas meter G 250	(65 - 100) m^3/h	
Turkey TUBITAK - UME	Bell prover	(2 - 100) m^3/h	Independent laboratory
Greece EIM	Volumetric device working on a positive displacement principle	(6.6 – 37.5) m^3/h	Independent laboratory
Bosnia-Herzegovina IBMH	Rotary gas meter (MM1)	(2 - 16) m^3/h	Traceability to VSL
	Rotary gas meter (MM2)	(24 - 24) m3/h	
	Turbine gas meter /MM3)	(50 - 100) m3/h	

4.3 Measurement and ambient conditions

The measured range was (2 to 100) m^3/h. If the laboratory was not able to cover the whole flow range they could make measurements in one part of the flow range.

- The transfer standard was tested in the horizontal position using air, near the barometric pressure,

- The reference pressure from the transfer standard was measured from the output "P_m" (pressure tap located at the outlet of the transfer standard),
- The second pressure point to determine the pressure loss of the transfer standard was defined at the inlet of the transfer standard,
- The reference temperature from transfer standard was measured upstream of the transfer standard (figure 2).

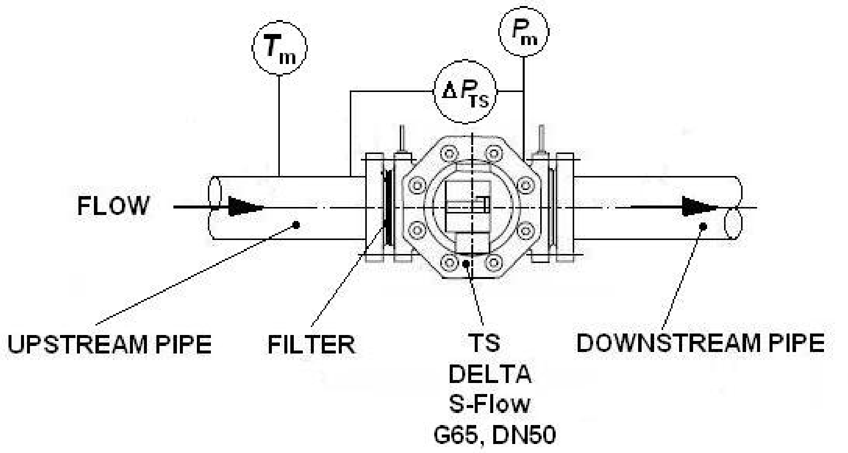


Figure 2 - Recommended installation of the transfer standard

- It was necessary to use the pulse transmitter,
- There was no lubrication of the transfer standard,
- Reference conditions:
  - the calibration medium was air,
  - air temperature: (20 ± 5)°C,
  - ambient relative humidity range: 25 % to 75 %,
  - ambient atmospheric pressure range: 86 kPa to 106 kPa (0.86 bar to 1.06 bar),
- The flow had to be within ± 3% of the required value,

Flow set points: (2; 4.5; 6.6; 9.1; 13.1; 16; 24; 32; 40; 50; 60; 70; 80; 90; 100) m^3/h.

5 Measurements results

5.1 Stability of the transfer standard

The stability of the transfer standard was checked before starting the comparison by LNE-LADG France and 7 times before, during and after the comparison by the pilot laboratory (Table 3 and Figure 3). The temperature sensitivity of the transfer standard was checked by PTB Germany (Figure 4).

Table 3 Relative errors (%) of the transfer standard obtained at SMU

Flow/(m^3/h) → Date	February 2010	Jun 2010	August 2010	February 2011	May 2011	February 2012	September 2012
2	-0.122	-0.102	-0.142	-0.170	-0.158	-0.162	-0.152
4.5	-0.036	-0.027	-0.068	-0.060	-0.068	-0.099	-0.028
6.6	0.014	0.035	0.005	0.028	-0.011	-0.012	0.030
9.1	0.051	0.079	0.059	0.091	0.030	0.051	0.072
13.1	0.088	0.117	0.110	0.148	0.066	0.106	0.111
16	0.107	0.134	0.134	0.173	0.083	0.129	0.130
24	0.144	0.159	0.176	0.213	0.112	0.162	0.165
32	0.170	0.172	0.202	0.236	0.133	0.176	0.189
40	0.191	0.182	0.223	0.251	0.152	0.185	0.208
50	0.213	0.192	0.244	0.268	0.176	0.193	0.228
60	0.231	0.203	0.264	0.283	0.203	0.203	0.246
70	0.246	0.216	0.282	0.298	0.233	0.215	0.261
80	0.258	0.230	0.301	0.314	0.267	0.230	0.274
90	0.267	0.248	0.319	0.332	0.305	0.249	0.286
100	0.274	0.267	0.338	0.352	0.348	0.272	0.297

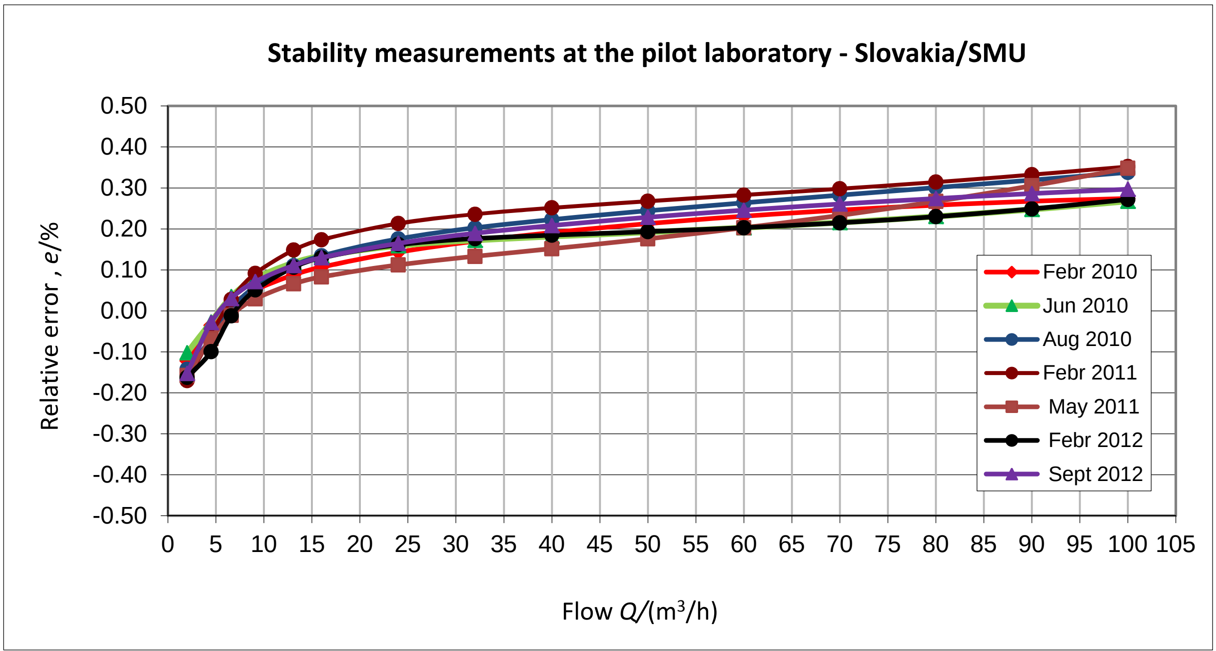


Figure 3 - Stability of the transfer standard

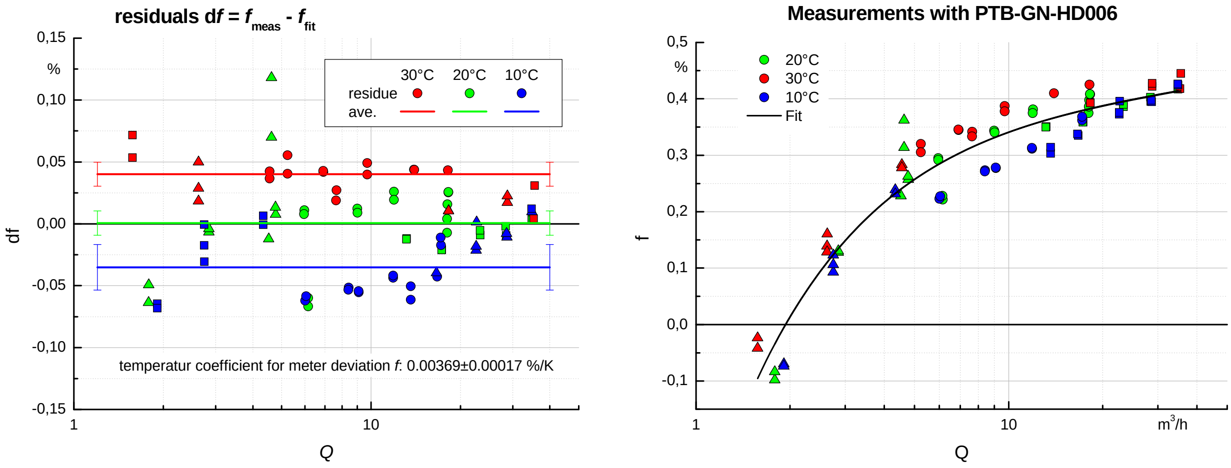


Figure 4. Temperature stability

5.2 Laboratory results

All data collected from the participating laboratories are summarized in the following tables and pictures.

Table - 4 Relative errors (%) of the transfer standard obtained by the participating laboratories

Flow/(m^3/h) → NMI	Slovakia SMU	Germany PTB	Spain CEM	France LNE-LADG	Netherlands VSL	Czech Republic CMI	Austria BEV	Poland GUM
2	-0.120	-0.082	-	-	-0.09	-0.08	-0.20	-0.17
4.5	-0.057	0.039	-	-	0.07	0.06	-0.02	-0.06
6.6	0.038	0.089	0.26	-	0.11	0.09	0.05	-0.03
9.1	0.064	0.104	0.34	-	0.14	0.15	0.08	0.01
13.1	0.097	0.122	0.33	0.15	0.16	0.19	0.08	0.03
16	0.105	0.139	0.34	0.18	0.18	0.18	0.09	0.04
24	0.135	0.161	0.17	0.19	0.20	0.19	0.12	0.07
32	0.148	0.154	0.18	0.21	0.22	0.21	0.16	0.10
40	0.200	0.170	0.23	0.23	0.23	0.22	0.19	0.12
50	0.209	0.189	0.24	0.24	0.25	0.24	0.22	0.15
60	0.213	0.209	0.26	0.24	0.27	0.27	0.24	0.14
70	0.280	0.240	0.35	0.25	0.28	0.26	0.26	0.18
80	0.270	0.253	0.35	0.25	0.29	0.27	0.27	0.19
90	0.268	0.253	0.35	0.26	0.30	0.28	0.27	0.18
100	0.261	0.268	0.31	0.26	0.30	0.28	0.27	0.14

Table 4 - Continuation of relative errors (%) of the transfer standard obtained by participating laboratories

Flow/(m^3/h) → NMI	Hungary MKEH	Sweden SP	Switzerland METAS	Serbia DMDM	Turkey TUBITAK-UME	Greece EIM	Bosnia& Herzegovina IMBH
2	0.02	-0.31	-0.064	-0.63	0.08	-	0.036
4.5	0.15	0.23	0.064	-0.27	0.05	-	0.265
6.6	0.17	0.20	0.113	-0.15	0.03	-0.13	0.383
9.1	0.26	0.02	0.088	-	0.05	0.08	0.372
13.1	0.30	0.06	0.062	0.00	0.04	0.27	0.427
16	0.29	-0.05	0.117	0.04	0.04	0.29	0.424
24	0.22	-0.48	0.155	0.08	0.03	0.21	0.327
32	0.21	-0.53	0.145	0.03	0.02	0.12	0.556
40	0.17	-0.50	0.194	0.13	0.07	0.18	0.648
50	0.22	-0.41	0.247	-0.15	0.06	-	0.380
60	-	-0.36	0.254	-0.13	0.04	-	0.474
70	-	-0.37	0.252	-0.21	0.16	-	0.570
80	-	-0.30	0.262	0.12	0.24	-	0.660
90	-	-0.21	0.275	0.13	0.20	-	0.700
100	-	-0.20	0.277	0.05	0.30	-	0.760

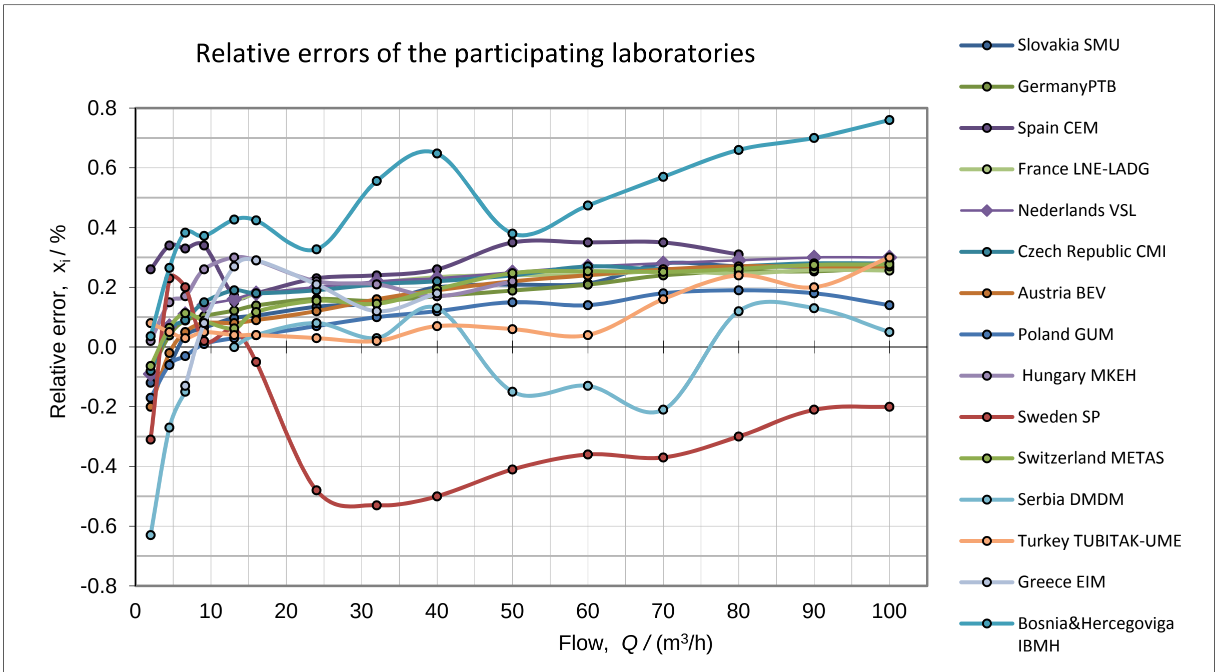


Figure 5 - Relative errors of participating laboratories

5.3 Laboratory uncertainty

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

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

$$u_A^2 = \frac{1}{n(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2 \qquad (2)$$

Type B uncertainty is determined on the basis of non-statistical methods. It consists the root-sum-of squares of the relevant sources of uncertainty from the mathematical model:

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

Combined uncertainty is calculated according to the following formula:

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

The expanded uncertainty U is obtained by multiplying the combined standard uncertainty u_c by coverage factor according to the formula:

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

where the coverage factor k=2 is usually used in the flow community.

