CIPM key comparison CCM.FF-K6.2011

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.

A comparison was initialised as a CCM Key Comparison for low-pressure gas flow. The results of this comparison can be used for review of CMC tables.

2 Participants

The 11 participants and the time schedule are shown in Table 1. An EURAMET comparison using the same transfer standard started in February 2010 and finished in May 2011. The K6 comparison 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 and during the comparison to assess its calibration stability.

Table 1 -Participants and the time schedule

Country	NMI	Contact	Date of calibration
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	August 17th, 2010
Republic of Ukraine	GP Ivano-Frankivs'kstandart-metrologia	Denys Seredyuk	December 23rd, 2010 to February 9th, 2011
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	February 15th, 2011
Germany	PTB Physikalisch-Technische Bundesanstalt	Bodo Mickan	May 17th to June 29th, 2011
Australia	NMI National Measurement Institute	Khaled Chahine	July 8th to August 10th, 2011
USA	NIST National Institute of Standards and Technology	John Wright	October 12th to October 28th, 2011
Mexico	CENAM Centro Nacional de Metrología	Roberto Arias	October 31st to December 7th, 2011
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	February 1st, 2012
Korea	KRISS Korea Research Institute of Standards and Science	Hae Man Choi	February 20th to March 15th, 2012
China	NIM National Institute of Metrology	Chunhui Li	April 9th to April 19th, 2012

Chinese Taipei	CMS Center for Measurement Standards	Chun-Min Su	May 9th to May 28th, 2012
Japan	NMIJ AIST National Research Laboratory of Metrology	Tatsuya Funaki	June 13th to August 20th, 2012
Slovakia (PILOT LAB)	SMU Slovak Institute of Metrology	Stefan Makovnik	September 26th, 2012
France	LNE-LADG Laboratoire Associé de Débitmétrie Gazeuse	Christophe Windenberg	November 16th to December 20th, 2012

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.

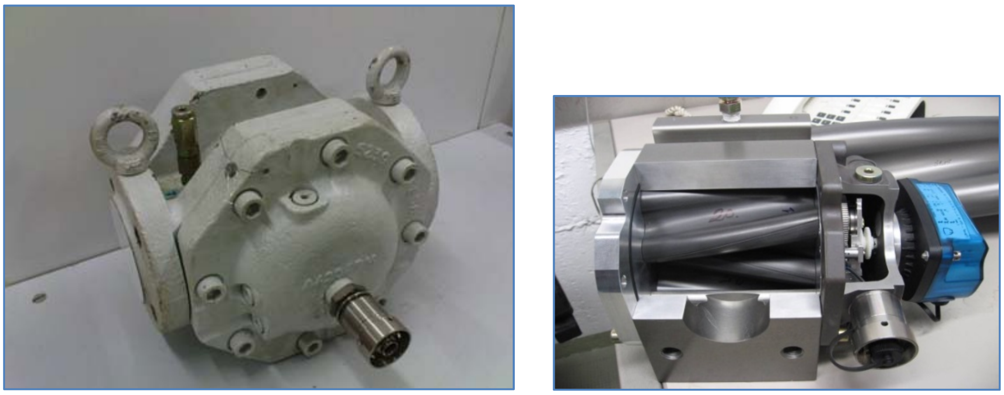


Figure 1 – Rotary gas meter Actaris Delta S-Flow

3.1 Basic technical specification

Type: Delta 2050 S-Flow
Manufacturer: ActarisGaszählerbau 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

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 meter** *e* 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:

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

where e 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 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 not.

A summary of the 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 to 100) m^3/h	Independent laboratory
Germany PTB	Bell prover	(2 to 100) m^3/h	Independent laboratory
Ukraine GP Ivano-Frankivs'kstandart-metrologia	Bell prover	(2 to 100) m^3/h	Independent laboratory
Australia NMI	Venturi nozzles	(2 to 100) m^3/h	Independent laboratory
USA NIST	Venturi nozzles (Working Gas Flow Standard)	(2 to 100) m^3/h	Independent laboratory
Mexico CENAM	Bell prover	(2 to 100) m^3/h	Independent laboratory
Korea KRISS	Venturi nozzles	(9 to 100) m^3/h	Independent laboratory
China NIM	Venturi nozzles	(9 to 100) m^3/h	Independent laboratory
Chinese Taipei CMS	Venturi nozzles	(2 to 60) m^3/h	Independent laboratory
Japan NMIJ AIST	Venturi nozzles	(6 to 100) m^3/h	Independent laboratory
France LNE-LADG	Venturi nozzles	(13 to 100) m^3/h	Independent laboratory

4.3 Measurement procedure 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 meter).
- The second pressure point to determine the pressure loss of the transfer standard was defined at the inlet of the meter.
- The reference temperature from transfer standard was measured upstream of the transfer standard (figure 2).

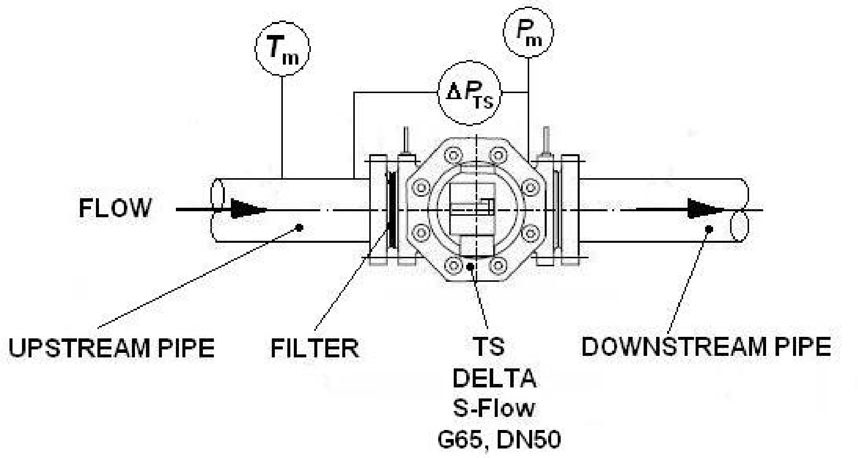


Figure 2 - Recommended installation of the meter

- It was necessary to use the pulse transmitter
- There was no lubrication of the meter
- 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 rate 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 and during the comparison by the pilot laboratory (Table 3, 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	June 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