Uncertainty values of participating laboratories for each flow rate are stated in Table 5 and Figure 6.

Table 5 - Expanded uncertainties (%) of measurements reported by participating laboratories

Flow/(m^3/h) → NMI	Slovakia SMU	Germany PTB	Spain CEM	France LNE-LADG	Netherlands VSL	Czech Republic CMI	Austria BEV	Poland GUM
2	0.12	0.064	-	-	0.094	0.18	0.30	0.17
4.5	0.12	0.064	-	-	0.094	0.18	0.30	0.16
6.6	0.12	0.064	0.27	-	0.094	0.19	0.30	0.19
9.1	0.12	0.064	0.27	-	0.094	0.18	0.30	0.15
13.1	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.15
16	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.16
24	0.12	0.064	0.27	0.25	0.094	0.19	0.30	0.16
32	0.12	0.064	0.27	0.25	0.094	0.19	0.30	0.16
40	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.15
50	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.16
60	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.16
70	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.16
80	0.12	0.064	0.27	0.25	0.094	0.18	0.30	0.16
90	0.12	0.083	0.27	0.25	0.094	0.18	0.30	0.19

Flow/(m^3/h) → NMI	Slovakia SMU	Germany PTB	Spain CEM	France LNE-LADG	Netherlands VSL	Czech Republic CMI	Austria BEV	Poland GUM
100	0.12	0.083	0.23	0.25	0.094	0.18	0.30	0.15

Table 5 – Continuation of Expanded uncertainties (%) of measurements reported by participating laboratories

Flow/(m^3/h) → NMI	Hungary MKEH	Sweden SP	Switzerland METAS	Serbia DMDM	Turkey TUBITAK-UME	Greece EIM	Bosnia & Herzegovina IMBH
2	0.12	1.13	0.17	0.32	0.20	-	0.31
4.5	0.12	1.10	0.17	0.31	0.20	-	0.30
6.6	0.12	1.09	0.17	0.29	0.20	0.63	0.28
9.1	0.12	1.08	0.17	-	0.20	0.31	0.28
13.1	0.12	1.05	0.17	0.31	0.20	0.23	0.28
16	0.12	1.06	0.17	0.29	0.20	0.2	0.28
24	0.12	0.99	0.17	0.29	0.20	0.23	0.27
32	0.12	0.96	0.17	0.29	0.20	0.18	0.27
40	0.12	1.01	0.17	0.29	0.20	0.41	0.35
50	0.12	0.96	0.17	0.39	0.20	-	0.35
60	-	1.00	0.17	0.39	0.20	-	0.34
70	-	0.98	0.18	0.39	0.20	-	0.28
80	-	0.96	0.18	0.30	0.20	-	0.28
90	-	0.95	0.17	0.30	0.20	-	0.28
100	-	0.95	0.17	0.31	0.20	-	0.26

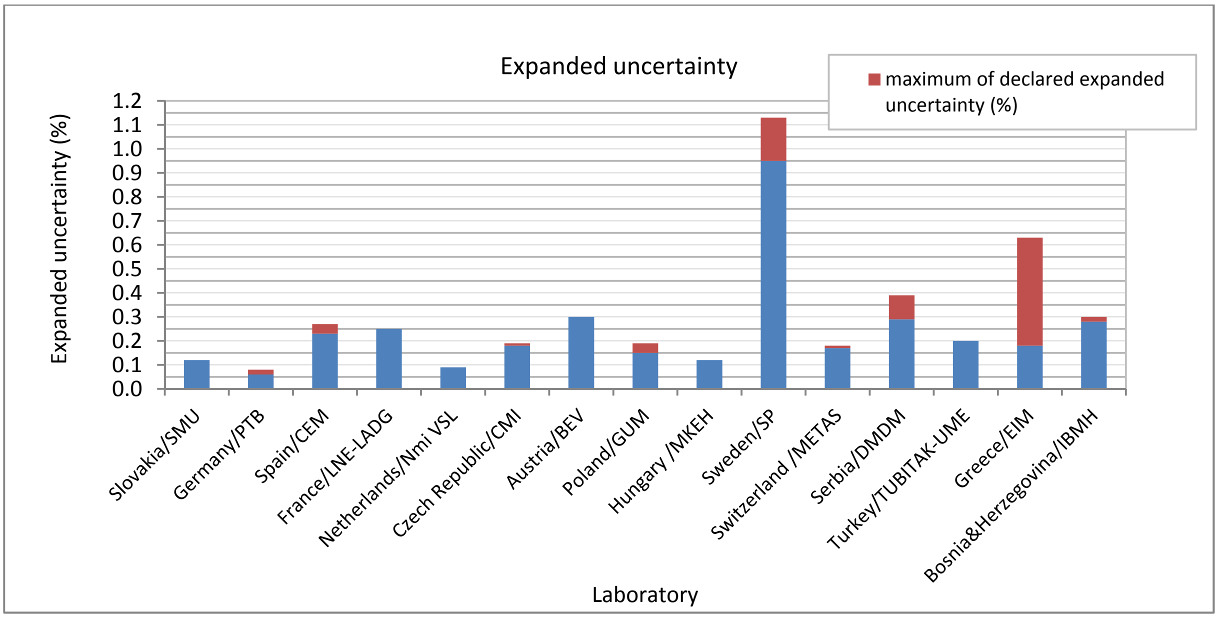


Figure 6 Expanded uncertainties of participating laboratories

5.4 Laboratory measurement conditions

The conditions during measurements were described by all participants. The values are given in Tables 6 and Figure 7.

Table 6 - Temperature (°C) in participating laboratories during measurements

NMI	Slovakia SMU	Germany PTB	Spain CEM	France LNE-LADG	Netherlands VSL	Czech Republic CMI	Austria BEV	Poland GUM
Max	20.28	21.76	19.62	19.12	19.99	21.52	20.71	20.94
Min	19.69	19.38	19.58	18.60	19.90	20.59	20.16	20.75
Max-Min	0.60	2.38	0.04	0.51	0.09	0.93	0.55	0.19
Mean	19.94	21.15	19.60	18.77	19.95	20.96	20.48	20.86

Tab. 6 – Continuation of Temperature (°C) in participating laboratories during measurements

NMI	Hungary MKEH	Sweden SP	Switzerland METAS	Serbia DMDM	Turkey TUBITAK-UME	Greece EIM	Bosnia & Herzegovina IMBH
Max	23.10	23.70	21.30	21.66	21.71	19.40	20.99
Min	22.10	23.30	20.62	21.11	20.59	18.10	20.53
Max-Min	1.00	0.40	0.68	0.55	1.12	1.30	0.46
Mean	22.61	23.38	20.84	21.39	21.02	18.76	20.87

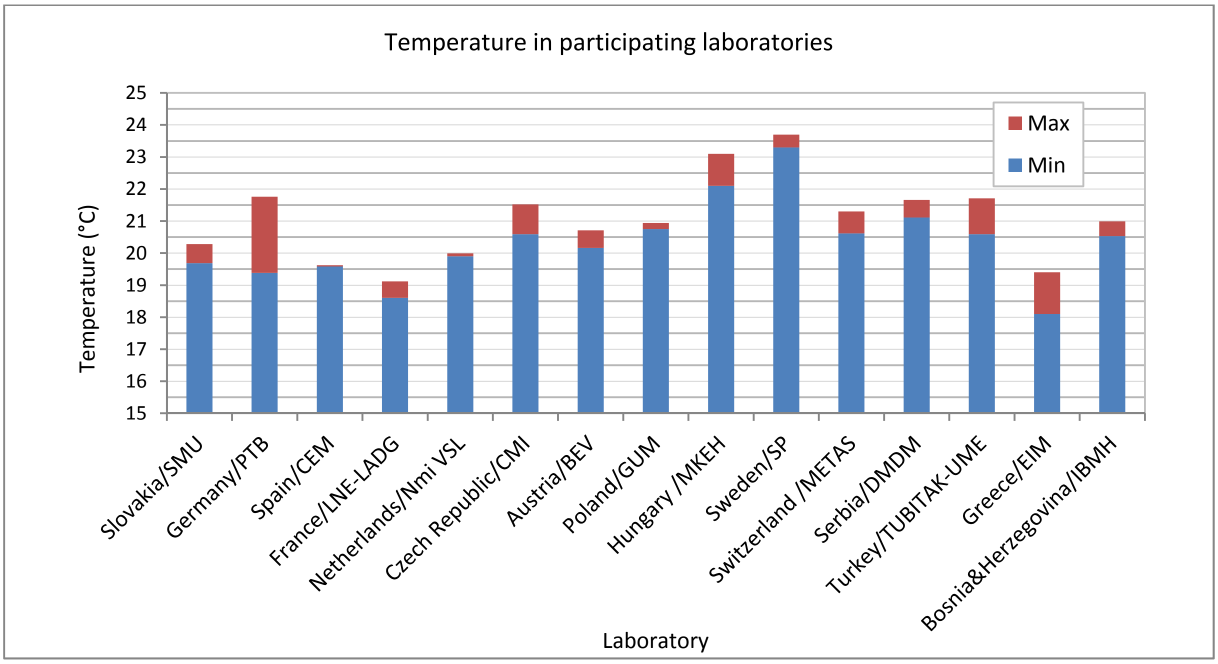


Figure 7 - Range of temperature in participating laboratories

5.5 Temperature, pressure and flow stability

This comparison lasted 2 years and the measurement were performed at different attitudes. Figure 4 shows, that for temperature differences of ± 10 ° C the transfer standard sensitivity does not exceed ± 0.05 %. Since the minimum and maximum temperature values in the laboratories were in the range (18.1 to 23.7) °C (see Table 6), the temperature sensitivity of the transfer standard will introduce lab to lab differences < 0.03 %. No temperature corrections were made to the data submitted by the participating laboratories and this temperature sensitivity was treated as a transfer standard uncertainty component with a rectangular probability distribution: ($u_T = 0.03\ \%/(2\sqrt{3})$).

All the participating laboratories measured the actual volumetric flow at the transfer standard based on the pressure and temperature measurements made at the transfer standard (see Figure 2). No further pressure corrections to the data submitted were necessary.

The tolerance of the flow during the measurement was specified to be 3 % in the comparison protocol. Some laboratories did not report whether or not this tolerance was met during their testing. For the laboratories that did report their flow stability it can be verified that the tolerance of 3 % was maintained at all flows except for one laboratory, that one minimum flow 2 m^3/h exceeded this required value. No correction was made for flows not meeting the 3 % criteria.

5.6 Uncertainty of the corrections and stability of the transfer standard

The standard uncertainties of the error in different laboratories u_{x1}. u_{x2}......u_{xn} (Equation (6)) include the uncertainty contributed by the transfer standard. This uncertainty was calculated according to the following formula

$$u_{xi} = \sqrt{\left(\frac{U(x_i)}{2}\right)^2 + u^2{}_{TS}} \qquad (6)$$

Where $u_{(xi)}$ is the standard uncertainty determined by laboratory *i* and presented in results of laboratory *I*,

u_{TS} is estimated standard uncertainty caused by the stability (reproducibility) and temperature sensitivity of the transfer standard.

The transfer standard was tested 7 times in the pilot laboratory (based on the time schedule) and the transfer standard calibration stability was determined based on these results. A maximum error of 0.103 % was found during the experiments e_{exp} (see Figure 3). Combining the uncertainties due to transfer standard calibration stability and temperature sensitivity by root-sum-of-squares leads to a transfer standard uncertainty of 0.031 %.

$$u_{TS} = \sqrt{\left(\frac{e_{exp}}{2\sqrt{3}}\right)^2 + \left(\frac{u_T}{2\sqrt{3}}\right)^2} = \mathbf{0.031\ \%} \qquad (7)$$

This transfer standard uncertainty component was combined by root-sum-of-squares with the standard uncertainty provided by each participating laboratory (Equation 6) and the results are stated in annex B. The ratio of the transfer standard uncertainty to any participant´s flow standard uncertainty is ≤ **1.0**.

6 Evaluation

6.1 Linking to the CCM.FF-K6.2011

Key comparison CCM.FF-K6.2011 was performed simultaneously with EURAMET.M-FF-K6 with the same transfer standard. The linking procedure and its uncertainty analysis are based on the principles which are given in the papers of Elster et al, [4], Kharitonov et al, [5] and Decker et al, [6].

The EURAMET.M.FF-K6 is linked to the CCM.FF-K6.2011 [10] by correcting results of three linking laboratories (Slovakia SMU, Germany PTB and France LNE LADG) with the following procedure. These results are plotted in Figure 8 with the KCRV. The results from EURAMET.M-FF-K6 are corrected by the procedure described by Delahaye and Witt [8]. The calculation was determined for each flow separately.
A correction, which should be applied to the result from KCRV, was obtained by equation (8)

$$D = \sum_{l=1}^{3} w_l D_l \qquad (8)$$

where D_l is the difference between the results from CCM.FF-K6.2011 and EURAMET.M-FF-K6 at a same linking laboratory (SMU, PTB, LNE-LADG) as presented by equation (9) and w_l is the weighting coefficient obtained from the uncertainty at each linking laboratory as presented by equation (10).

$$D_l = x_{l,CCM} - x_{l,EURAMET} \qquad (9)$$

where $x_{1,CCM}$, $x_{2,CCM}$, $x_{3,CCM}$ are relative errors of the transfer standard in the linking laboratories *l=1, 2, 3* in in the comparison CCM.FF-K6.2011,

$x_{1,EURAMET}$, $x_{2,EURAMET}$, $x_{3,EURAMET}$ are relative errors of the transfer standard in the linking laboratories *l=1, 2, 3* in the comparison EURAMET.M-FF-K6.