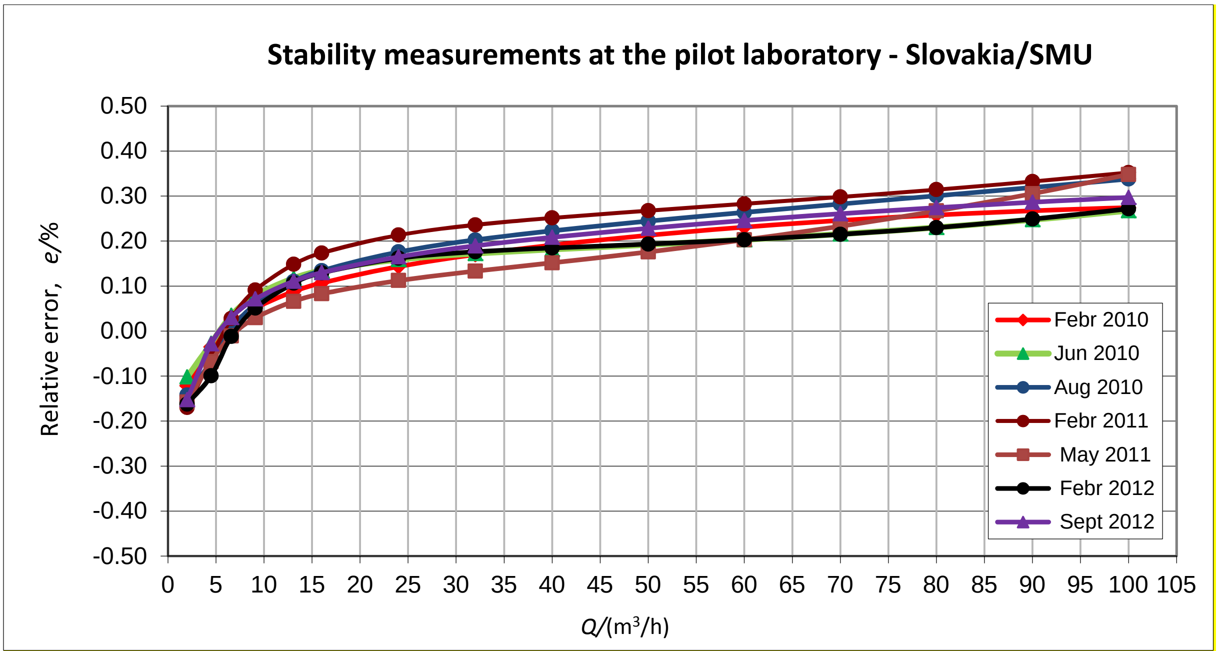


Figure 3 - Stability of the transfer standard

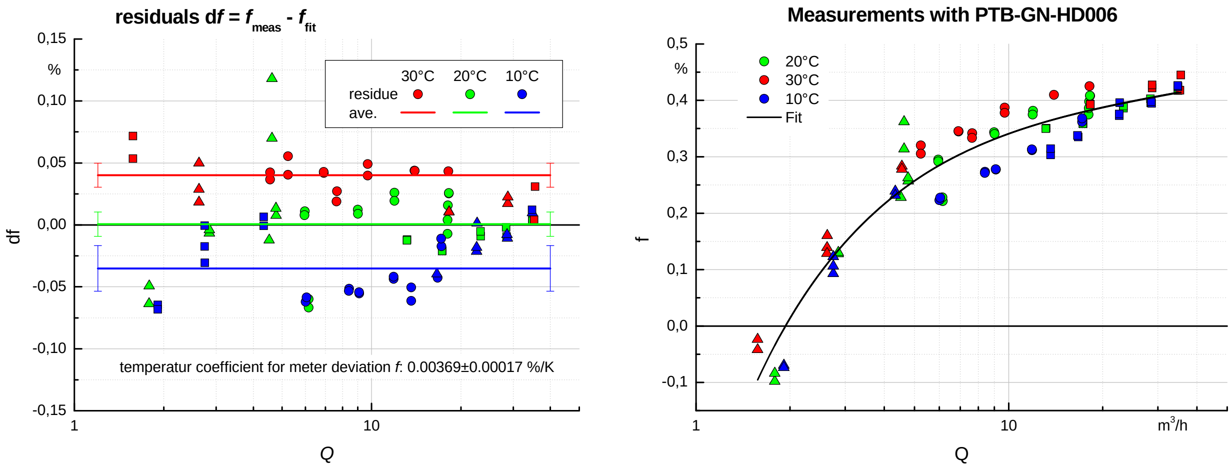


Figure 4 - Temperature stability

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	Ukraine GP Ivano-Frankivs'ks tandart-metrologia	Australia NMI	USA NIST	Mexico CENAM	Korea KRISS	China NIM	Chinese Taipei CMS	Japan NMIJ/ AIST	France LNE-LADG
2	-0.16	-0.10	-0.18	-0.01	-0.15	-0.22	-	-	-0.24	-	-
4.5	-0.07	0.06	-0.10	0.10	0.00	-0.02	-	-	0.06	-	-
6.6	-0.01	0.11	-0.05	0.14	0.04	0.02	-	-	0.15	0.00	-
9.1	0.03	0.14	-0.04	0.26	0.08	0.09	0.02	0.16	0.17	-	-
13.1	0.07	0.17	0.01	0.29	0.10	0.14	0.07	0.17	0.18	0.16	0.11
16	0.08	0.17	0.02	0.29	0.14	0.23	0.16	0.18	0.22	0.21	0.15
24	0.11	0.19	0.07	0.31	0.17	0.27	0.18	0.22	0.22	0.24	0.17
32	0.13	0.21	0.15	0.33	0.18	0.27	0.26	0.25	0.24	0.22	0.21
40	0.15	0.23	0.11	0.36	0.21	0.30	0.25	0.29	0.25	0.24	0.23
50	0.18	0.24	0.17	0.38	0.24	0.31	0.27	0.32	0.25	0.20	0.25
60	0.20	0.25	0.15	0.38	0.25	0.30	0.28	0.35	0.27	0.23	0.26
70	0.23	0.27	0.22	0.40	0.27	0.31	0.30	0.38	-	0.22	0.25
80	0.27	0.29	0.24	0.40	0.29	0.32	0.30	0.4	-	0.24	0.29
90	0.31	0.31	0.25	0.40	0.29	0.32	0.32	0.41	-	0.26	0.27
100	0.35	0.35	0.25	0.41	0.31	0.33	0.30	0.42	-	0.21	0.28

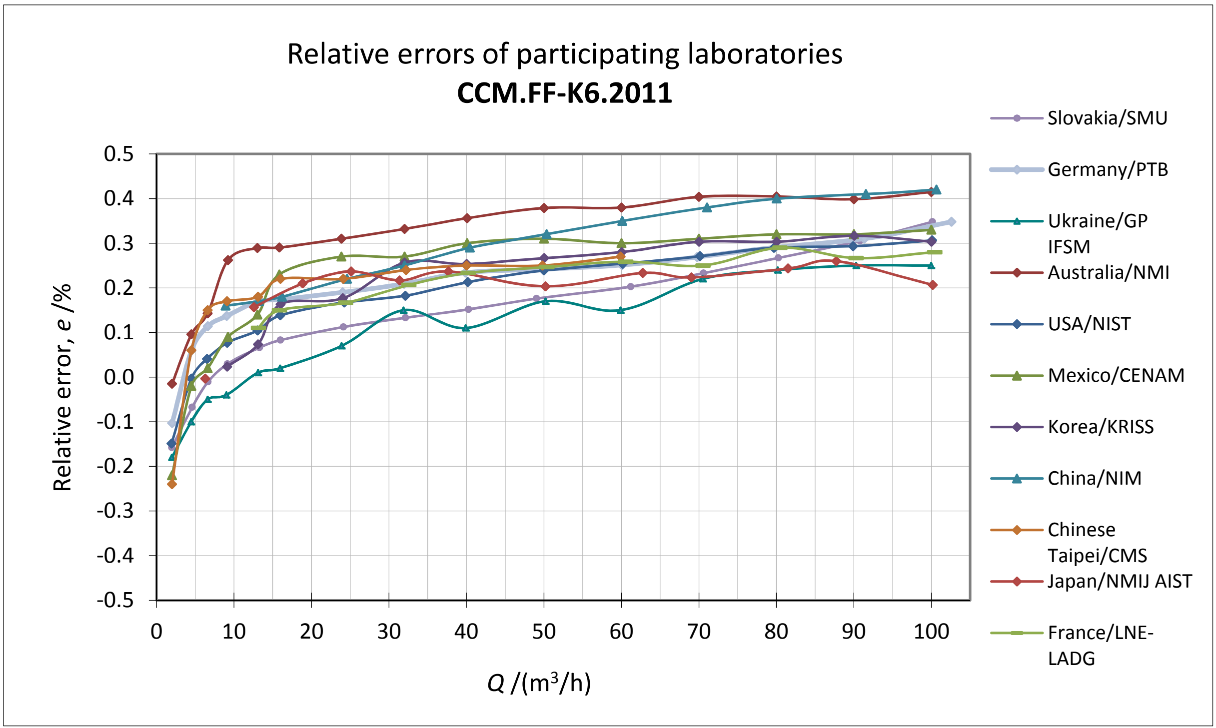


Figure 5 - Relative error curves of participating laboratories

5.3 Laboratory uncertainty

The uncertainties are calculated according to the following formulas [5].

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

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

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:

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

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

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

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

Flow/(m^3/h) → NMI	Slovakia SMU	Germany PTB	Ukraine GP Ivano-Frankivs'ks tandart-metrologia	Australia NMI	USA NIST	Mexico CENAM	Korea KRISS	China NIM	Chinese Taipei CMS	Japan NMIJ/ AIST	France LNE-LADG
2	0.12	0.05	0.20	0.16	0.10	0.17	-	-	0.18	-	-
4.5	0.12	0.05	0.17	0.16	0.11	0.16	-	-	0.18	-	-
6.6	0.12	0.05	0.17	0.16	0.11	0.16	-	-	0.15	0.28	-
9.1	0.12	0.05	0.17	0.16	0.10	0.16	0.18	0.18	0.15	-	-
13.1	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	0.15	0.28	0.25
16	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.19	0.15	0.28	0.25
24	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	0.15	0.28	0.25
32	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	0.15	0.28	0.25
40	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	0.15	0.28	0.25
50	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	0.15	0.28	0.25
60	0.12	0.05	0.17	0.16	0.11	0.15	0.18	0.18	0.15	0.28	0.25
70	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	-	0.28	0.25
80	0.12	0.05	0.17	0.16	0.10	0.15	0.18	0.18	-	0.28	0.25
90	0.12	0.083	0.17	0.16	0.10	0.15	0.18	0.18	-	0.28	0.25
100	0.12	0.083	0.17	0.16	0.10	0.15	0.18	0.18	-	0.28	0.25