The weighted mean coefficient was calculated:

$$w_l = \frac{\frac{1}{u_l^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \frac{1}{u_{x3}^2}} \qquad (10)$$

where u_{x1}, u_{x2}, u_{x3} are standard uncertainties (not expanded) of the relative error in laboratories *l = 1, 2, 3* by the CCM.FF-K6.2011 including the uncertainty caused by stability of the transfer standard

Finally, the corrected value x'_i for each flow and each participant of EURAMET was calculated as:

$$x_i' = x_{i,EURAMET} + D \tag{11}$$

where x_1, x_2, ….. x_n are relative errors of the transfer standard in one flow in different laboratories $i = 1, 2, …...n$

This correction D provides an estimate of what would have been the result from the EURAMET.M-FF-K6 participants, if they had actually participated in CCM.FF-K6.2011.

6.2 The determination of the differences "Lab to KCRV"

For each participating laboratory the degree of equivalence (DoE) was calculated using a following equations

$$d_{iD} = x_i' - x_{KCRV} = x_{i,EURAMET} + D - x_{KCRV} \tag{12}$$

where x_{KCRV} is relative error from the comparison CCM.FF-K6.2011 (Table 8).

The expanded uncertainty was obtained using following equations

$$U(d_{iD}) = 2u(d_{iD}) \tag{13}$$

$$u^2(d_{iD}) = u^2(x_i) + u^2(D) + u^2(x_{KCRV}) \tag{14}$$

where $u_{x1}, u_{x2}, ……u_{xn}$ are the standard uncertainties of the relative error in different laboratories $i=1, 2, ……n$ including the uncertainty caused by the stability of the transfer standard (Table 5)

$u(D)$ is the standard uncertainty of the correction "D" including the uncertainty caused by linking laboratories $l=1,2,3$.

$$u^2(D_l) = u^2_{xl(CCM)} + u^2_{xl(EURAMET)} - 2.\mathrm{cov} \tag{15}$$

$$\frac{1}{u_D^2} = \frac{1}{u_{D1}^2} + \frac{1}{u_{D2}^2} + \frac{1}{u_{D3}^2} \tag{16}$$

u_{xKCRV} *is the* standard uncertainty (not expanded) of the KCRV (Table 8).

Based on these differences the Degree of Equivalence (*DoE*) was calculated according to:

$$Ei = \left| \frac{d_{iD}}{U(d_{iD})} \right| \tag{17}$$

The Degree of equivalence (*DoE)* is a measure for the equivalence of the results of any laboratory with the KCRV, respectively:

- the results of a laboratory were *equivalent (**passed**) if Ei or Eij ≤ 1.0*

- the laboratory was determined as *not equivalent (**failed**) if Ei or Eij >1.2*

- for values of *DoE* in the range *1 <Ei or Eij ≤ 1.2* the "**warning level**" was defined. In this case some actions to check are recommended to the laboratory.

The calculation of the *DoE* requires information about the uncertainty of the differences d_{iD}. To make statements about this, it is necessary to consider first the general problem of the difference of two values x_1 and x_2. If we look to the pure propagation of (standard) uncertainty we find:

$$u_{x_1-x_2}^2 = \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} & \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} \begin{pmatrix} u_1^2 & \mathrm{cov} \\ \mathrm{cov} & u_2^2 \end{pmatrix} \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} \\ \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} = u_1^2 + u_2^2 - 2.\mathrm{cov} \qquad (18)$$

The (standard) uncertainty of the difference is the quadratic sum of the uncertainties of the inputs (u_1 and u_2) subtracting twice the covariance (cov) between the two input values.

Therefore it is possible to handle the different cases in this comparison (see Table 2):

a) *Independent laboratories with contribution to the KCRV*

The covariance between the result of a laboratory (with contribution to the KCRV) and the KCRV is the variance of the KCRV itself [1]. Therefore the uncertainty of that laboratory's degree of equivalence with the KCRV is:

$$=> u(d_{iD}) = \sqrt{u_{xi}^2 + u_D^2 + u_{KCRV}^2 - 2.u_{KCRV}^2} = \sqrt{u_{xi}^2 + u_D^2 - u_{KCRV}^2} \qquad (19)$$

b) *Independent laboratories without contribution to the KCRV*

There is no covariance between the result of a laboratory without contribution and the KCRV and the uncertainty of its degree of equivalence is.

$$=> u(d_{iD}) = \sqrt{u_{xi}^2 + u_D^2 + u_{KCRV}^2} \qquad (20)$$

c) *Laboratories with traceability to a laboratory contributing to the KCRV*

In this case we have covariance between the laboratory and the KCRV because the laboratory is linked to the KCRV via the source of traceability. Although we have no detailed information about it, we can determine a conservative estimation of an upper limit of this covariance. The upper limit is determined for the theoretical case if we have no additional stochastic influence in the traceability of the laboratory from its source (which is the laboratory contributing to the KCRV). Then the results of the laboratory considered here would be strongly correlated with the results of the laboratory contributing to the KCRV (correlation coefficient = 1) and there would be the same covariance to the

KCRV as in case a). In the case of additional uncertainty caused stochastically, the correlation and consequently the covariance, is smaller.

$$=> u(d_{iD}) = \sqrt{u_{xi}^2 + u_D^2 + u_{KCRV}^2 - 2u_{KCRV}^2} = \sqrt{u_{xi}^2 + u_D^2 - u_{KCRV}^2} \qquad (21)$$

The expanded uncertainty *U(di)* is determined by

$$U(di) = 2.u(di) \qquad (22)$$

6.3 The determination of the differences “Lab to Lab”

For each participating laboratory, the degree of equivalence (DoE) is calculated using a following equations

$$d_{ijD} = x_i + D - x_j - D = x_i - x_j \qquad (23)$$

where $x_{1,}$ $x_{2,}$ ….. x_n are relative errors of the transfer standard in one flow in different laboratories *i=1, 2, ……n*

$x_{1,}$ $x_{2,}$ ….. x_n are relative errors of the transfer standard in one flow in different laboratories *j=1, 2, ……n*

Based on these differences the Degree of Equivalence (*DoE*) was calculated according to:

$$Eij = \left| \frac{d_{ijD}}{U(d_{ijD})} \right| \qquad (24)$$

The Degree of equivalence (*DoE)* is a measure for the equivalence of the results of any laboratory with any other laboratory, respectively:

- the results of a laboratories were *equivalent (**passed**) if Ei or Eij ≤ 1.0*
- the laboratories were determined as *not equivalent (**failed**) if Ei or Eij >1.0*.

The calculation of the *DoE* requires information about the uncertainty of the differences d_{ijD} (see equation 18*.* The uncertainty of the difference is the quadratic sum of the uncertainties of the inputs (u_1 and u_2) subtracting twice the covariance (cov) between the two input values.

Therefore it is possible find the different cases in this comparison:

a) *Independent laboratories*

There is no covariance between the results of two independent laboratory *i* and *j* and the uncertainty of the difference between two labs is:

$$=> u(d_{ijD}) = \sqrt{u_{xi}^2 + u_{xj}^2} \qquad (25)$$

b) *Dependent laboratories with common source of traceability*

In the case of two labs *i* and *j* with a common source of traceability we will find again a covariance between these labs which is caused by the common source. In our case the common source is another laboratory from which the traceability of both laboratories are derived. Again we can determine a conservative upper limit of the covariance for the same reason as in 6.2 c) as cov = $u^2_{SourceLab}$.

$$=> u(d_{ijD}) = \sqrt{u_{xi}^2 + u_{xj}^2 - 2.u_{SourceLab}^2} \quad (26)$$

The expanded uncertainty $U(d_{ij})$ is determined by

$$U(d_{ij}) = 2.u(d_{ij}) \quad (27)$$

Remark: The 14th CCM meeting (February, 2013) recommended that pair-wise degrees of equivalence no longer be published in the KCDB and that information on pair-wise degrees of equivalence published in KC reports be limited to the equations needed to calculate them, with the addition of any information on correlations that may be necessary to estimate them more accurately.

6.4 Laboratory results and the uncertainties of the linking laboratories

Table 7 - Relative errors of the transfer standard and expanded uncertainties obtained by the linking laboratories

Flow/(m³/h) → NMI	Slovakia SMU		Germany PTB		France LNE-LADG	
	Relative error %	Expanded uncertainty (%)	Relative error %	Expanded uncertainty (%)	Relative error %	Expanded uncertainty (%)
2	-0.16	0.12	-0.10	0.05	-	-
4.5	-0.07	0.12	0.06	0.05	-	-
6.6	-0.01	0.12	0.11	0.05	-	-
9.1	0.03	0.12	0.14	0.05	-	-
13.1	0.07	0.12	0.17	0.05	0.11	0.25
16	0.08	0.12	0.17	0.05	0.15	0.25
24	0.11	0.12	0.19	0.05	0.17	0.25
32	0.13	0.12	0.21	0.05	0.21	0.25
40	0.15	0.12	0.23	0.05	0.23	0.25
50	0.18	0.12	0.24	0.05	0.25	0.25
60	0.20	0.12	0.25	0.05	0.26	0.25
70	0.23	0.12	0.27	0.05	0.25	0.25
80	0.27	0.12	0.29	0.05	0.29	0.25
90	0.31	0.12	0.31	0.083	0.27	0.25
100	0.35	0.12	0.35	0.083	0.28	0.25

6.5 The KCRV and its uncertainty from the CCM.FF-K6.2011

Table 8 - Key comparison reference values (KCRVs)

Flow/ (m3/h)	2	4.5	6.6	9.1	13.1	16	24	32	40	50
KCRV (%)	-0.134	0.017	0.070	0.107	0.139	0.165	0.189	0.214	0.233	0.250
u_{KCRV} (%)	0.025	0.025	0.024	0.023	0.022	0.022	0.022	0.022	0.022	0.022

Table 8 -Continuation of Key comparison reference values (KCRVs)

Flow/ (m3/h)	60	70	80	90	100
KCRV (%)	0.261	0.282	0.301	0.314	0.332
u_{KCRV} (%)	0.022	0.023	0.023	0.025	0.025

6.6 Correction "D" and its uncertainty

Table 9 - Correction "D" and its uncertainty

Flow/ (m3/h)	2	4.5	6.6	9.1	13.1	16	24	32	40	50
D (%)	-0.038	0.052	0.044	0.039	0.033	0.023	0.015	0.033	0.041	0.038
u_D (%)	0.036	0.036	0.036	0.036	0.035	0.035	0.035	0.035	0.035	0.036

Table 9 -Continuation of Correction "D" and its uncertainty

Flow/ (m3/h)	60	70	80	90	100
D (%)	0.036	0.031	0.045	0.059	0.079
u_D (%)	0.036	0.036	0.036	0.046	0.046

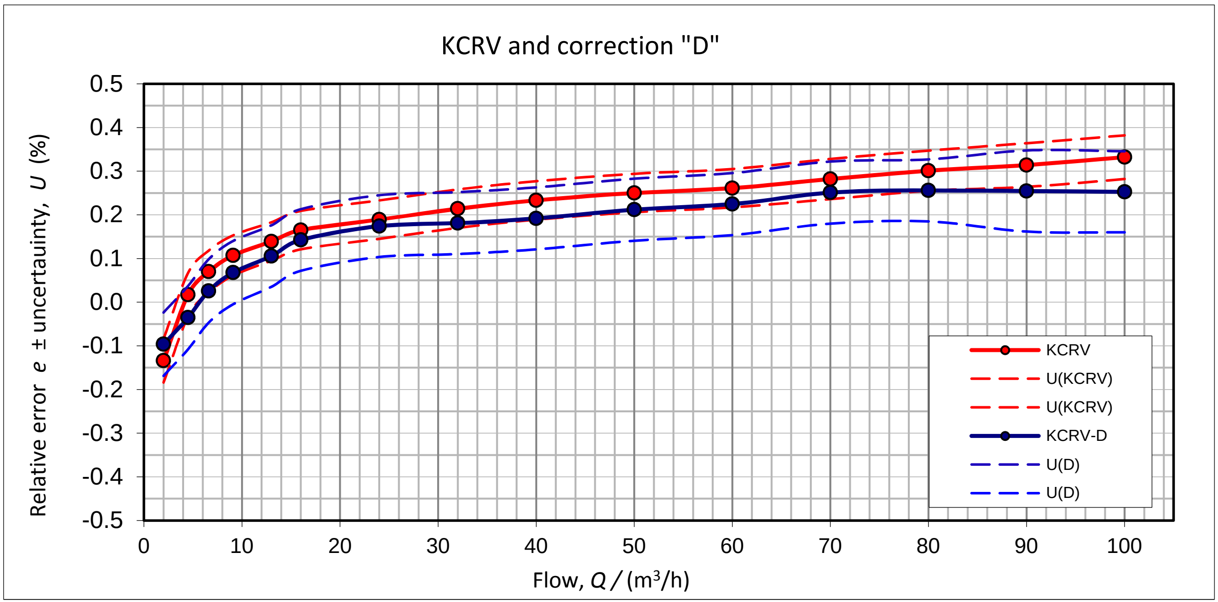


Figure 8 - Key comparison reference value

7 Summary

The standardized degree of equivalence to the KCRV is a measure for the equivalence of the results of any laboratory with the KCRV or with any other laboratory, respectively. *Eni* ≤ 1 means that *i*-th laboratory is in good agreement with the KCRV, whereas and *Eni* > 1.2 means that the *i*-th laboratory is not in good agreement. For values of *DoE* in the range *1 < Eni* ≤ 1.2 the "warning level" is defined. In this case, some actions to check their standards are recommended to the laboratory. The "lab to KCRV" equivalence degrees En_i are summarized in Figure 9 and Table 10.