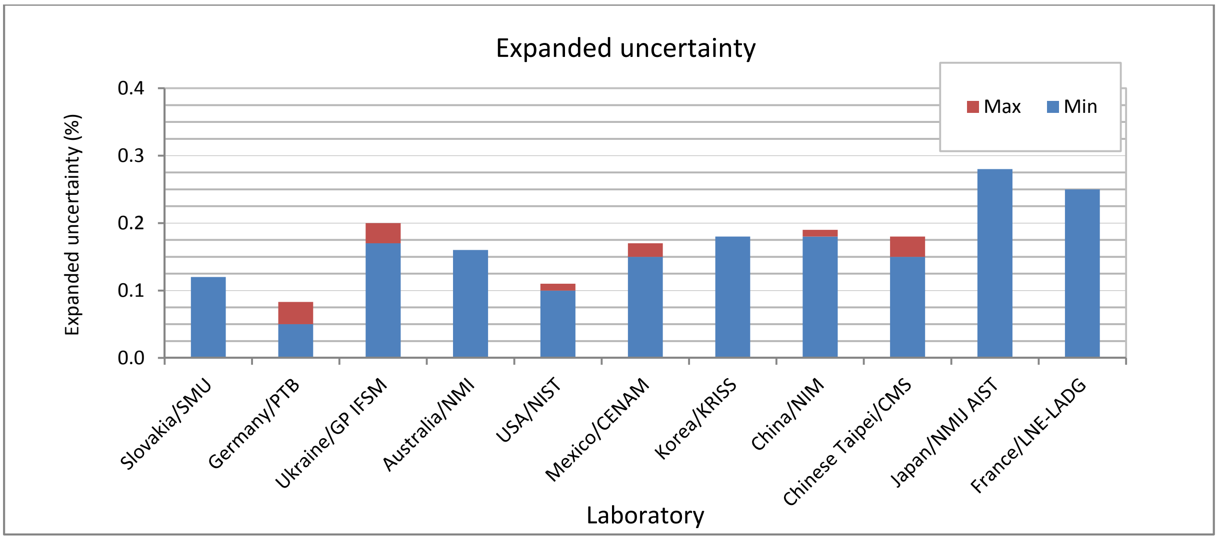


Figure 6 - Expanded uncertainties of participating laboratories

5.4 Laboratory measurement conditions

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

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

NMI	Slovakia SMU	Germany PTB	Ukraine GP Ivano-Frankivs'ks tandart-metrologia	Australia NMI	USA NIST	Mexico CENAM	Korea KRISS	China NIM	Chinese Taipei CMS	Japan NMIJ/ AIST	France LNE-LADG
Max	20.71	22.71	18.89	21.45	23.89	20.40	21.33	21.49	22.83	24.45	18.43
Min	19.84	21.42	18.76	21.30	23.13	19.80	18.67	20.26	22.26	23.91	17.65
Max-Min	0.88	1.29	0.13	0.16	0.76	0.60	2.66	1.23	0.57	0.54	0.78
Mean	20.19	21.77	18.82	21.38	23.66	20.16	20.07	20.89	22.63	24.14	18.15

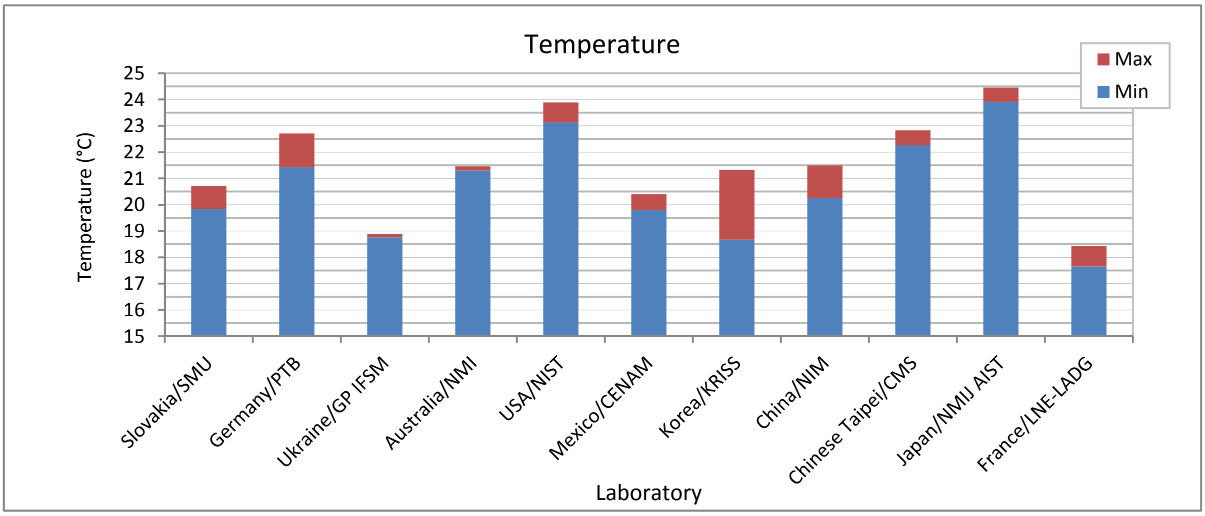


Figure 7 - Range of temperature in the participating laboratories

5.5 Temperature, pressure, and flow stability

This comparison lasted 2 years and the measurements were performed at different altitudes.

Figure 4 shows that for temperature differences of ± 10 ° C the meter sensitivity does not exceed ± 0.05 %. Since the minimum and maximum temperature values in the laboratories were in the range (17.65 to 24.45) °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: $(u_T = 0.03\ \%/\left(2\sqrt{3}\right)$.

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 which exceeded this value at the following flows - (13.1; 16.0; 24.0; 40.0 and 60.0) m^3/h . 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 of 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*, and

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 presented in annex B. The ratio of the transfer standard uncertainty to any participant's flow standard uncertainty is ≤ 1.24.

6 Evaluation

The reference value was determined at each flow separately following procedure A presented by M. G. Cox [1]. All laboratories reported independent traceability chains to the SI, so all results were taken into account for the determination of the key comparison reference value (KCRV) and of the uncertainty of the KCRV.

The determination of the KCRV based on the independent laboratories includes a consistency check according to [1]. If some reported results are found to be inconsistent then the concept of largest consistent subset explained by Cox [2] was applied.

6.1 Determination of the Key Comparison Reference Value (KCRV) and its uncertainty

The reference value y was calculated as weighted mean error (WME):

$$y = \frac{\frac{x_1}{u_{x1}^2} + \frac{x_2}{u_{x2}^2} + \dots\dots\dots \frac{x_n}{u_{xn}^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots\dots\dots \frac{1}{u_{xn}^2}} \tag{8}$$

where x_1, x_2, ….. x_n are errors of the meter in one flow in different independent laboratories *1, 2, ……n*

u_{x1}, u_{x2},…..u_{xn} are standard uncertainties (not expanded) of the error in different independent laboratories *1, 2, ……n* including the uncertainty caused by stability of the meter.

The standard uncertainty of the reference value u_y is given by

$$\frac{1}{u_y^2} = \frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots\dots\dots \frac{1}{u_{xn}^2} \tag{9}$$

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

$$U(y) = 2\,u_y \tag{10}$$

The chi-squared test for consistency check was performed using values of errors of the meter at each flow. At first the chi-squared value χ_{obs}^2 was calculated by

$$\chi_{obs}^2 = \frac{(x_1 - y)^2}{u_{x1}^2} + \frac{(x_2 - y)^2}{u_{x2}^2} + \dots\dots\dots\dots \frac{(x_n - y)^2}{u_{xn}^2} \tag{11}$$

The degrees of freedom ν were assigned

$$\nu = n - 1 \tag{12}$$

where n is a number of evaluated laboratories.

The consistency check failed if

$$Pr\{\chi_\nu^2 > \chi_{obs}^2\} < 0.05 \tag{13}$$

(The function CHIINV(0.05; ν) in MS Excel was used. The consistency check failed if CHIINV(0.05; ν)< χ_{obs}^2).

If the consistency check passed, then y was accepted as the key comparison reference value x_{ref} and $U(y)$ was accepted as the expanded uncertainty of the key comparison reference value $U(x_{ref})$.

If the consistency check failed, then the laboratory with the highest value of $\frac{(x_i - y)^2}{u_{xi}^2}$ was excluded for the next round of evaluation and the new reference value y (WME). The new standard uncertainty of the reference value u_y and the chi-squared value χ^2_{obs} were calculated again without the values of the excluded laboratory. The consistency check was performed again too.

All laboratories passed the consistency check.

6.2 The determination of the differences "Lab to KCRV" and "Lab to Lab"

When the KCRV was determined, the differences between the participating laboratories and the KCRV were calculated according to

$$d_i = x_i - x_{ref} \tag{14}$$

and
$$d_{ij} = x_i - x_j \tag{15}$$

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

$$En_i = \left| \frac{d_i}{U(d_i)} \right| \tag{16}$$

and
$$En_{ij} = \left| \frac{d_{ij}}{U(d_{ij})} \right| \tag{17}$$

The *DoE* is a measure for the equivalence of the results of any laboratory with the KCRV or with any other laboratory, respectively:

- the results of a laboratory were *equivalent* (***passed***) *if* En_i *or* $En_{ij} \le 1$.

- the laboratory was determined as *not equivalent* (***failed***) *if* En_i *or* $En_{ij} > 1$.

The calculation of the *DoE* needs information about the uncertainty of the differences d_i and d_{ij} (Equations (14) and (15)). 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:

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

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 find the different cases in this comparison:

6.3 Differences to the KCRV

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:

$$u(d_i) = \sqrt{u_{xi}^2 + u_{xref}^2 - 2\,u_{xref}^2} = \sqrt{u_{xi}^2 - u_{xref}^2} \tag{19}$$

b) *Independent laboratories without contribution to the KCRV*

There is no covariance between the result of a laboratory without contribution and the KCRV.

$$u(d_i) = \sqrt{u_{xi}^2 + u_{xref}^2} \tag{20}$$

6.4 Lab to Lab Differences

All of the participants in this comparison have independent traceability chains. There is no covariance between the results of two independent laboratories *i* and *j* and the uncertainty of the difference between two labs is:

$$u(d_{ij}) = \sqrt{u_{xi}^2 + u_{xj}^2} \tag{21}$$

Equations (18) to (21) use the standard uncertainties. The expanded uncertainties $U(d_i)$ and $U(d_{ij})$ are determined by using a coverage factor of 2 to obtain an approximately 95 % confidence level value:

$$U(d_i) = 2\,u(d_i) \tag{22}$$

$$U(d_{ij}) = 2\,u(d_{ij}) \tag{23}$$

Note: According to the 14th CCM meeting (February, 2013) pair-wise degrees of equivalence should no longer be published in the KCDB. Information on pair-wise degrees of equivalence published in KC reports should 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.

6.5 The KCRV and its uncertainty

The KCRV and its uncertainty are in Table 8 and also shown graphically in appendix B.

The consistency check passed and then y was accepted as the KCRV x_{ref} and $U(y)$ was accepted as the expanded uncertainty of the KCRV $U(x_{ref})$. The results of the consistency check are in the Table 7.

Table 7 -Results of the chi-squared test at each flow

Flow/(m3/h)	1. round		
	χ^2_{obs}	$\chi^2(\nu)$	Results of the chi-squared test
2	5.13	12.59	passed
4.5	5.87	12.59	passed
6.6	7.06	14.07	passed
9.1	9.90	15.51	passed
13.1	8.24	18.31	passed
16	7.76	18.31	passed
24	6.63	18.31	passed
32	5.11	18.31	passed
40	6.68	18.31	passed
50	5.61	18.31	passed
60	5.51	18.31	passed
70	4.67	16.92	passed
80	3.62	16.92	passed
90	2.95	16.92	passed
100	4.00	16.92	passed

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

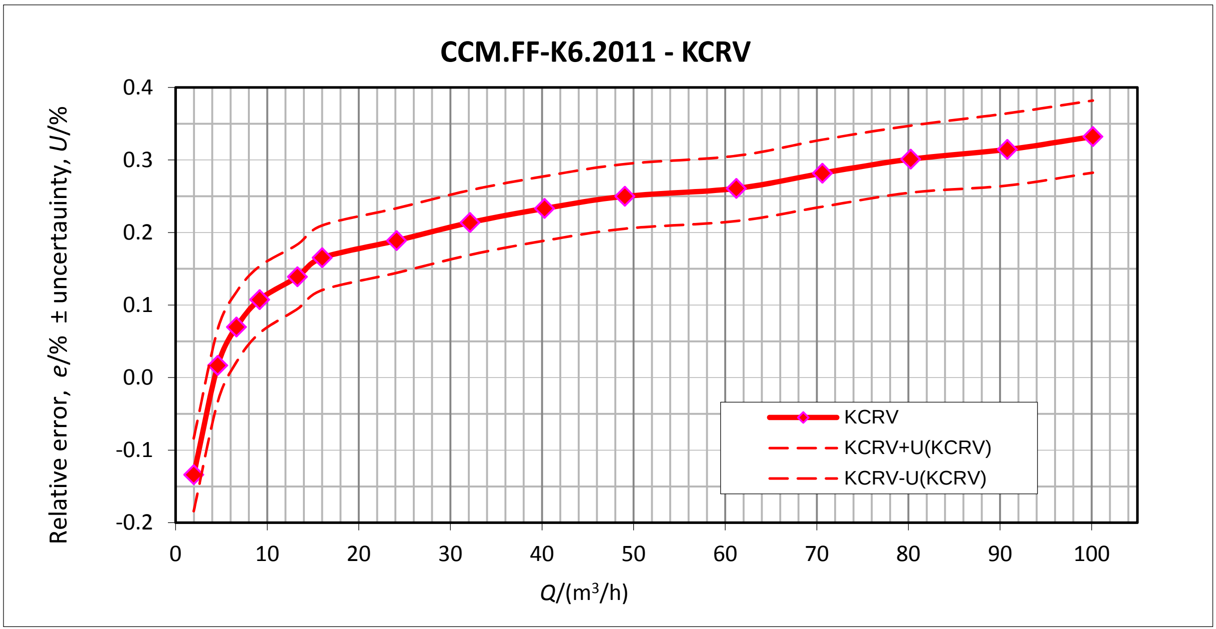


Figure 8 - Key comparison reference value

7 Summary

The degree of equivalence with the KCRV is a measure of the agreement of the results of each participating laboratory with the KCRV. $En_i \leq 1$ means that *i*-th laboratory is in good agreement with KCRV, whereas $En_i > 1$ means that *i*-th laboratory is not in a good agreement. The "lab to KCRV" equivalence degrees En_i are summarized in Figure 9 and Table 9.

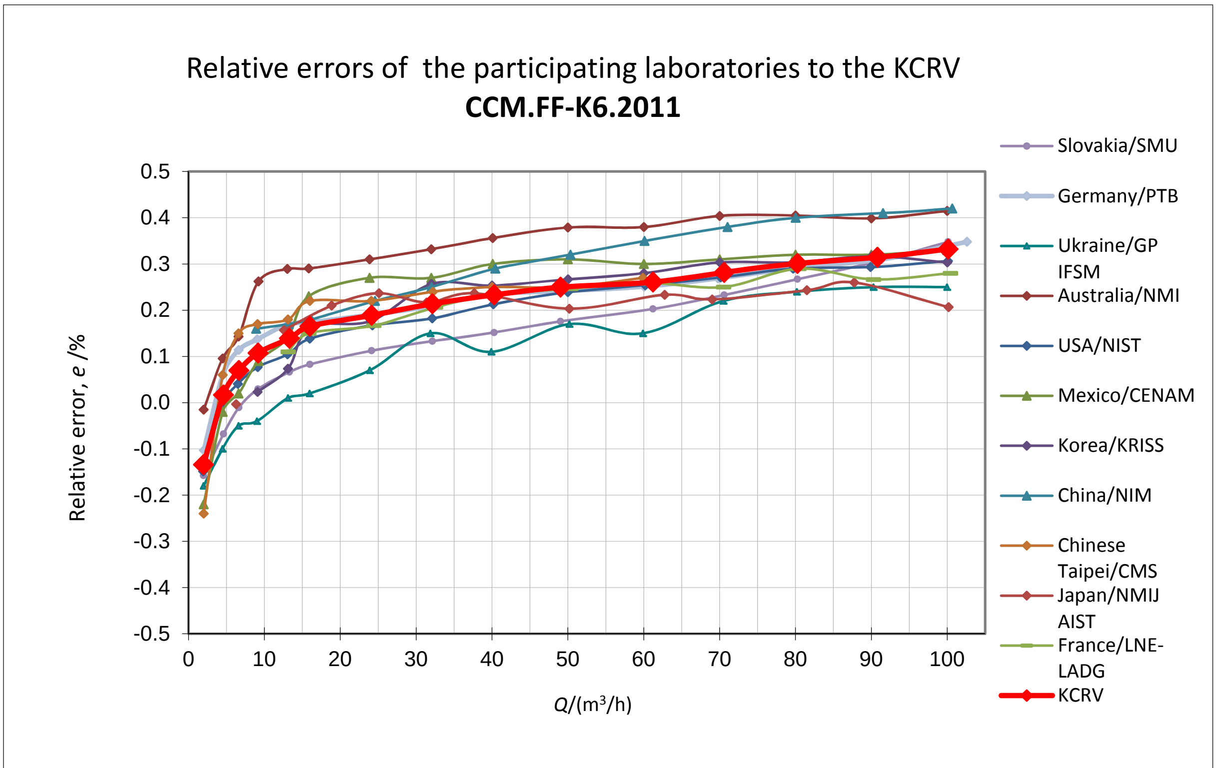


Figure 9 - Relationship to the KCRV

Table 9 - Degree of Equivalence to KCRV

Flow/(m^3/h) → NMI	Slovakia SMU	Germany PTB	Ukraine GP Ivano-Frankivs'ks tandart-metrologia	Australia NMI	USA NIST	Mexico CENAM	Korea KRISS	China NIM	Chinese Taipei CMS	Japan NMIJ/ AIST	France LNE-LADG
2	0.19	0.50	0.23	0.73	0.14	0.49	-	-	0.58	-	-
4.5	0.67	0.70	0.67	0.48	0.17	0.22	-	-	0.24	-	-
6.6	0.64	0.70	0.69	0.44	0.25	0.30	-	-	0.52	0.26	-
9.1	0.61	0.46	0.84	0.94	0.27	0.11	0.46	0.28	0.40	-	-
13.1	0.57	0.47	0.74	0.91	0.31	0.01	0.35	0.17	0.26	0.06	0.11
16	0.65	0.13	0.83	0.76	0.24	0.42	0.01	0.08	0.35	0.16	0.06
24	0.60	0.02	0.68	0.73	0.19	0.52	0.07	0.17	0.20	0.17	0.09
32	0.63	0.07	0.36	0.71	0.28	0.36	0.23	0.20	0.17	0.01	0.03
40	0.64	0.01	0.70	0.74	0.18	0.43	0.11	0.31	0.11	0.01	0.00
50	0.58	0.12	0.46	0.78	0.10	0.39	0.09	0.38	0.00	0.16	0.01
60	0.46	0.15	0.63	0.72	0.06	0.25	0.10	0.48	0.06	0.10	0.01
70	0.38	0.20	0.35	0.74	0.10	0.18	0.12	0.53	-	0.21	0.13
80	0.27	0.16	0.35	0.63	0.10	0.12	0.01	0.54	-	0.20	0.04
90	0.07	0.05	0.37	0.51	0.20	0.04	0.01	0.52	-	0.19	0.19
100	0.13	0.17	0.47	0.50	0.24	0.01	0.16	0.48	-	0.44	0.21

8 Conclusions

Eleven laboratories participated in this key comparison of a rotary gas meter – CCM.FF-K6.