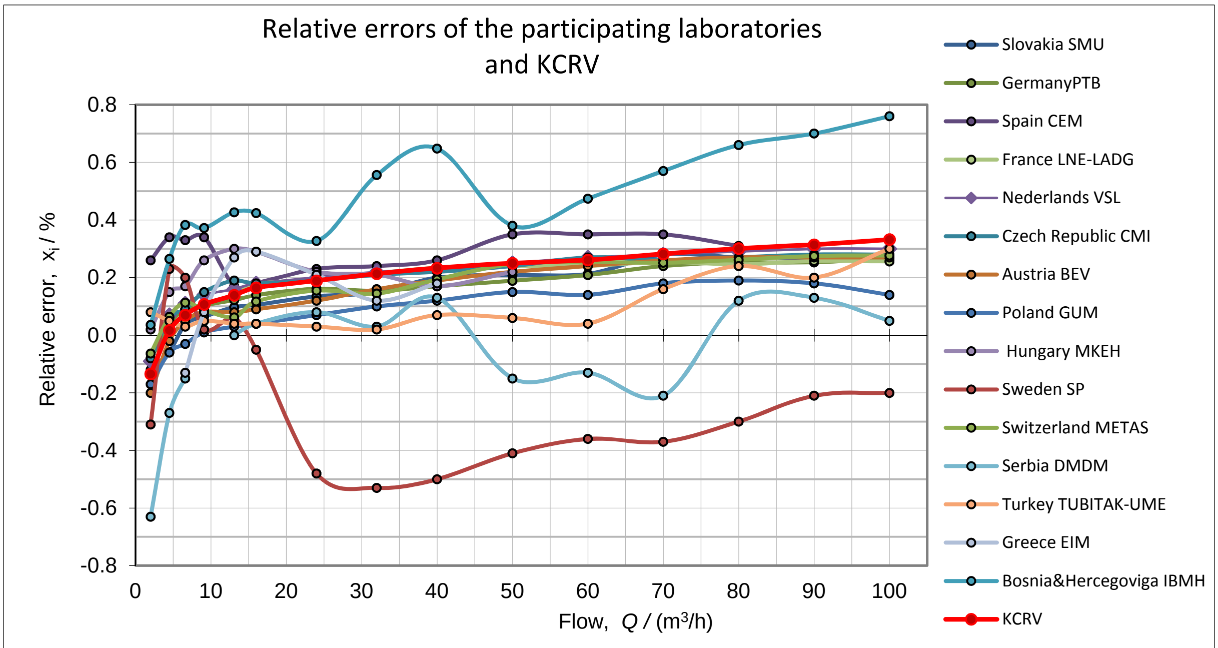


Figure 9 - Relative errors of the participating laboratories and KCRV

Table 10 – Standardized Degree of Equivalence to KCRV (Eni)

Flow/(m³/h) → NMI	Slovakia SMU	Germany PTB	Spain CEM	France LNE-LADG	Netherlands VSL	Czech Republic CMI	Austria BEV	Poland GUM
2	0.16	0.11	-	-	0.04	0.07	0.32	0.34
4.5	0.00	0.59	-	-	0.66	0.43	0.05	0.12
6.6	0.07	0.50	0.80	-	0.53	0.28	0.07	0.24
9.1	0.10	0.28	0.93	-	0.45	0.37	0.04	0.29
13.1	0.11	0.13	0.77	0.17	0.35	0.39	0.08	0.39
16	0.22	0.03	0.68	0.13	0.24	0.17	0.16	0.50
24	0.19	0.10	0.01	0.08	0.16	0.07	0.17	0.51
32	0.07	0.21	0.00	0.12	0.25	0.13	0.06	0.40
40	0.00	0.17	0.13	0.16	0.24	0.13	0.01	0.37
50	0.01	0.18	0.10	0.11	0.24	0.13	0.03	0.30
60	0.04	0.12	0.12	0.06	0.29	0.21	0.05	0.42
70	0.03	0.09	0.34	0.01	0.18	0.04	0.03	0.35
80	0.01	0.02	0.32	0.04	0.22	0.06	0.04	0.32
90	0.07	0.01	0.32	0.01	0.25	0.11	0.05	0.31
100	0.12	0.10	0.21	0.01	0.26	0.12	0.05	0.53

Table 10 – Continuation of Standardized Degree of Equivalence to KCRV (Eni)

Flow/(m³/h) → NMI	Hungary MKEH	Sweden SP	Switzerland METAS	Serbia DMDM	Turkey TUBITAK-UME	Greece EIM	Bosnia & Herzegovina IMBH
2	0.66	0.19	0.15	1.55	0.74	-	0.40
4.5	1.05	0.24	0.47	0.70	0.36	-	0.97
6.6	0.82	0.16	0.41	0.55	0.02	0.24	1.16
9.1	1.09	0.04	0.09	-	0.07	0.04	0.99
13.1	1.12	0.04	0.20	0.32	0.28	0.63	1.05
16	0.85	0.18	0.12	0.32	0.43	0.63	0.92
24	0.26	0.66	0.09	0.30	0.61	0.14	0.50
32	0.17	0.73	0.17	0.48	0.68	0.28	1.22
40	0.13	0.68	0.01	0.20	0.52	0.03	1.49
50	0.05	0.64	0.17	0.88	0.64	-	0.55
60	-	0.58	0.14	0.87	0.78	-	0.81
70	-	0.62	0.00	1.12	0.38	-	1.04
80	-	0.58	0.03	0.42	0.07	-	1.31
90	-	0.48	0.09	0.37	0.22	-	1.39
100	-	0.47	0.10	0.59	0.19	-	1.59

8 Conclusions

Fifteen laboratories participated in EURAMET.M.FF-K6, a low pressure gas flow comparison that was running simultaneously with CCM.FF-K6 KCRV. Three laboratories (Slovakia SMU, Germany PTB and France LNE-LADG) participated in both comparisons and their results were used to link the EURAMET.M.FF-K6 results with the CCM.FF-K6 KCRV.

Seven sets of calibration results from the pilot laboratory showed reproducibility for the transfer standard of 0.03 %. According to the evaluation 93.7 % of the results were consistent with KCRV, 3.4 % of the results were in the warning level and 2.9 % of the results were inconsistent. Table 11 is based on information supplied by the participant laboratories regarding their CMCs. If the country does not yet have CMC tables, the results will be used for support of a new database entry.

Table 11 - Consistency with the CMC tables

Country NMI	CMC tables			Comparison E 1180		Consistency with CMC tables
	Flow range (m^3/h)	Expanded uncertainty (%)	Identification	Flow range (m^3/h)	Expanded uncertainty (%)	
Slovakia SMU	1 to 65	0.12	SK13	2 to 100	0.12	100% consistent results
Germany PTB	2 to 80	0.045		2 to 100	0.064 to 0.083	100% consistent results
Spain CEM	-	No entry yet	-	6.6 to 100	0.27	To support a new CMC entry
France LNE-LADG	13 to 100	0.26	LADG2	13 to 100	0.25	100% consistent results
Netherlands VSL	1 to 400	0.09	NE04	2 to 100	0.094	100% consistent results
Czech Republic CMI	0.15 to 17 4 to 400	0.18	CZ1	2 to 16 24 to 100	0.18 to 0.19	100% consistent results
Austria BEV	0.5 to 400	0.30	BEV/AT2	2 to 25 25 to 100	0.30	100% consistent results
Poland GUM	0.16 to 110	0.14	PL9	2 to 100	0.15 to 0.17	100% consistent results
Hungary MKEH	0.20 to 50	0.12	HU7	2 to 50	0.12	80% consistent results 20% results in warning level
Sweden SP	-	No entry yet	-	2 to 100	0.95 to 1.13	To support a new CMC entry
Switzerland METAS	1 to 1000	0.15	5135-CH7	2 - 100	0.17 to 0.18	100% consistent results
Republic of Serbia DMDM	-	No entry yet	-	2 to 65 65 to 100	0.29 to 0.32	To support a new CMC entry
Turkey TUBITAK - UME	0.2 to 85 3 to 600	0.25 0.50	TR1 TR2	2 to 100	0.20	100% consistent results

Country NMI	CMC tables			Comparison E 1180		Consistency with CMC tables
	Flow range (m^3/h)	Expanded uncertainty (%)	Identification	Flow range (m^3/h)	Expanded uncertainty (%)	
Greece EIM	1 to 60	0.2	CAL-FLO-100	6.6 to 37.5	0,18 to 0,63*)	100% consistent results *)
Bosnia-Herzegovina IBMH	-	No entry yet	-	2 to 16 24 to 24 50 to 100	0.26 to 0.35	47 % consistent results, 20% results in warning level

*) Greece/EIM explained in the report, that during this comparison, due to signal sampling constraints, they were forced to give higher uncertainty values which did not correspond to the actual measurement capabilities of their gas flow laboratory but it was the only way available to capture the signal from the transfer standard. This concerns 3 from 7 measured flows.

9 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] Rousseeuw P.J., Leroy A.M., Robust Regression and outlier detection, John Wiley & Sons, New York, 1987

[4] Elster C., Link A., Wöger W., Proposal for linking the results of CIPM and RMO key comparisons, Metrologia, 2003, 40, 189-194

[5] Kharitonov I.A., Chunovkina A.G., Evaluation of regional key comparison data: two approaches for data processing, Metrologia, 2006, 43, 470-476

[6] Decker J.E., Steele A.G., Douglas R.J., Measurement science and the linking of CIPM and regional key comparisons, Metrologia, 2008, 45, 223-232

[7] Engel R., Mickan B., Aspects of traceability and comparisons in flow measurement, 7th ISFFM, Anchorage/Alaska, August 12-14, 2009

[8] JCGM 100:2008 (GUM 1995 with minor corrections) Evaluation of measurement data — Guide to the expression of uncertainty in measurement

[9] Delahaye F., Witt T. J., Linking the Results of Key Comparison CCEM-K4 with 10 pF Results of EUROMET Project 345, Metrologia 39 (2002), Technical Supplement 01005

[10] http://kcdb.bipm.org/appendixB/KCDB_ApB_info.asp?cmp_idy=1132&cmp_cod=CCM%2EFF%2DK6%2E2011&search=2&cmp_cod_search=m%2Eff%2Dk6&page=1&met_idy=&bra_idy=&epo_idy=&cmt_idy=&ett_idy_org=&cou_cod=

Appendix A – NMI reports

Characteristic information \ picture of the primary standard used by measurements	Working procedure

SMU - Slovak Institute of Metrology

Karloveska 63. 842 55 Bratislava. Slovakia

Basic range of flow rate:	(1 to 65) m^3/h
Expanded range of flow rate:	(0.5 to 100) m^3/h
Temperature:	20°C
Working pressure:	atmospheric conditions
Uncertainty (*k*=2):	0.12 %

The Bell prover is a part of the national standard of flow and delivered volume of gas. Traceability of the national standard of flow and delivered volume of gas - the Bell prover - is derived from the SI base units, i.e the unit of the length and the time.

PTB - Physikalisch-Technische Bundesanstalt

Bundesallee 100. 38116 Braunschweig. Germany

Range of flow rate:	(1 to 80) m^3/h
Temperature:	(20 ± 2)°C
Working pressure:	atmospheric conditions
Uncertainty (*k*=2):	0.045 %

The bell prover of the Physikalisch-Technische Bundesanstalt serves as the fundamental realisation of the unit "Volume" within the field of gas measurement and is the primary standard for gas volume at lower pressure ranges. The unit of volume, respectively of its flow, can be passed on to various users by a direct or indirect connection for the calibration of secondary standards.

The measurement uncertainty for the data acquisition during the measuring period amounts for the temperature to £ 0.02° C and for the pressure to £ 5 Pa. The verification of high-quality standards (critical nozzles) showed repeatability of ± 0.02 %.

Characteristic information \ picture of the primary standard used by measurements	Working procedure

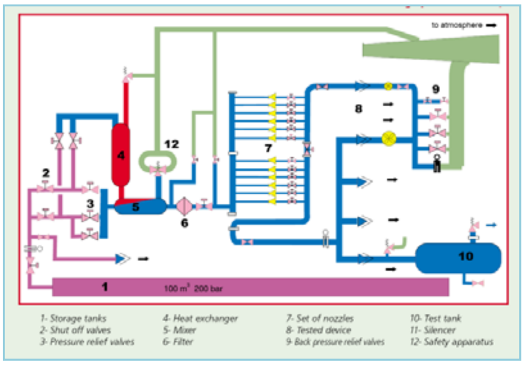
CEM – Ministerio de industria. turismo y comercio. Enagás. S.A.
LABORATORIO DE CONTADORES DE GAS
Autovía A-2. km. 306.4. 50012 – ZARAGOZA (SPAIN)

Range of flow rate:	(5 to 1000) m^3/h
Temperature:	(20 ± 1)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	0.27 %

The calibration has been carried out with air at close to atmospheric pressure. The laboratory temperature was 20 ºC ± 1 ºC. The error determination of the meter is based on the comparison of the air volume which was indicated by the standard meter and the air volume which was indicated by the meter under test after calculations of corrections concerning temperature and pressure differences in the standard meter and the meter under test. The reference pressure of the turbine gas meter was measured through the output “pr”. The pressure loss of the meter was measured between the output “pr” and the meter outlet. - The calibration was performed by means of the high frequency pulse emitter. - The minimum volumes established for each nominal calibration flow rate were the following (108 second minimum test time).

LNE-LADG
CESAME EXADEBIT - 43. route de l’aerodrome - F - 86036 Poitiers Cedex

Range of flow rate:	(1.5 to 1000) m^3/h
Temperature:	(20 ± 2)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	0.20 %



The meter under test is placed on a pipeline downstream from the set of nozzles. This configuration allows a comparison between the reference and tested device mass flows. The pressure and the temperature can be measured at the level of the meter under test in order to determine the volumetric flow rate going through.

The air coming from a storage vessel (200 bar, 110 m^3) goes through the valves and the heating control system. This adjusts the suitable temperature and pressure upstream from the nozzles automatically. The pipe lines bear the reference nozzles chosen according to the flow set points to be generated for the tests.

Characteristic information \ picture of the primary standard used by measurements	Working procedure

Nederlands VSL

Thijsseweg 11. Delft, Nederlands

Range of flow rate:	(1 to 400) m^3/h
Temperature:	(20 ± 1)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	0.09 %

Working procedure: To start a measurement the bell prover is filled with air beyond the start-sensor of the used volume. A few runs are used to automatically regulate the flow rate. The pulse of the start-sensor starts the time measurement of the reference. After the pulse of the start-sensor the first pulse of the DUT is used to start the time measurement of the DUT. The stop-sensor stops the time measurement of the reference and the first pulse of the DUT after the pulse of the stop-sensor stops the time measurement of the DUT. With the available data regarding pressure and temperature the reference flow rate and the error of the DUT are calculated.

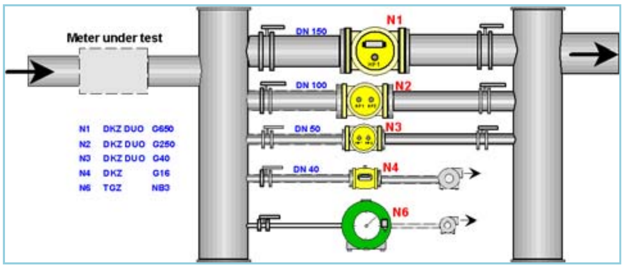
CMI – Czech Metrology Institute

Husova 10. 539 73 Skuteč. Czech Republic

Range of flow rate:	(0.1 to 400) m^3/h
Temperature:	(20 ± 2)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	(0.18 to 0.19) %

Working procedure: The constant pressure under the bell is ensured by means of two counterweights. One counterweight serves to maintain the constant oil level in the vessel in which the bell dips. The other counterweight ensures the compensation of the buoyancy force.