All reported results were consistent with the reference value determined by the Cox method. This KCRV can now be used in the regional comparisons.

The results obtained by the pilot laboratory (Slovakia) also showed a very good reproducibility of the transfer standard. Based on the information supplied by the participant laboratories regarding their CMCs, the following table was elaborated:

Table 10 -Relationship to the CMCs tables

Country NMI	Flow range declared in CMCs tables	Expanded uncertainty declared in CMCs tables *)	Result
Slovakia SMU	(1 to 65) m^3/h	0.12	In accordance
Germany PTB	(2 to 80) m^3/h	0.045	In accordance
Ukraine GP Ivano-Frankivs'kstandart-metrologia	(0.016 to 200) m^3/h	0.16	In accordance

Country NMI	Flow range declared in CMCs tables	Expanded uncertainty declared in CMCs tables *)	Result
Australia NMI	(2 to 100) m^3/h	No entry yet	For further support
USA NIST	(0.06 to 120) m^3/h	0.12	In accordance
Mexico CENAM	(1.8 to 108) m^3/h	0.25	In accordance **)
Korea KRISS	(0.12 to 36) m^3/h	0.13	In accordance
China NIM	(10 to 510) m^3/h	0.18	In accordance
Chinese Taipei CMS	(2 to 60) m^3/h	No entry yet	For further support
Japan NMIJ AIST	(5 to 1000) m^3/h	0.28	In accordance
France LNE-LADG	(13 to 100) m^3/h	0.26	In accordance

*) If the country has not yet CMC tables, the results will be used for support a new service.

**) Mexico CENAM explained the reduction of uncertainty compared to their present CMCs for Volume gas flow rate is due to additional development of volumetric transfer methods using 50 L volumetric standards and a laser interferometer to determine the inside diameter of the bell. These changes resulted in a reduction of the uncertainty in the diameter of the bell to a level of 0.04 %, at approximately 95 % level of confidence.

All laboratories that have CMCs published in the KCDB presented uncertainty values in accordance with their CMC claims.

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

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

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

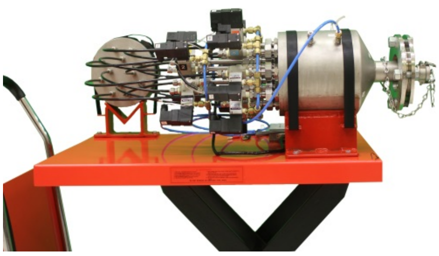
Basic range of flow rate:	(1 to 65) m^3/h
Expanded range of flow rate:	(0.5 to 100) m^3/h
Temperature:	20°C
Working pressure:	atmospheric conditions
Uncertainty (*k*=2):	0.12 %

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, 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 %.

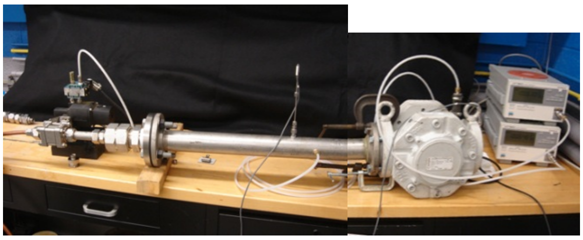
Characteristic information\ picture of the primary standard used by measurements	Working procedure
GP IFSM - National Research & Metrological Laboratory Vovchynetska St., 127 Ivano-Frankovsk, Ukraine Range of flow rate: (4 – 200) m^3/h Expanded range of flow rate: (2 – 250) m^3/h Temperature: (20 ± 2)°C Working pressure: Atmospheric pressure Uncertainty (k=2): (0.10 to 0.16) % 	GP Ivano-Frankivs'kstandartmetrologia is performing calibrations using state standard unit of volume and flow of gas (bell prover) DETU 03-01-96. The principle of operation is based on measuring a reference time interval during the displaced accurately known volume of gas with simultaneous measurement of temperature and pressure gas. The volume of gas that has passed through the test gas meter is determined based on the equation of state of gas.
NMI - National Measurement Institute Bradfield Rd., West Lindfield NSW 2070 PO Box 264 Lindfield NSW 2070, Australia Range of flow rate: (0.005 to 300) m^3/h Temperature: (21.2±0.5) °C Working pressure: 85kPa to 102kPa Uncertainty (k=2): (0,11 to 0,13) % 	Two arrays of critical flow Venturi nozzles, or sonic nozzles, with diameters varying from 0.1 mm to 6.5 mm were used in this key comparison. Each array consists of 12 nozzles placed in parallel and controlled by pneumatic valves that are in-turn connected to a PC to produce various flows. The nozzles were calibrated using the NMI's Brooks and bell provers. Mass flows generated by both standards, the Brooks and the bell are traceable to NMI (Australia) length, time, pressure and temperature standards. The uncertainties associated with the calibration of nozzles using the Brooks and the bell provers are 0.11% and 0.13% respectively.

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

NIST - National Institute of Standards and Technology

100 Bureau Drive, Stop 8361. Gaithersburg, MD 20899-8361, USA

Range of flow rate:	(0.09 to 4200) m^3/h
Temperature:	(20 ± 1)°C
Working pressure:	(100 to 700) kPa
Uncertainty (*k*=2):	0.1 % to 0.07 %



Working Gas Flow Standard was used to calibrate the transfer standard, specifically five critical flow venturis (CFVs) with throat diameters from 0.65 mm to 4.83 mm. In the overlapping portions of the five CFV ranges, two CFVs were used in series and their agreement was within 0.03 %. A document is available (SP 250-80) that describes this facility and its uncertainty (0.10 % at *k*=2). All instrumentation is traceable to NIST and the CFVs, temperature sensors, and pressure sensors are calibrated annually.

CENAM - Centro Nacional de Metrología

km 4.5 Carr. A los Cués,
El Marqués, Qro, México 76241

Range of flow rate:	(2 to 160) m^3/h
Temperature:	(20 ± 1)°C
Working pressure:	around 81.261 kPa
Uncertainty (*k*=2):	0.13 %

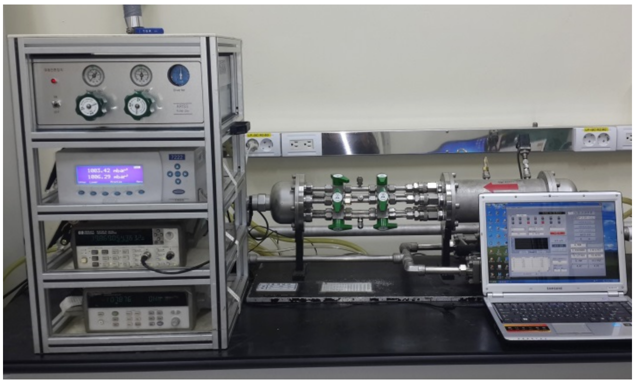
The bell prover uses a volumetric method to determine gas flow rate. It measures a displaced volume of air by collecting the air at "quasi" constant temperature and pressure conditions.

Constant pressure is achieved by using a counter weight and pulley to balance the weight of the bell and by hanging an additional small counter weight from an involute cam to compensate for linear effects as buoyancy. The constant temperature depends on variability of environmental conditions.

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

KRISS
Korea Research Institute of Standards and Science
209 Gajeong-Ro, Yuseong-Gu, Daejeon 305-340
Republic of Korea

Range of flow rate:	(2 to 100) m^3/h
Temperature:	(20 ± 2)°C
Working pressure:	atmospheric conditions
Uncertainty (*k*=2):	0.18 %



The sonic nozzle bank was used to calibrate the transfer standard as shown in Figure. Transfer standard rotary gas meter is installed at the downstream of sonic nozzle bank. Straight pipe of 60D and 35D is installed at the upstream and downstream of transfer standard flow meter.
The nozzles are manufactured according to the ISO 9300 specification. These sonic nozzles were calibrated with a mercury sealed piston prover and bell provers which is a primary gas flow standard of KRISS.

NIM - National Institute of Metrology
No.18, Bei-San-HuanDong Str., Beijing 100013, China

Range of flow rate:	(9.1 to 510) m^3/h
Temperature:	(20.13 ± 1.50)°C
Working pressure:	(99.3 to 101.0) kPa
Uncertainty (*k*=2):	(0.18 to 0.19) %

The sonic nozzle bench is chosen to make this comparison, which is located in the new campus of NIM. The facility is shown in Figure.

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

CMS - Centre for Measurement Standards
30 TA Hsueh Rd., Hsinchu,
Chinese Taipei 30080, R.O.C.

<table>
<tr><td>Range of flow rate:</td><td>(0.39 to 60) m^3/h</td></tr>
<tr><td>Temperature:</td><td>(23 ± 1.5) °C</td></tr>
<tr><td>Working pressure:</td><td>Atmospheric pressure</td></tr>
<tr><td>Uncertainty (k=2):</td><td>0.15 % (≧ 6 m^3/h)
0.18 % (< 6 m^3/h)</td></tr>
</table>

</td><td>

The reference standard used in this low pressure gas flow key comparison is a set of four critical flow Venturis (CFVs) with throat diameters ranging from 0.6096 mm (0.024 inch) to 5.1816 mm (0.204 inch), having a flow range from 6.5 L/min to 1000 L/min. The reference standard is calibrated by the primary flow standard (Bell Prover) maintained by CMS once every 2 years. A photograph of the calibration setup is shown in the figure.
Compressed air is dried first to reach a dew point of -40 °C by flowing through a refrigeration dryer and an adsorption dryer successively. The dry air is then stored in three tanks with a total volume of 5 m^3 and maximum gauge pressure of 8 bars. The CFVs are installed upstream of the meter under test (MUT). Pressure and temperature sensors are installed upstream of the CFVs for the measurement of flow. Instrumentation for measuring pressure, differential pressure, pulse, time or temperature may be selected to acquire outputs from the MUT.
During calibration, the dry air discharged from the pressurized storage tanks passes through two stages of manual pressure regulation to adjust the pressure at the CFV and hence flow. To set up the reference standard, a CFV is selected to achieve the desired range of flows.

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

NMIJ AIST
National Metrology Institute of Japan. AIST
Central 3. 1-1, Umezono 1, Tsukuba-city, Ibaraki-prefecture, 305-8563. Japan

<table>
<tr><td>Range of flow rate:</td><td>(5 to 1 000) m^3/h</td></tr>
<tr><td>Temperature:</td><td>(24 ± 1)°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>

The Medium Gas Flow Calibration System sets up and maintains the national standard of air flow measurement and distributes its values in the flow range from 5 to 200 m^3/h at the pressure from 100 to 500 kPa.
The primary standard is realized by the Pressure-Volume-Temperature-Time method (PVTt method) based on a constant volume tank of about 11 m^3. The standard can calibrate critical nozzles with flows from 5 to 200 m^3/h at pressures from 100 to 500 kPa with the best measurement capability of the flow measurement at 0.17 % (*k*=2). It calibrates mainly High-Precision Nozzles (HPNs), which have the minimum machining error thus the maximum reproducibility, which enables one to judge the calibration quality.
Calibrations of flow meters are performed in a closed-loop calibration facility (CLCF) against HPNs of at most 12 pieces connected in parallel. Flow meters under calibration are connected in series with the parallel connection of HPNs. The facility generates a constant flow from 5 to 1000 m^3/h at a pressure from 100 to 500 kPa during the calibration then the true mass or volumetric flows

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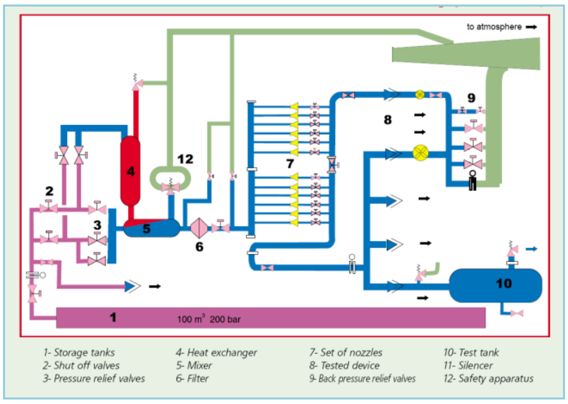
</table>

<table>
<tr><th>Characteristic information\ picture of the primary standard used by measurements</th><th>Working procedure</th></tr>
<tr><td></td><td>of flow meters are calculated from the mass flow conservation through the facility. The facility has three blower compressors, each of which can generate 100 kPa pressure increase at any pressure, thus the facility can have a pressure increase up to 300 kPa, which can put the HPNs in the critical condition. The best measurement capability of a flow meter calibration is estimated at 0.28 % (k=2).</td></tr>
<tr><td>
LNE-LADG

CESAME EXADEBIT - 43, route de l’aerodrome - F - 86036 Poitiers Cedex

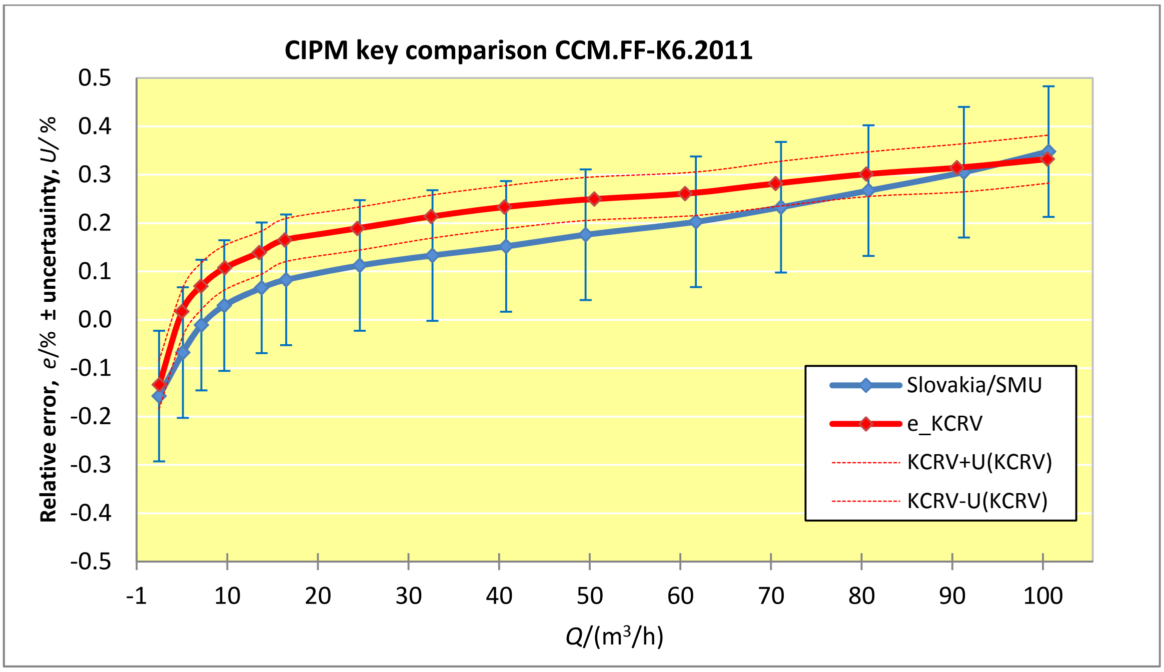
<table>
<tr><td>Range of flow rate:</td><td>(1.5 to 1 000) m^3/h</td></tr>
<tr><td>Temperature:</td><td>(20 ± 2)°C</td></tr>
<tr><td>Working pressure:</td><td>atmospheric conditions</td></tr>
<tr><td>Uncertainty (k=2):</td><td>0.20 %</td></tr>
</table>



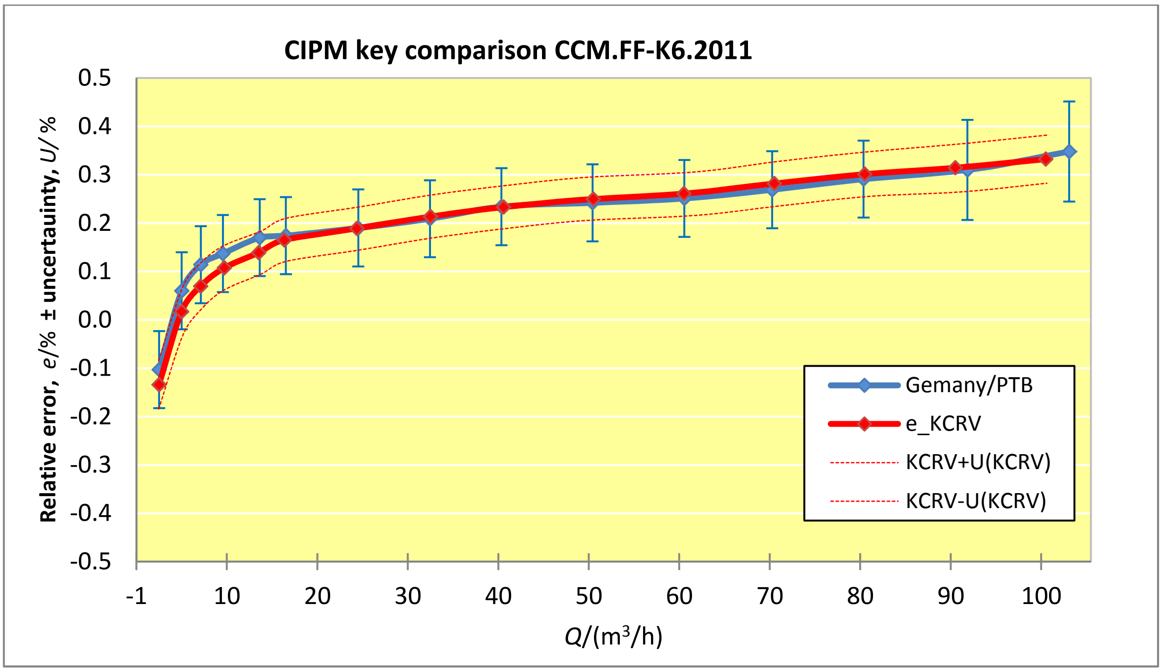
</td><td>The meter under test is placed on a pipeline downstream from the set of nozzles. This configuration allows a comparison between the reference and tested device mass flows. The pressure and the temperature can be measured at the level of the meter under test in order to determine the volumetric 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.</td></tr>
</table>