At the end of the test the mean temperatures and the mean pressures are calculated. The bell prover is controlled by special software in a PC. The volume of air for the starting run of the bell and the volume of air for the test are set by the operator in the software. In the moment when all the volume for the starting run passes through the gas meter the position of the bell is recorded by the two optical pickups. From this time pulses of gas meter are accumulated again. In the end of the test (in the moment of the last pulse of the gas meter) the position of the bell is recorded in the same way. It is clear that the mean of two values of the optical pickups is calculated and this mean is used for subsequent calculations.

Characteristic information \ picture of the primary standard used by measurements	Working procedure
BEV - Bundesamt für Eich- und Vermessungswesen Arltgasse 35. A-1160 Wien. Austria Range of flow rate: (0.1 to 1000) m^3/h Temperature: (20 ± 1)°C Working pressure: atmospheric conditions Uncertainty (k=2): 0.30 %  	The transfer standard was installed without an upstream straightening pipe according to our normal practice. Air was sucked from the laboratory by a fan through the meter under test and afterwards through the chosen normal meter. The flow rate was adjusted by a valve behind the normal meter. The pressure at the test meter and the normal meter was measured on the gas meter body at the point marked “pm”. The meter temperatures where measured downstream of the meters. The duration of each test was 180 seconds (3 minutes) or more. The indicated volume for the meters was calculated from the counted pulses. The flow rate was derived from measuring the time and the passed volume during one test point. The reference volume at the transfer meter was obtained by correcting the volume measured by the normal meter to the conditions of the meters.
GUM - Central Office of Measures ul. Elektoralna 2. 00-139 Warszawa. Poland Range of flow rate: (0.18 to 110) m^3/h Temperature: (19 to 22) °C Working pressure: atmospheric conditions Uncertainty (k=2): 0.13 % 	Calibration of a gas meter is carried out by determination of the error-flow rate relationship. Errors of the calibrated gas meter are calculated as a ratio of the difference of the volume measured by the gas meter and the reference volume relative to the reference volume. The reference volume is determined on the basis of measurement dose of the bell prover and calculated to the conditions of the gas meter. The volume measured by a gas meter is calculated by multiplying a number of high frequency pulses by the pulse generator constant.

Characteristic information \ picture of the primary standard used by measurements	Working procedure

MKEH - Hungarian Trade Licensing Office
H-1124 Budapest. Németvölgyi út 39. Hungary

Range of flow rate:	(0.02 to 50) m^3/h
Temperature:	(23 ± 1)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	0.12 %

The installation operates on the bell prover principle, by comparing the output of a Meter-under-Test that is installed in series with the bell prover. The piping system is tested for leaks and the flow is regulated after the MUT. The bell prover descends at a constant velocity and steady state conditions and passes through the calibrated interval. The calibrated interval for the bell is measured using detector gates which designate the start and stop position.
The temperature and pressure is measured over the calibration procedure. The gas temperature is measured with a sensor inserted into the upper part of the bell and upstream of the rotary gas meter. The gas pressure is measured under the bell with a differential pressure sensor connected to a tap in the outflow pipe and at the "pm" pressure output tap of the meter.
The time of calibration and the impulses from the meter are measured with an electronic device (counter and timer). The quantity of gas flowing through the meter is identical by taking pressure and temperature in both bell and transfer meter into account the volume can be compared.

SP - Technical Research Institute of Sweden
Department: Energy Technology, Calibration (ETks)
Brinellgatan 4, Box 857, 501 15 BORÅS
SWEDEN

Range of flow rate:	(0,00003 to 8700) m^3/h
Temperature:	Room temperature
Working pressure:	atmospheric conditions
Uncertainty (k=2):	(0,9 to 1,4) %

The laboratory reference was fitted at the incoming air connection on the transfer standard. The air flow was controlled by a variable-speed controlled fan which was fitted at the end of the formation. Normal room air at current room temperature and atmospheric pressure was used. The volumetric flow at the laboratory reference was converted to a mass flow. This mass flow was converted back to actual volumetric flow at the meter under test with current temperature and absolute pressure at the transfer standard. From this volumetric flow and the output signal indicated by the transfer standard (frequency), the error determination was calculated. The time for each point at measurement, was about 30 s. In this comparison, two different sizes of Laminar Flow Element were used. For the whole flow rate calibration range, there are ten laboratory references, seven Laminar Flow Elements and three nozzles (ISO 5167)

<table>
<tr><th>Characteristic information \ picture of the primary standard used by measurements</th><th>Working procedure</th></tr>
<tr><td>

METAS - Federal Office of Metrology
Laboratory Flow and Volume
Lindenweg 50. CH-3003 Bern-Wabern. Switzerland

Range of flow rate:	(0.1 to 4500) m^3/h
Temperature:	(21 ± 1)°C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	(0.17 to 0.18)%

</td><td>

Ambient air is first sucked through the DUT and then through the secondary standards of the test facility.
The reference flow rates at the DUT are adjusted by means of the regulation of the rotation speed of the ventilators and the positions of the flap valves.
Once the reference flow rate reaches a steady state, 5 consecutive comparison measurements between the secondary standards and the DUT are performed.
The generated air flow is measured by the secondary standards as volume flow which is then transformed to mass flow by taking into account the pressure, the temperature and the humidity of the air at the secondary standards. The mass flow is considered to be constant along the pipes. Therefore the mass flow is converted back into actual volume flow at the DUT with respect to the pressure, the temperature and the humidity of the air at this position.

</td></tr>
<tr><td>

DMDM - Directorate for measures and precious metals
Srbija Gas. 21000 Novi Sad. Put Šajkaškog odreda 3
Republic of Serbia

Range of flow rate:	(0.6 to 400) m^3/h
Temperature:	(21 to 22) °C
Working pressure:	atmospheric conditions
Uncertainty (k=2):	(0.29 to 0.31) %

</td><td>

The process of testing samples –is completely automated. The software which manages the testing process is adjusted so that any working standard can be active only individually.
Measuring installation has a range from Q_{min} = 0.6 m^3/h to Q_{max} = 400 m^3/h and is made of two working standards IRM-3 / G-40 and IRM-3 / G-250.

</td></tr>
</table>

<table>
<tr><th>Characteristic information \ picture of the primary standard used by measurements</th><th>Working procedure</th></tr>
<tr><td>

TUBITAK-UME - TÜBİTAK National Metrology Institute

<table>
<tr><td>Range of flow rate:</td><td>(0.2 to 100) m³/h</td></tr>
<tr><td>Temperature:</td><td>(21 ± 1)°C</td></tr>
<tr><td>Working pressure:</td><td>atmospheric conditions</td></tr>
<tr><td>Uncertainty (k=2):</td><td>0.05 %</td></tr>
</table>

</td><td>UME national standard for gas flow rate measurement is the Bell Prover. Gas flow rate in the range of (0.2 to 100) m^3/h is measured by this system with an uncertainty of 0.05 %. It is calibrated at UME Dimensional and Time & Frequency Laboratories with primary standards.</td></tr>
<tr><td>

HELLENIC INSTITUTE OF METROLOGY
Mechanical Measurements Department
Fluid Flow & Volume Laboratory
Industrial Area of Thessaloniki
Block 45. Sindos. GR-57 022. GREECE

<table>
<tr><td>Range of flow rate:</td><td>(0.6 to 400) m³/h</td></tr>
<tr><td>Temperature:</td><td>(18 to 20) °C</td></tr>
<tr><td>Working pressure:</td><td>atmospheric conditions</td></tr>
<tr><td>Uncertainty (k=2):</td><td>0.18 %</td></tr>
</table>

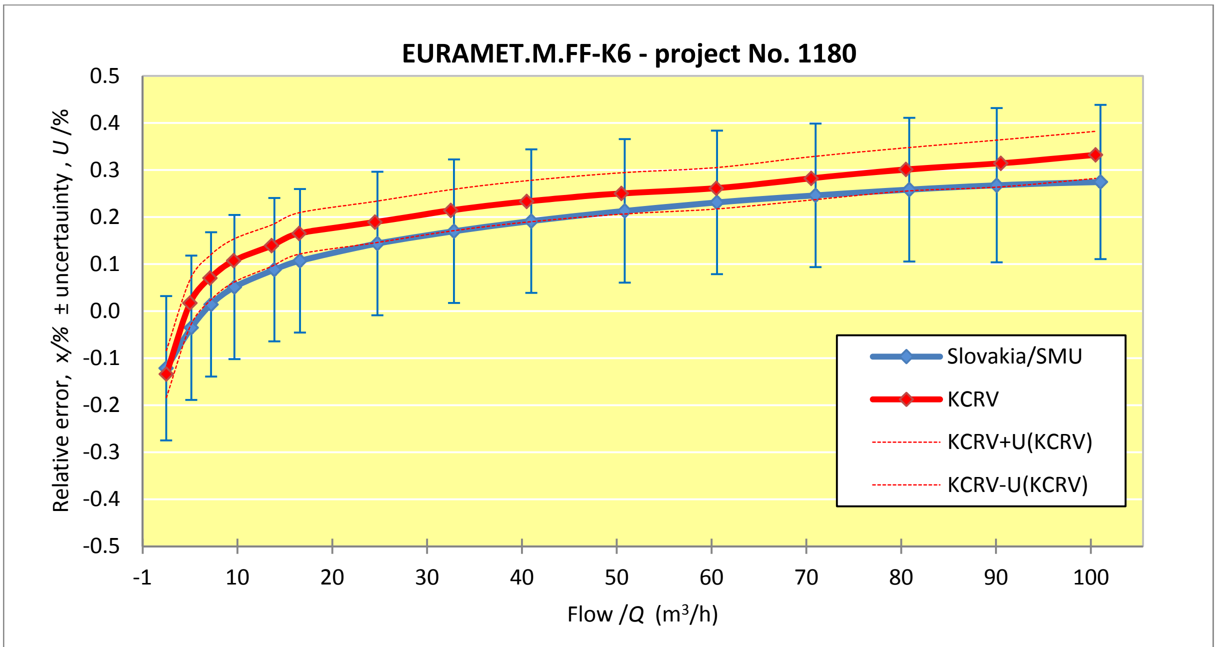
</td><td>The reference facility used in this project is a volumetric device working on a positive displacement principle. Therefore, the reference flow rate was expressed in [sm^3/h] which means that the actual flow rate was corrected to user defined STP conditions. In this case the standard conditions were 101325 Pa and 20 °C. The flow rate measured by the TS was also corrected to standard conditions and therefore also expressed in [sm^3/h].</td></tr>
</table>

<table>
<tr><th>Characteristic information \ picture of the primary standard used by measurements</th><th>Working procedure</th></tr>
<tr><td>
IMBiH – Bosnia and Herzegovina
SARAJEVOGAS, LABORATORIJ ZA ISPITIVANJE I KALIBRACIJU MJERNIH INSTRUMENATA ZA GAS
Rajlovacka bb, 71000 Sarajevo
<table>
<tr><td>Range of flow rate:</td><td>(0,5 to 4000) m3/h</td></tr>
<tr><td>Temperature:</td><td>21 °C</td></tr>
<tr><td>Working pressure:</td><td>atmospheric conditions</td></tr>
<tr><td>Uncertainty (k=2):</td><td>0,28 %</td></tr>
</table>

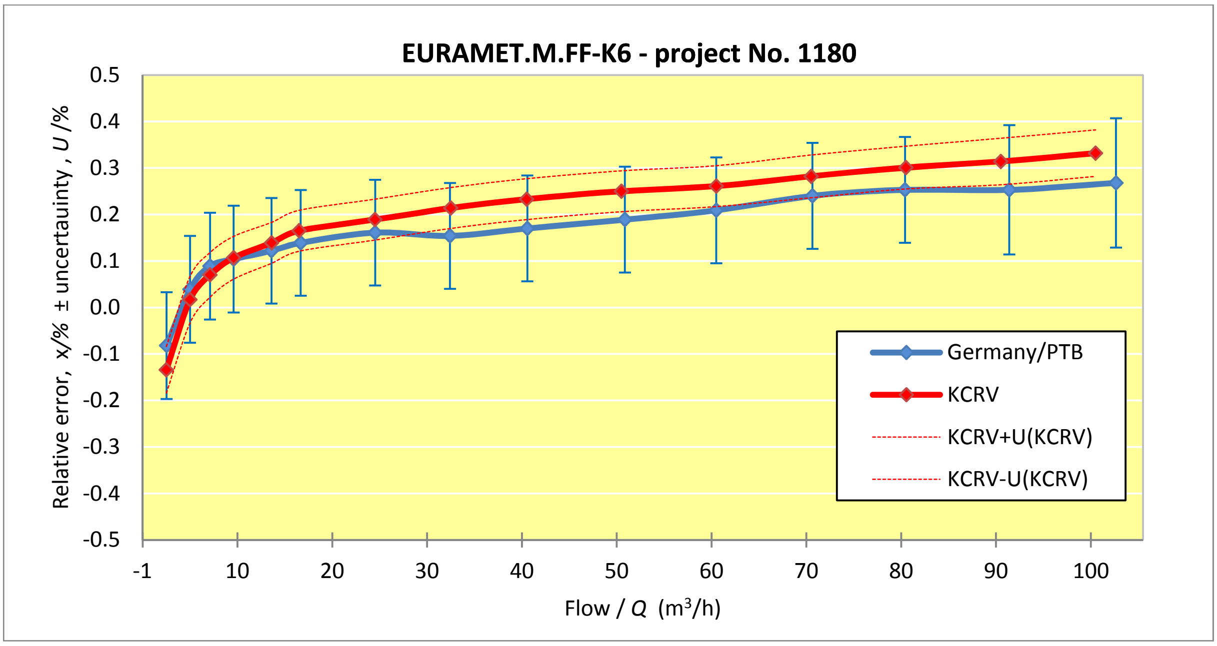
</td><td>
Ambient air is sucked by a fan through the standard meter and afterwards through the meter under test. The test was performed at atmospheric conditions with air temperature of about 21°C. System is automated by software and the flow rate is adjusted by regulation of the rotation speed of the fan and electromotive valve. After reaching the stable flow rate, the test was performed during minimum 360 seconds.
The error of the meter under test was calculated after correction of indicated volume for pressure and temperature conditions.
Standard meters used for this inter-laboratory comparison are rotary gas meters G16 in the range: (0.35 – 25) m^3/h) and G40 in the range: (0.5 – 65) m^3/h and turbine gas meter G250 in the range (20 – 400) m^3/h.
</td></tr>
</table>