Appendix B – graphical representation of relative error and expanded uncertainty

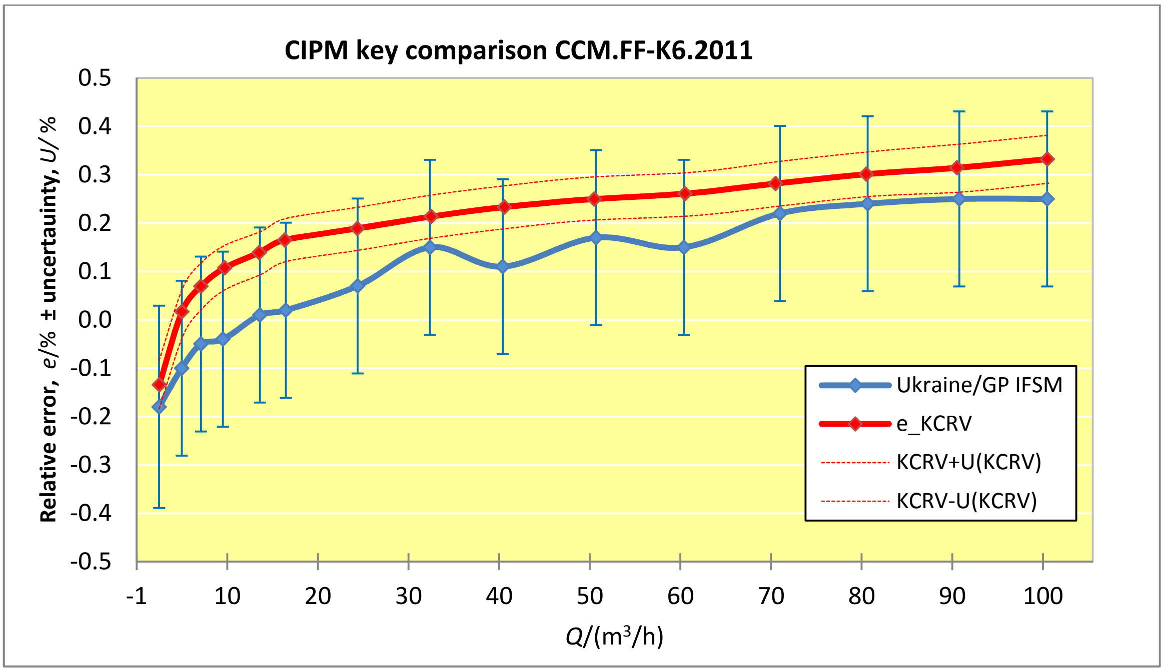
Slovakia/SMU					
Flow of the transfer standard, $Q/(m^3/h)$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
1.98	-0.16	0.12	0.135	-0.02	0.19
4.60	-0.07	0.12	0.135	-0.09	0.67
6.64	-0.01	0.12	0.135	-0.08	0.64
9.17	0.03	0.12	0.135	-0.08	0.61
13.29	0.07	0.12	0.135	-0.07	0.57
16.00	0.08	0.12	0.135	-0.08	0.65
24.12	0.11	0.12	0.135	-0.08	0.60
32.14	0.13	0.12	0.135	-0.08	0.63
40.27	0.15	0.12	0.135	-0.08	0.64
49.04	0.18	0.12	0.135	-0.07	0.58
61.21	0.20	0.12	0.135	-0.06	0.46
70.60	0.23	0.12	0.135	-0.05	0.38
80.25	0.27	0.12	0.135	-0.03	0.27
90.79	0.31	0.12	0.135	-0.01	0.07
100.13	0.35	0.12	0.135	0.02	0.13



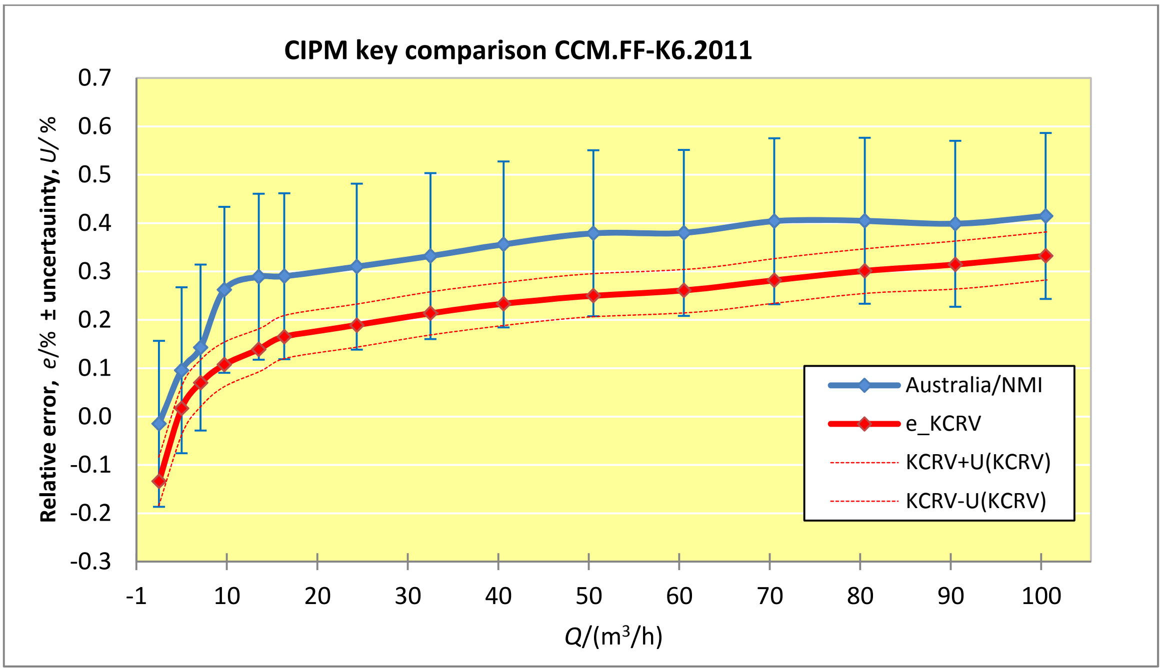
Germany/PTB					
Flow of the transfer standard, $Q/(m^3/h)$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
2.02	-0.10	0.05	0.080	0.03	0.50
4.51	0.06	0.05	0.080	0.04	0.70
6.62	0.11	0.05	0.080	0.04	0.70
9.06	0.14	0.05	0.080	0.03	0.46
13.13	0.17	0.05	0.080	0.03	0.47
16.02	0.17	0.05	0.080	0.01	0.13
24.03	0.19	0.05	0.080	0.00	0.02
31.95	0.21	0.05	0.080	0.00	0.07
39.85	0.23	0.05	0.080	0.00	0.01
49.92	0.24	0.05	0.080	-0.01	0.12
60.06	0.25	0.05	0.080	-0.01	0.15
69.77	0.27	0.05	0.080	-0.01	0.20
79.87	0.29	0.05	0.080	-0.01	0.16
91.35	0.31	0.083	0.104	0.00	0.05
102.60	0.35	0.083	0.104	0.02	0.17