Appendix B – graphical representation of relative error and expanded uncertainty

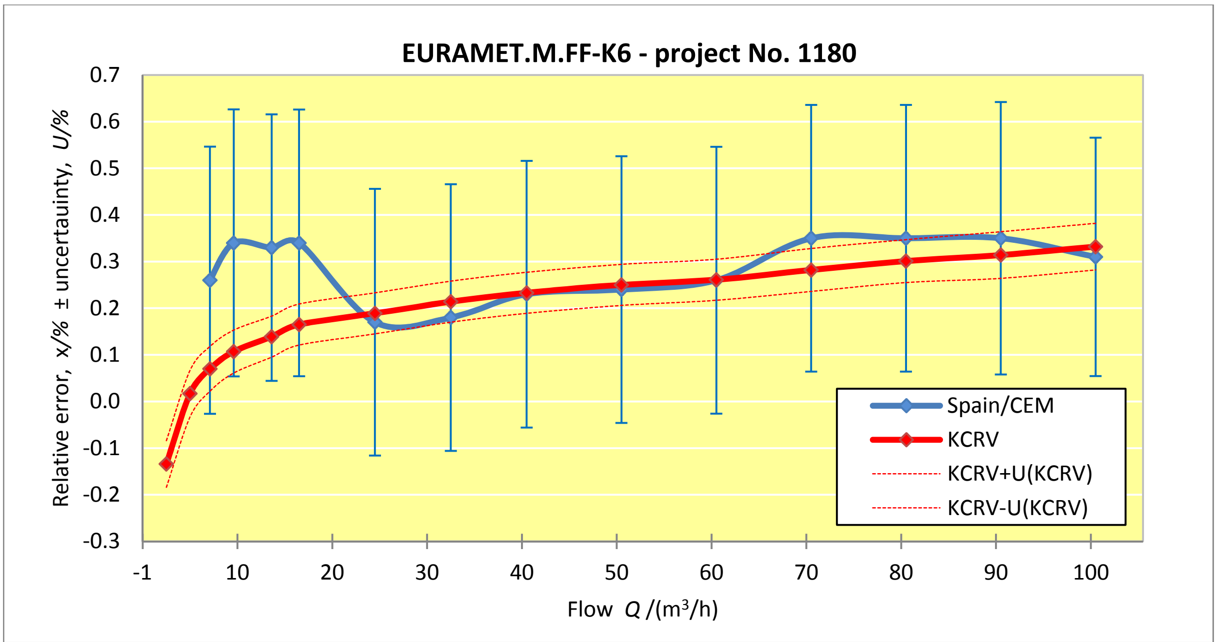
Slovakia/SMU					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
1.98	-0.12	0.12	0.153	-0.025	0.16
4.63	-0.06	0.12	0.153	0.000	0.00
6.71	0.04	0.12	0.153	-0.011	0.07
9.18	0.06	0.12	0.153	-0.017	0.10
13.39	0.10	0.12	0.152	-0.018	0.11
16.09	0.11	0.12	0.152	-0.036	0.22
24.26	0.13	0.12	0.152	-0.031	0.19
32.34	0.15	0.12	0.153	-0.011	0.07
40.49	0.20	0.12	0.153	-0.001	0.00
50.34	0.21	0.12	0.153	0.001	0.01
60.07	0.21	0.12	0.153	0.006	0.04
70.47	0.28	0.12	0.153	-0.005	0.03
80.35	0.27	0.12	0.153	0.002	0.01
89.57	0.27	0.12	0.164	0.013	0.07
100.52	0.26	0.12	0.164	0.022	0.12



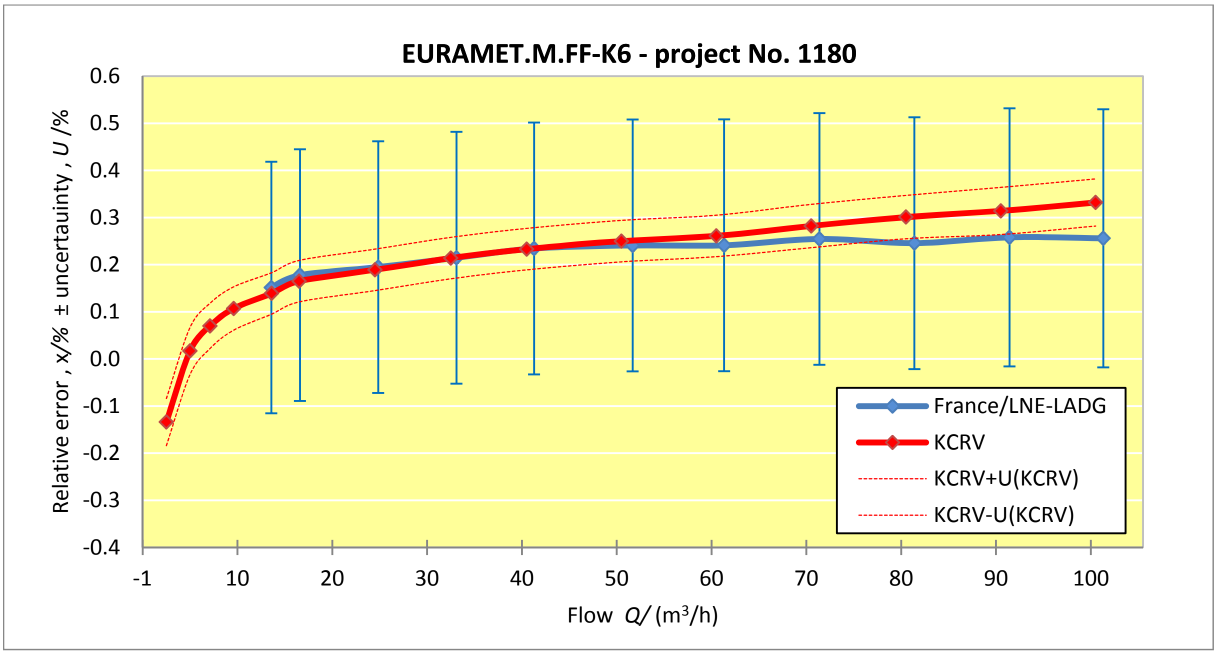
Germany/PTB					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.02	-0.08	0.064	0.115	0.014	0.11
4.50	0.04	0.064	0.115	0.074	0.59
6.60	0.09	0.064	0.115	0.063	0.50
9.10	0.10	0.064	0.115	0.036	0.28
13.09	0.12	0.064	0.114	0.016	0.13
16.16	0.14	0.064	0.114	-0.003	0.03
24.02	0.16	0.064	0.114	-0.013	0.10
31.92	0.15	0.064	0.114	-0.027	0.21
40.07	0.17	0.064	0.114	-0.022	0.17
50.36	0.19	0.064	0.114	-0.023	0.18
60.00	0.21	0.064	0.114	-0.016	0.12
70.14	0.24	0.064	0.114	-0.011	0.09
79.90	0.25	0.064	0.114	-0.003	0.02
90.90	0.25	0.083	0.139	-0.002	0.01
102.16	0.27	0.083	0.139	0.015	0.10



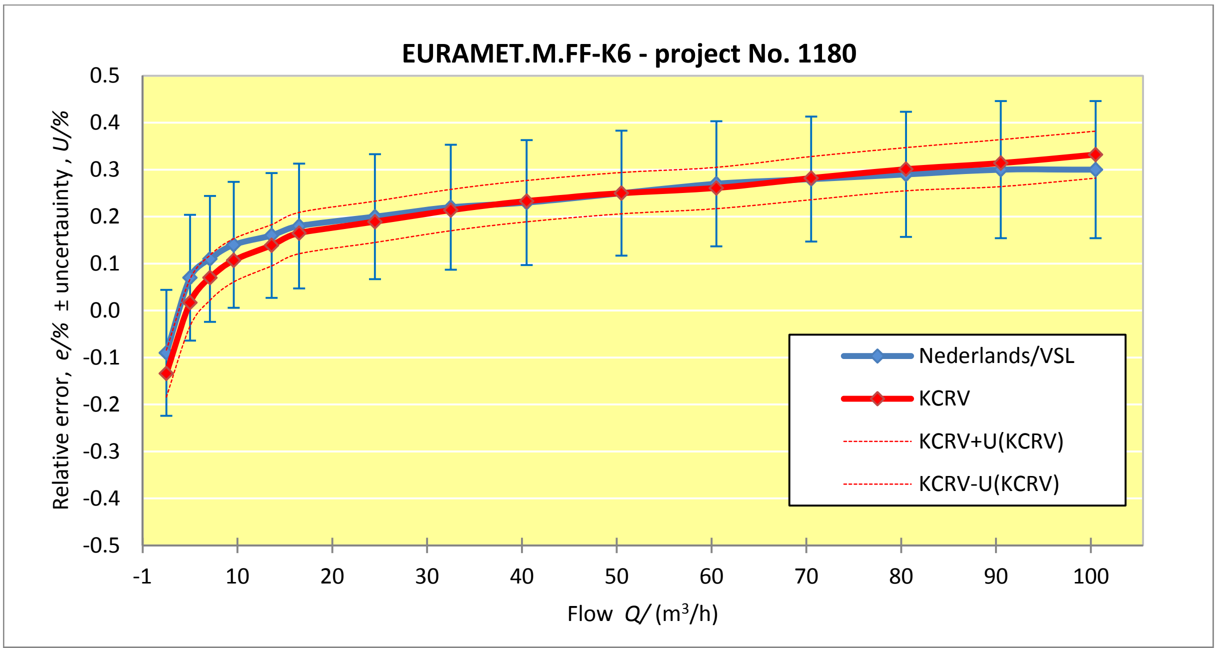
Spain/CEM					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
6.60	0.26	0.27	0.286	0.234	0.80
9.10	0.34	0.27	0.286	0.272	0.93
13.10	0.33	0.27	0.286	0.224	0.77
16.00	0.34	0.27	0.286	0.198	0.68
24.00	0.17	0.27	0.286	-0.004	0.01
32.00	0.18	0.27	0.286	-0.001	0.00
40.00	0.23	0.27	0.286	0.038	0.13
50.00	0.24	0.27	0.286	0.028	0.10
60.00	0.26	0.27	0.286	0.035	0.12
70.00	0.35	0.27	0.286	0.099	0.34
80.00	0.35	0.27	0.286	0.094	0.32
90.00	0.35	0.27	0.292	0.095	0.32
100.00	0.31	0.23	0.256	0.057	0.21



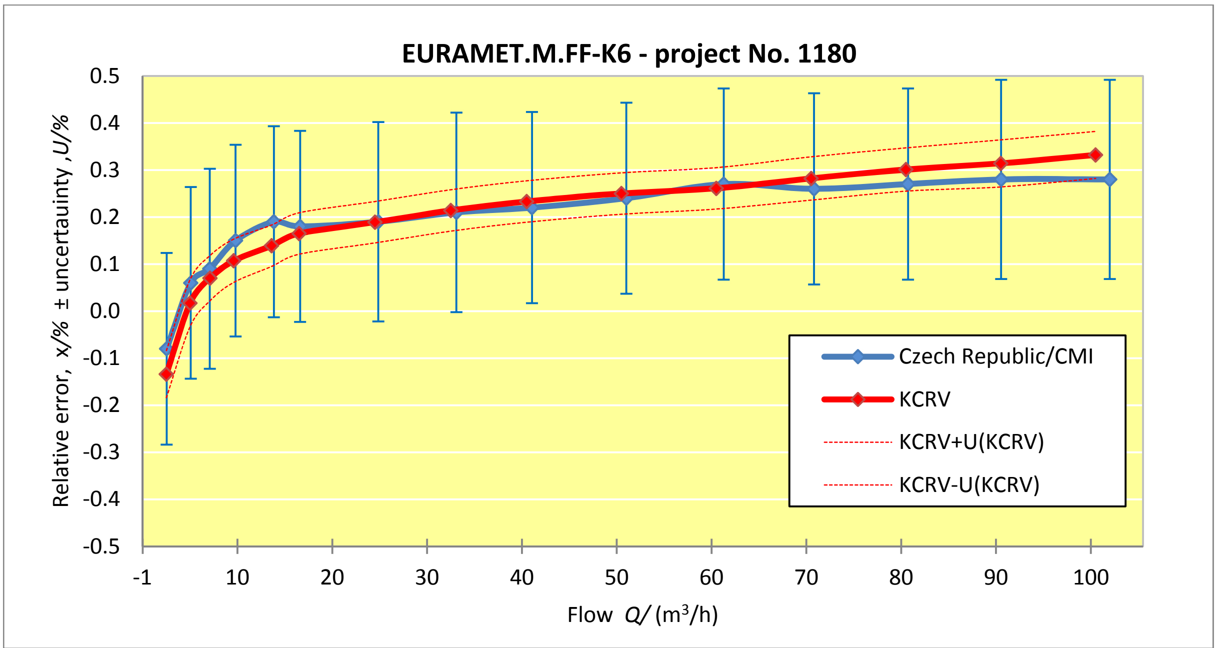
France/LNE-LADG					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
13.07	0.15	0.25	0.267	0.046	0.17
16.09	0.18	0.25	0.267	0.035	0.13
24.35	0.19	0.25	0.267	0.021	0.08
32.60	0.21	0.25	0.267	0.034	0.12
40.78	0.23	0.25	0.267	0.042	0.16
51.18	0.24	0.25	0.267	0.029	0.11
60.82	0.24	0.25	0.267	0.016	0.06
70.87	0.25	0.25	0.267	0.004	0.01
80.89	0.25	0.25	0.267	-0.010	0.04
90.92	0.26	0.25	0.274	0.003	0.01
100.81	0.26	0.25	0.274	0.003	0.01



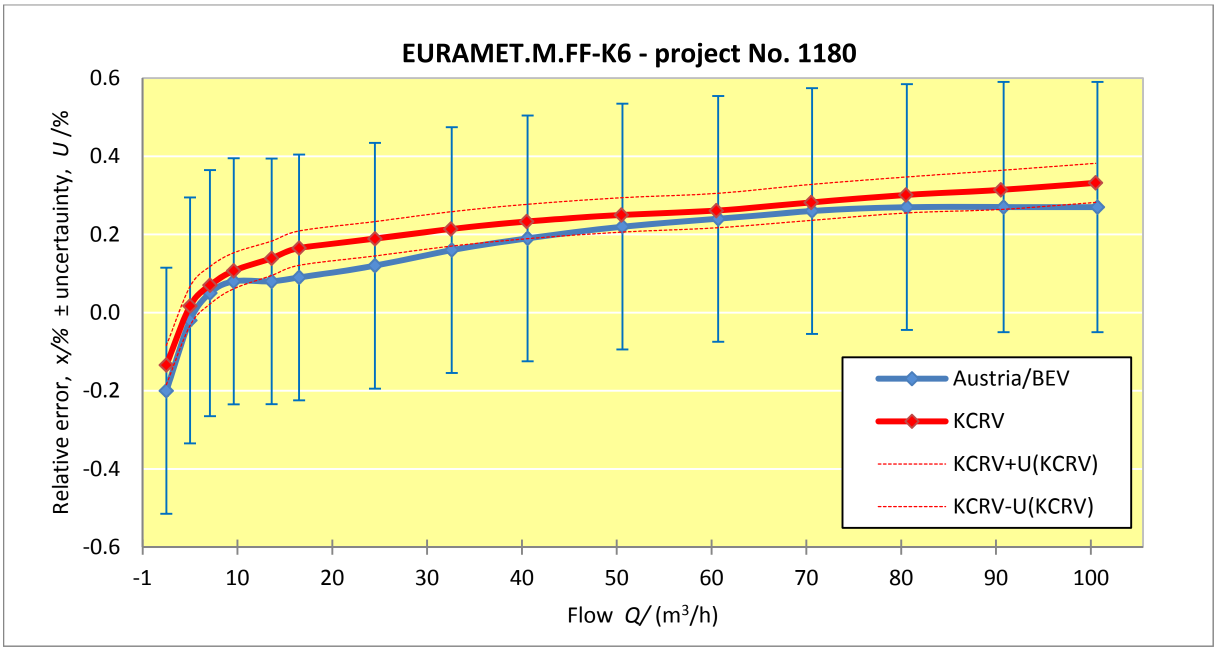
Netherlands/VSL					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
2.00	-0.09	0.094	0.134	0.006	0.04
4.50	0.07	0.094	0.134	0.105	0.66
6.60	0.11	0.094	0.134	0.084	0.53
9.10	0.14	0.094	0.134	0.072	0.45
13.10	0.16	0.094	0.133	0.054	0.35
16.00	0.18	0.094	0.133	0.038	0.24
24.00	0.20	0.094	0.133	0.026	0.16
32.00	0.22	0.094	0.133	0.039	0.25
40.00	0.23	0.094	0.133	0.038	0.24
50.00	0.25	0.094	0.133	0.038	0.24
60.00	0.27	0.094	0.133	0.045	0.29
70.00	0.28	0.094	0.133	0.029	0.18
80.00	0.29	0.094	0.133	0.034	0.22
90.00	0.30	0.094	0.146	0.045	0.25
100.00	0.30	0.094	0.146	0.047	0.26



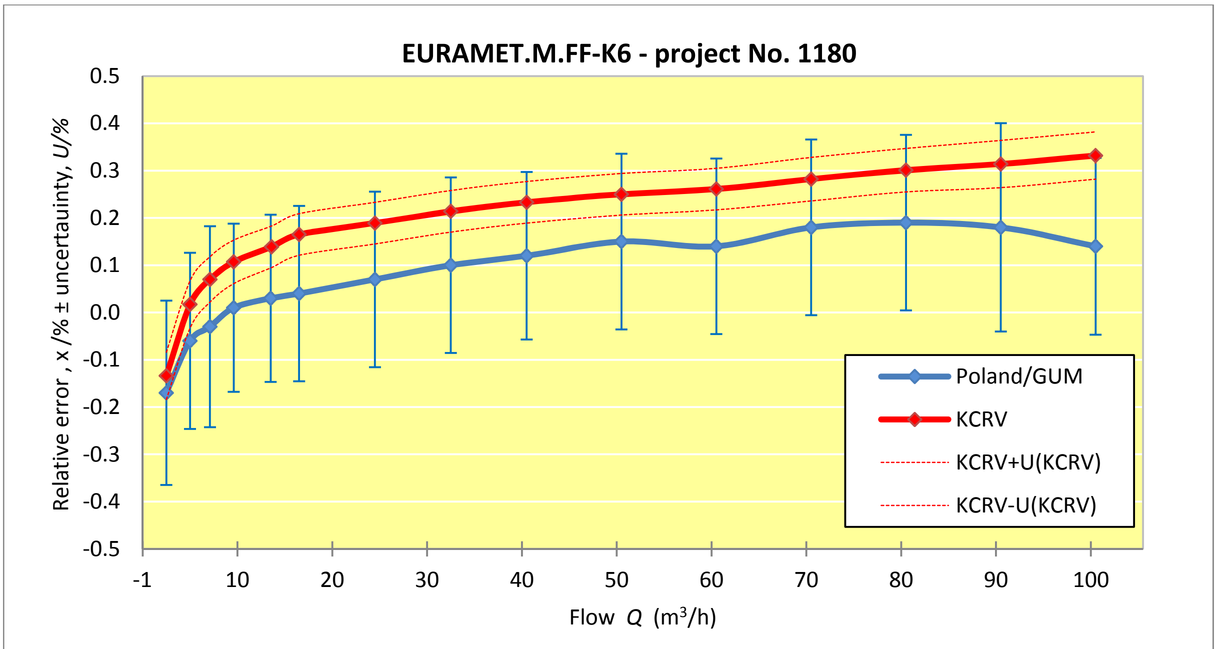
Czech Republic/CMI					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.03	-0.08	0.18	0.204	0.016	0.07
4.57	0.06	0.18	0.204	0.095	0.43
6.58	0.09	0.19	0.213	0.064	0.28
9.30	0.15	0.18	0.204	0.082	0.37
13.34	0.19	0.18	0.203	0.084	0.39
16.11	0.18	0.18	0.203	0.038	0.17
24.35	0.19	0.19	0.212	0.016	0.07
32.59	0.21	0.19	0.212	0.029	0.13
40.56	0.22	0.18	0.203	0.028	0.13
50.51	0.24	0.18	0.203	0.028	0.13
60.78	0.27	0.18	0.203	0.045	0.21
70.31	0.26	0.18	0.203	0.009	0.04
80.22	0.27	0.18	0.203	0.014	0.06
90.04	0.28	0.18	0.212	0.025	0.11
101.50	0.28	0.18	0.212	0.027	0.12



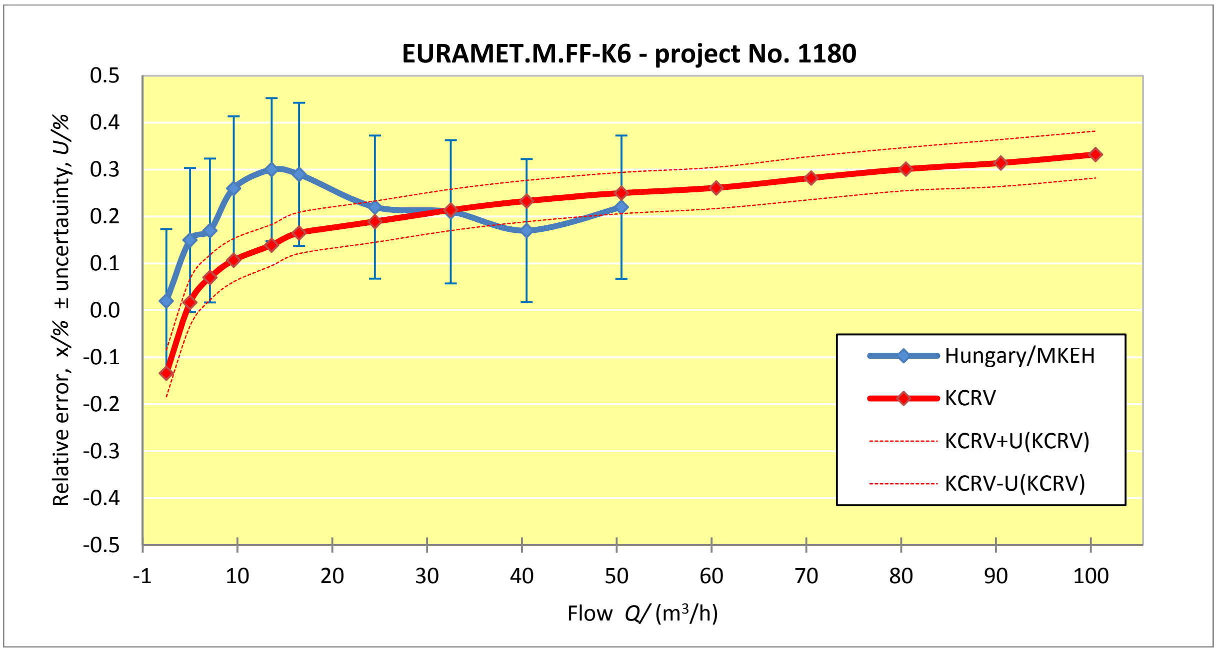
Austria/BEV					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.00	-0.20	0.30	0.315	-0.104	0.32
4.50	-0.02	0.30	0.315	0.015	0.05
6.60	0.05	0.30	0.315	0.024	0.07
9.10	0.08	0.30	0.315	0.012	0.04
13.10	0.08	0.30	0.314	-0.026	0.08
16.00	0.09	0.30	0.314	-0.052	0.16
24.00	0.12	0.30	0.314	-0.054	0.17
32.10	0.16	0.30	0.314	-0.021	0.06
40.10	0.19	0.30	0.314	-0.002	0.01
50.10	0.22	0.30	0.314	0.008	0.03
60.20	0.24	0.30	0.314	0.015	0.05
70.10	0.26	0.30	0.314	0.009	0.03
80.10	0.27	0.30	0.314	0.014	0.04
90.30	0.27	0.30	0.320	0.015	0.05
100.20	0.27	0.30	0.320	0.017	0.05



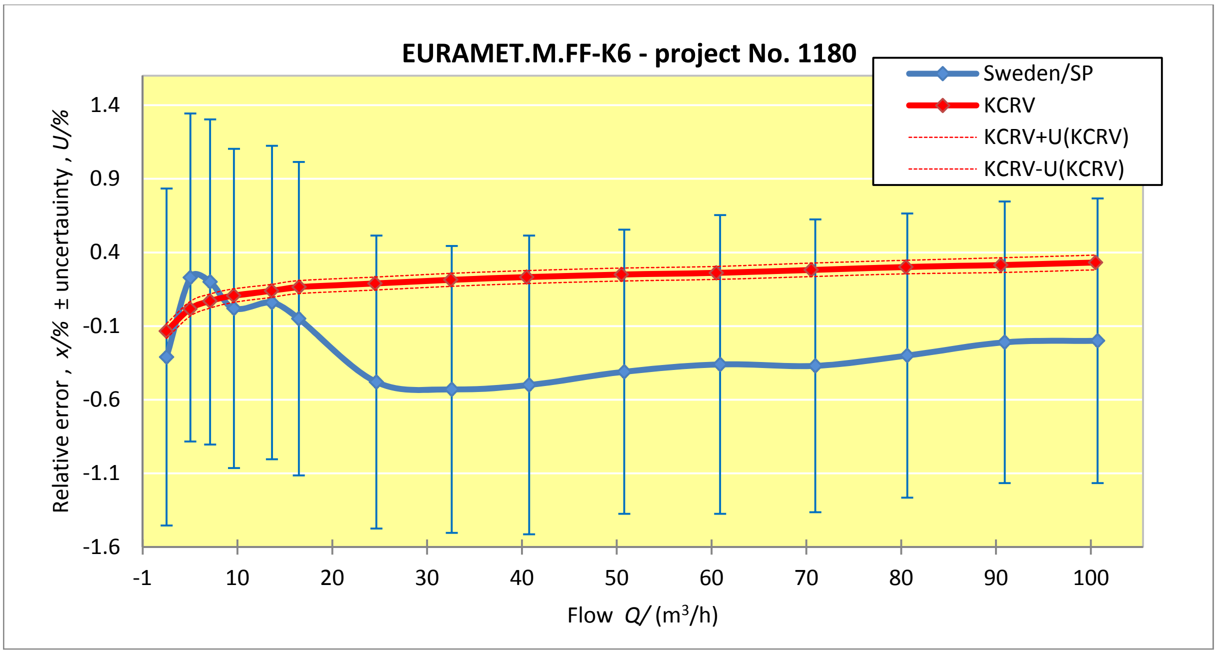
Poland/GUM					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
2.00	-0.17	0.17	0.195	-0.074	0.34
4.50	-0.06	0.16	0.186	-0.025	0.12
6.60	-0.03	0.19	0.213	-0.056	0.24
9.10	0.01	0.15	0.178	-0.058	0.29
13.00	0.03	0.15	0.177	-0.076	0.39
16.00	0.04	0.16	0.186	-0.102	0.50
24.00	0.07	0.16	0.186	-0.104	0.51
32.00	0.10	0.16	0.186	-0.081	0.40
40.00	0.12	0.15	0.177	-0.072	0.37
50.00	0.15	0.16	0.186	-0.062	0.30
60.00	0.14	0.16	0.186	-0.085	0.42
70.00	0.18	0.16	0.186	-0.071	0.35
80.00	0.19	0.16	0.186	-0.066	0.32
90.00	0.18	0.19	0.220	-0.075	0.31
100.00	0.14	0.15	0.187	-0.113	0.53



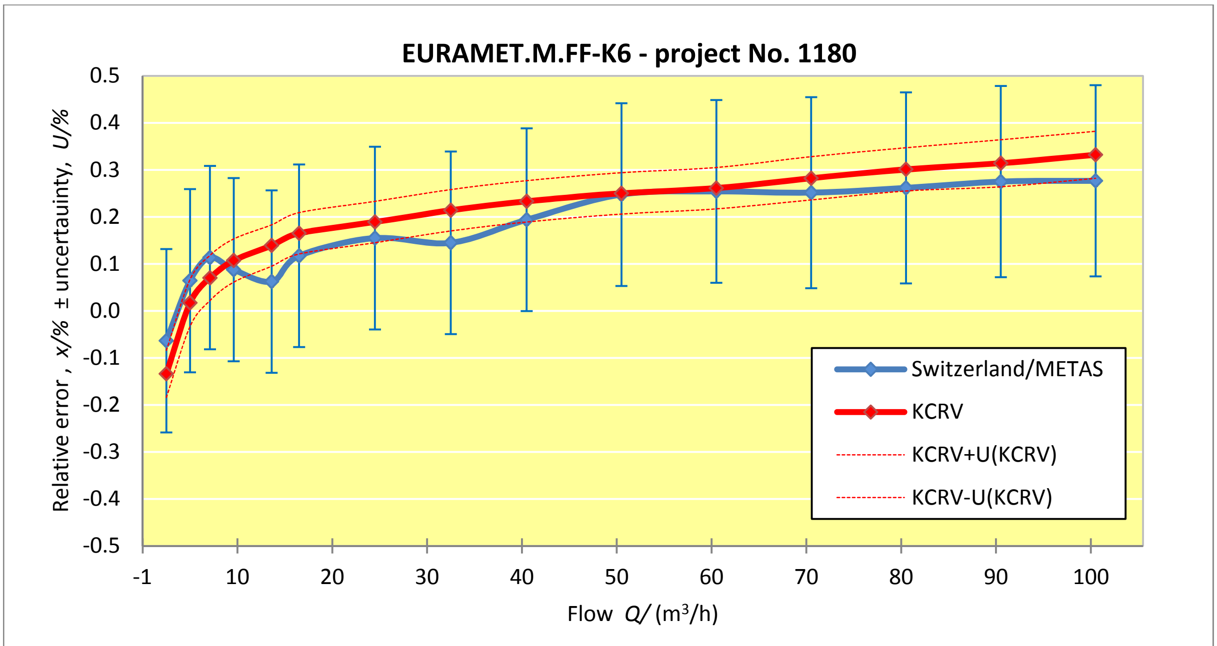
Hungary/MKEH					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
2.0	0.02	0.12	0.153	0.116	0.66
4.5	0.15	0.12	0.153	0.185	1.05
6.6	0.17	0.12	0.153	0.144	0.82
9.1	0.26	0.12	0.153	0.192	1.09
13.1	0.30	0.12	0.152	0.194	1.12
16.0	0.29	0.12	0.152	0.148	0.85
24.0	0.22	0.12	0.152	0.046	0.26
32.0	0.21	0.12	0.153	0.029	0.17
40.0	0.17	0.12	0.153	-0.022	0.13
50.0	0.22	0.12	0.153	0.008	0.05



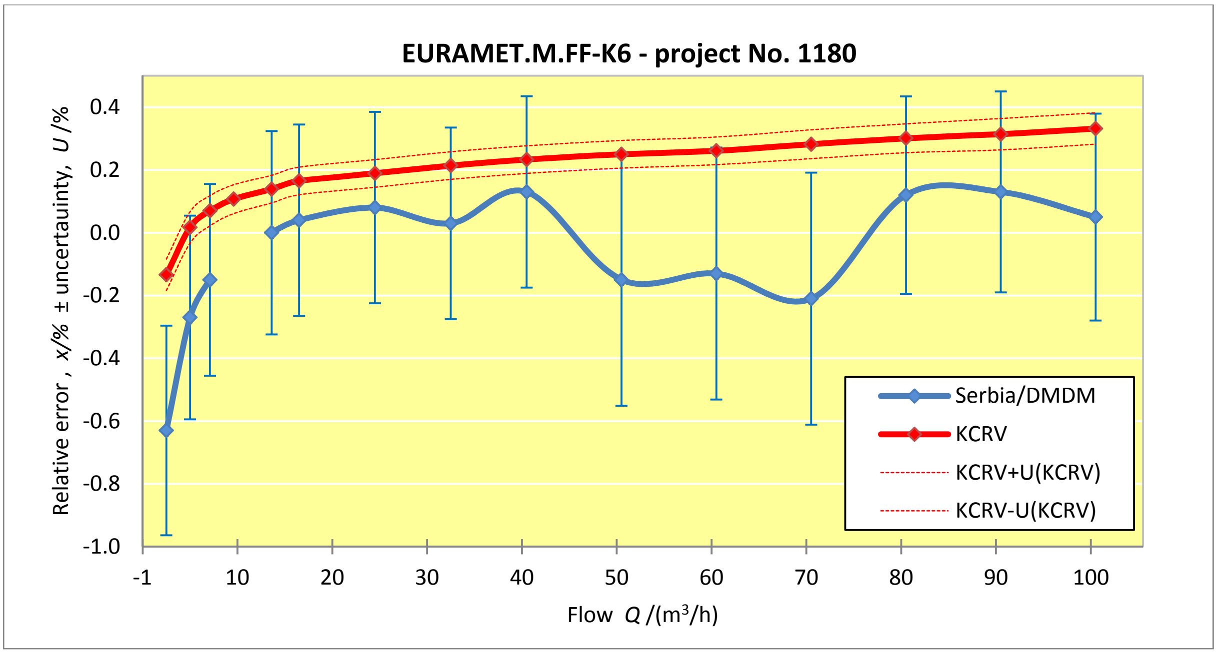
Sweden/SP					
Flow of the transfer standard Q/(m^3/h)	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.02	-0.31	1.14	1.144	-0.214	0.19
4.54	0.23	1.11	1.114	0.265	0.24
6.64	0.20	1.10	1.104	0.174	0.16
9.17	0.02	1.08	1.084	-0.048	0.04
13.23	0.06	1.06	1.064	-0.046	0.04
16.10	-0.05	1.06	1.064	-0.192	0.18
24.15	-0.48	0.99	0.994	-0.654	0.66
32.10	-0.53	0.97	0.975	-0.711	0.73
40.26	-0.50	1.01	1.014	-0.692	0.68
50.29	-0.41	0.96	0.965	-0.622	0.64
60.40	-0.36	1.01	1.014	-0.585	0.58
70.44	-0.37	0.99	0.994	-0.621	0.62
80.14	-0.30	0.96	0.965	-0.556	0.58
90.42	-0.21	0.95	0.957	-0.465	0.48
100.21	-0.20	0.96	0.966	-0.453	0.47



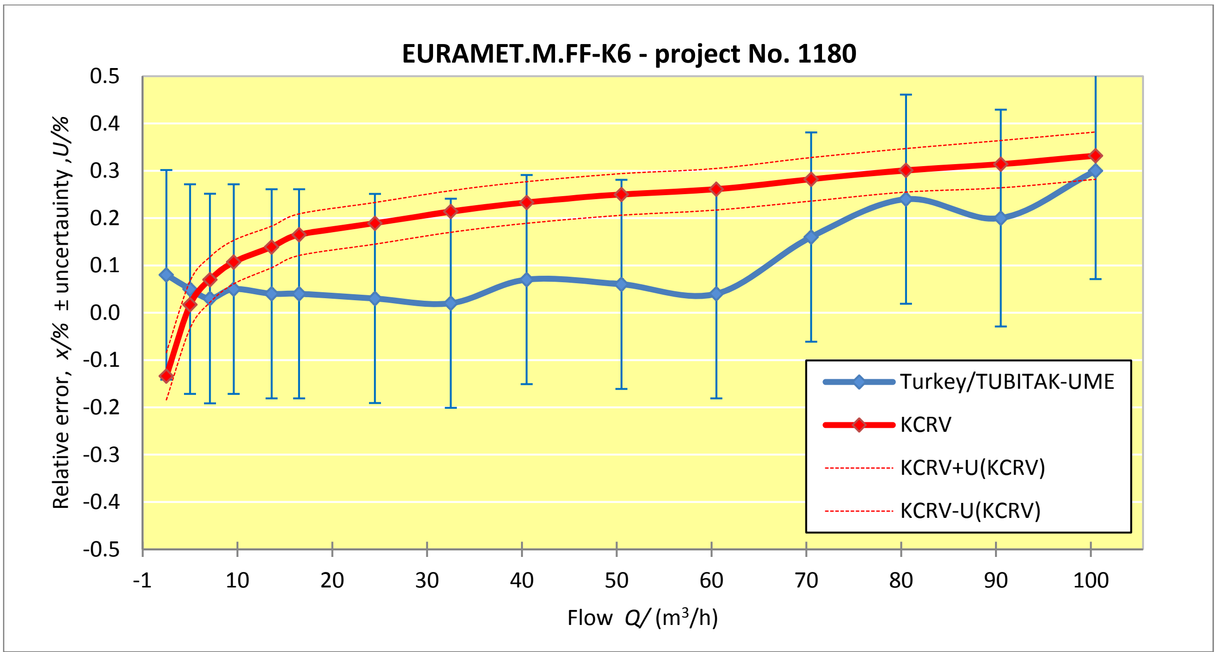
Switzerland/METAS					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
2.0	-0.06	0.17	0.195	0.033	0.15
4.5	0.06	0.17	0.195	0.100	0.47
6.6	0.11	0.17	0.195	0.088	0.41
9.1	0.09	0.17	0.195	0.020	0.09
13.1	0.06	0.17	0.194	-0.043	0.20
16.0	0.12	0.17	0.194	-0.025	0.12
24.0	0.15	0.17	0.194	-0.019	0.09
32.0	0.14	0.17	0.194	-0.036	0.17
40.0	0.19	0.17	0.194	0.002	0.01
50.0	0.25	0.17	0.194	0.036	0.17
60.0	0.25	0.17	0.194	0.029	0.14
70.0	0.25	0.18	0.203	0.001	0.00
80.0	0.26	0.18	0.203	0.006	0.03
90.0	0.27	0.17	0.203	0.020	0.09
100.0	0.28	0.17	0.203	0.024	0.10



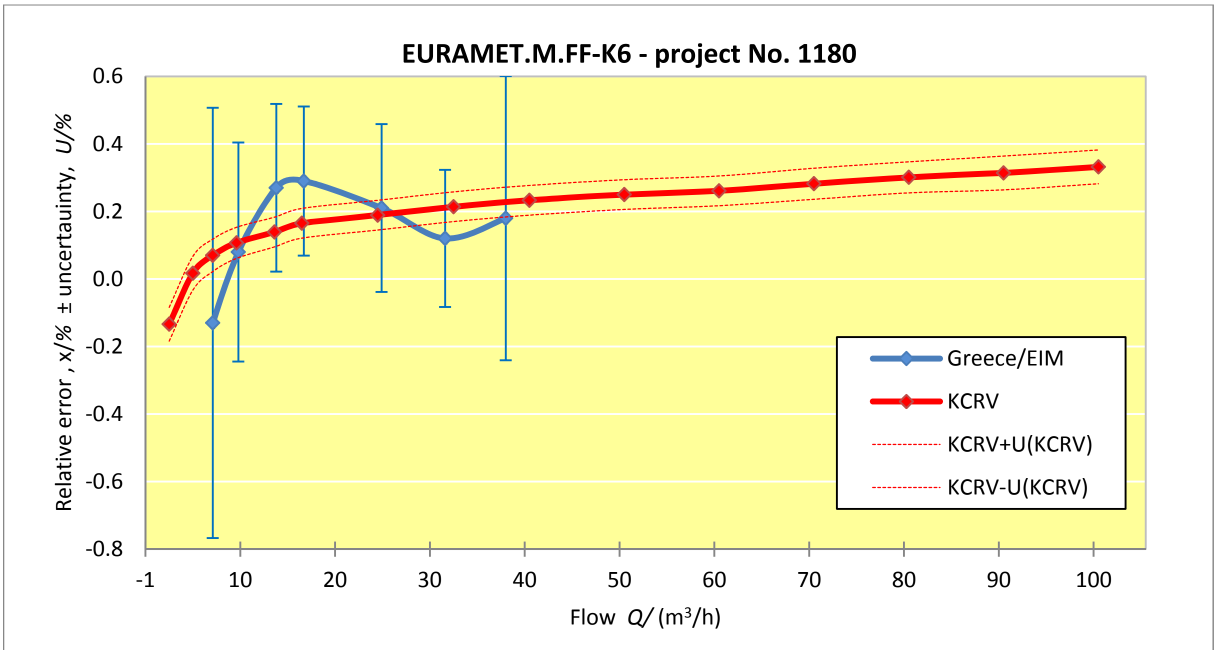
Serbia/DMDM					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.00	-0.63	0.32	0.334	-0.534	1.55
4.50	-0.27	0.31	0.324	-0.235	0.70
6.60	-0.15	0.29	0.305	-0.176	0.55
13.10	0.00	0.31	0.324	-0.106	0.32
16.00	0.04	0.29	0.305	-0.102	0.32
24.00	0.08	0.29	0.305	-0.094	0.30
32.00	0.03	0.29	0.305	-0.151	0.48
40.00	0.13	0.29	0.305	-0.062	0.20
50.00	-0.15	0.39	0.401	-0.362	0.88
60.00	-0.13	0.39	0.401	-0.355	0.87
70.00	-0.21	0.39	0.401	-0.461	1.12
80.00	0.12	0.30	0.314	-0.136	0.42
90.00	0.13	0.30	0.320	-0.125	0.37
100.00	0.05	0.31	0.329	-0.203	0.59



Turkey/TUBITAK-UME					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard x/(%)	Expanded uncertainty of measurement declared by laboratory U_{xi}/(%)	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.00	0.08	0.20	0.222	0.176	0.74
4.50	0.05	0.20	0.222	0.085	0.36
6.60	0.03	0.20	0.222	0.004	0.02
9.10	0.05	0.20	0.222	-0.018	0.07
13.10	0.04	0.20	0.221	-0.066	0.28
16.00	0.04	0.20	0.221	-0.102	0.43
24.00	0.03	0.20	0.221	-0.144	0.61
32.00	0.02	0.20	0.221	-0.161	0.68
40.00	0.07	0.20	0.221	-0.122	0.52
50.00	0.06	0.20	0.221	-0.152	0.64
60.00	0.04	0.20	0.221	-0.185	0.78
70.00	0.16	0.20	0.221	-0.091	0.38
80.00	0.24	0.20	0.221	-0.016	0.07
90.00	0.20	0.20	0.229	-0.055	0.22
100.00	0.30	0.20	0.229	0.047	0.19



Greece/EIM					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	$d_i/\%$	En_i
6.60	-0.13	0.63	0.637	-0.156	0.24
9.30	0.08	0.31	0.324	0.012	0.04
13.30	0.27	0.23	0.248	0.164	0.63
16.20	0.29	0.20	0.221	0.148	0.63
24.40	0.21	0.23	0.248	0.036	0.14
31.10	0.12	0.18	0.203	-0.061	0.28
37.50	0.18	0.41	0.421	-0.012	0.03



Bosnia & Herzegovina/IMBH					
Flow of the transfer standard $Q/(m^3/h)$	Relative error of the transfer standard $x/(\%)$	Expanded uncertainty of measurement declared by laboratory $U_{xi}/(\%)$	Expanded uncertainty of measurement extended by stability U_{TS} and linking $U(D)$ / (%)	d_i/%	En_i
2.07	0.04	0.30	0.315	0.132	0.40
4.61	0.27	0.28	0.296	0.300	0.97
6.71	0.38	0.28	0.296	0.357	1.16
9.19	0.37	0.28	0.296	0.304	0.99
13.20	0.43	0.28	0.295	0.321	1.05
16.17	0.42	0.28	0.295	0.282	0.92
24.33	0.33	0.28	0.295	0.153	0.50
32.26	0.56	0.28	0.295	0.375	1.22
40.28	0.65	0.28	0.295	0.456	1.49
50.17	0.38	0.28	0.295	0.168	0.55
60.02	0.47	0.28	0.295	0.249	0.81
69.97	0.57	0.28	0.295	0.319	1.04
80.03	0.66	0.28	0.295	0.404	1.31
90.00	0.70	0.28	0.301	0.445	1.39
100.25	0.76	0.28	0.301	0.507	1.59