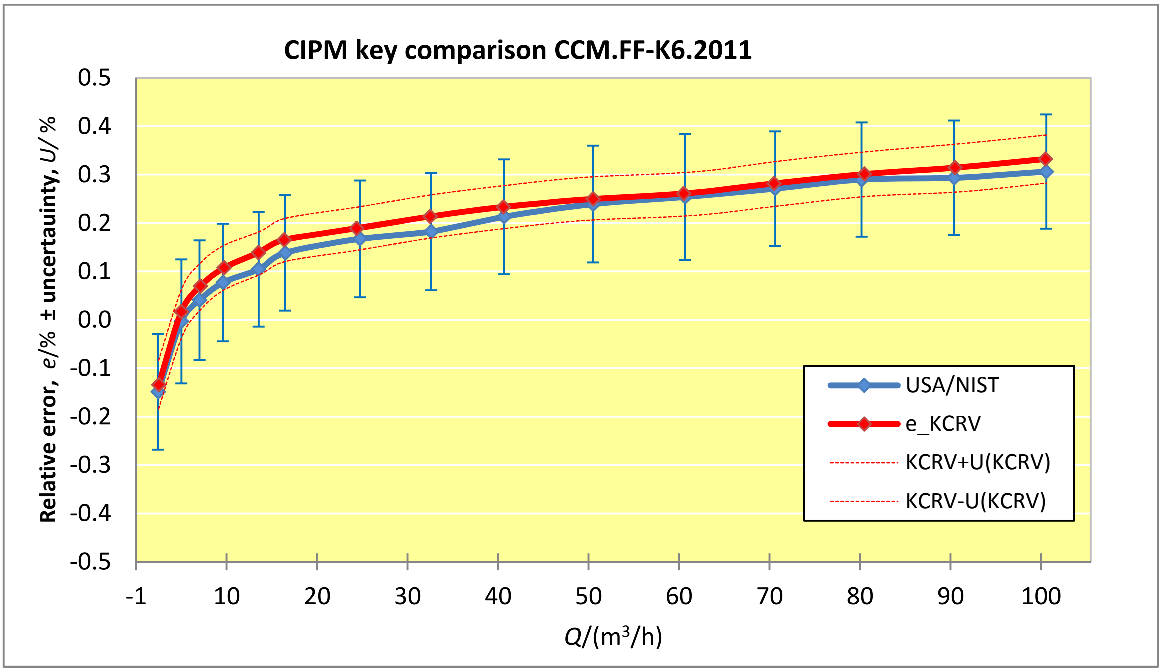
Ukraine/ GP Ivano-Frankivs'kstandartmetrologia					
Flow of the transfer standard, Q/(m^3/h)	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
1.98	-0.18	0.20	0.209	-0.05	0.23
4.48	-0.10	0.17	0.181	-0.12	0.67
6.60	-0.05	0.17	0.181	-0.12	0.69
9.02	-0.04	0.17	0.181	-0.15	0.84
13.10	0.01	0.17	0.181	-0.13	0.74
15.96	0.02	0.17	0.181	-0.15	0.83
23.88	0.07	0.17	0.181	-0.12	0.68
31.87	0.15	0.17	0.181	-0.06	0.36
39.90	0.11	0.17	0.181	-0.12	0.70
50.19	0.17	0.17	0.181	-0.08	0.46
59.89	0.15	0.17	0.181	-0.11	0.63
70.49	0.22	0.17	0.181	-0.06	0.35
80.17	0.24	0.17	0.181	-0.06	0.35
90.28	0.25	0.17	0.181	-0.06	0.37
99.97	0.25	0.17	0.181	-0.08	0.47



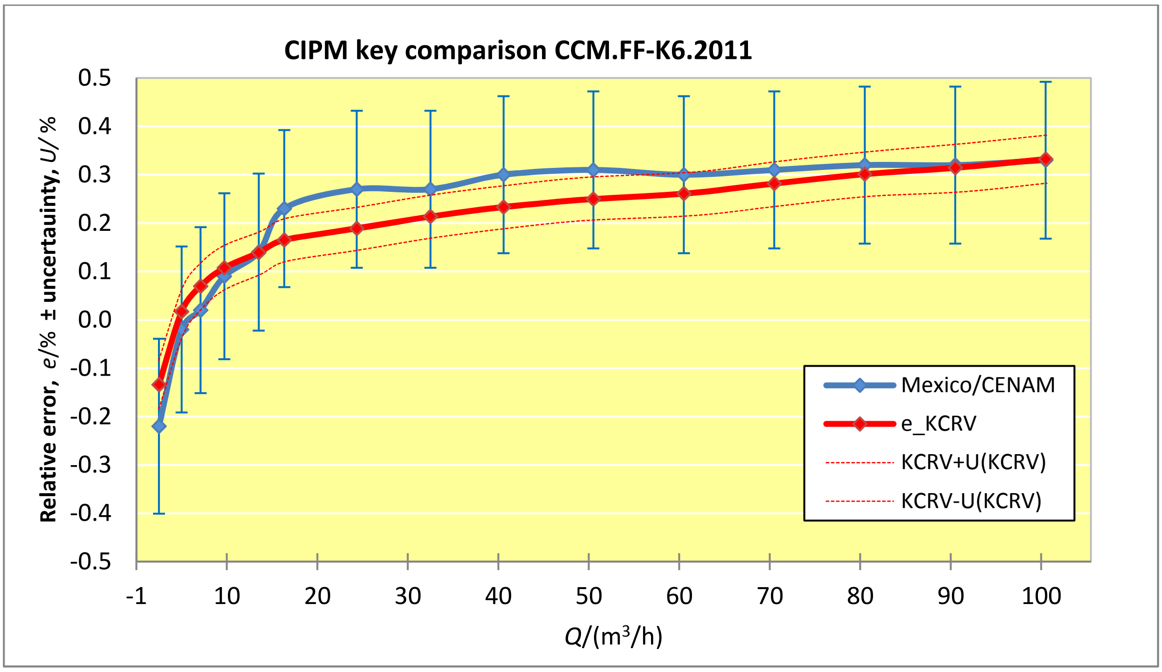
Australia/NMI					
Flow of the transfer standard, Q/(m^3/h)	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
2.00	-0.01	0.16	0.172	0.12	0.73
4.50	0.10	0.16	0.172	0.08	0.48
6.60	0.14	0.16	0.172	0.07	0.44
9.22	0.26	0.16	0.172	0.15	0.94
13.02	0.29	0.16	0.172	0.15	0.91
15.84	0.29	0.16	0.172	0.13	0.76
23.86	0.31	0.16	0.172	0.12	0.73
32.00	0.33	0.16	0.172	0.12	0.71
40.08	0.36	0.16	0.172	0.12	0.74
50.00	0.38	0.16	0.172	0.13	0.78
60.01	0.38	0.16	0.172	0.12	0.72
70.00	0.40	0.16	0.172	0.12	0.74
80.01	0.40	0.16	0.172	0.10	0.63
90.00	0.40	0.16	0.172	0.08	0.51
100.00	0.41	0.16	0.172	0.08	0.50



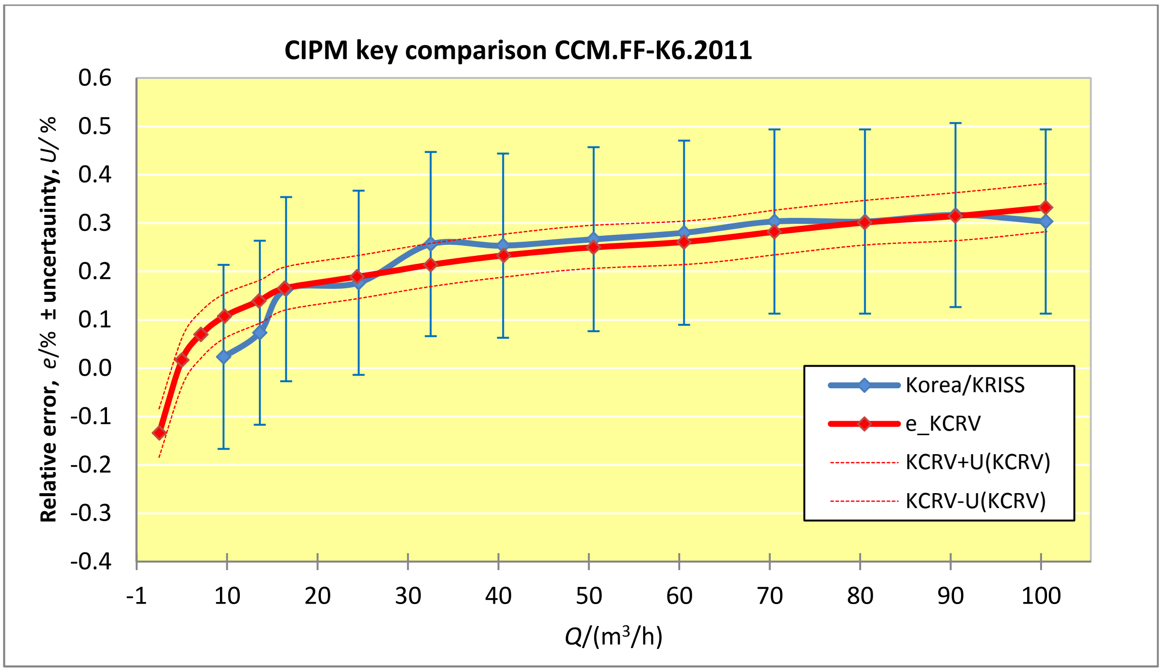
USA/NIST					
Flow of the transfer standard, Q/(m^3/h)	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
1.94	-0.15	0.10	0.120	-0.02	0.14
4.50	0.00	0.11	0.128	-0.02	0.17
6.51	0.04	0.11	0.123	-0.03	0.25
9.12	0.08	0.10	0.121	-0.03	0.27
13.05	0.10	0.10	0.118	-0.03	0.31
15.97	0.14	0.10	0.119	-0.03	0.24
24.24	0.17	0.10	0.121	-0.02	0.19
32.12	0.18	0.10	0.121	-0.03	0.28
40.17	0.21	0.10	0.119	-0.02	0.18
50.00	0.24	0.10	0.121	-0.01	0.10
60.18	0.25	0.11	0.130	-0.01	0.06
70.13	0.27	0.10	0.118	-0.01	0.10
79.68	0.29	0.10	0.118	-0.01	0.10
89.90	0.29	0.10	0.118	-0.02	0.20
100.09	0.31	0.10	0.118	-0.03	0.24



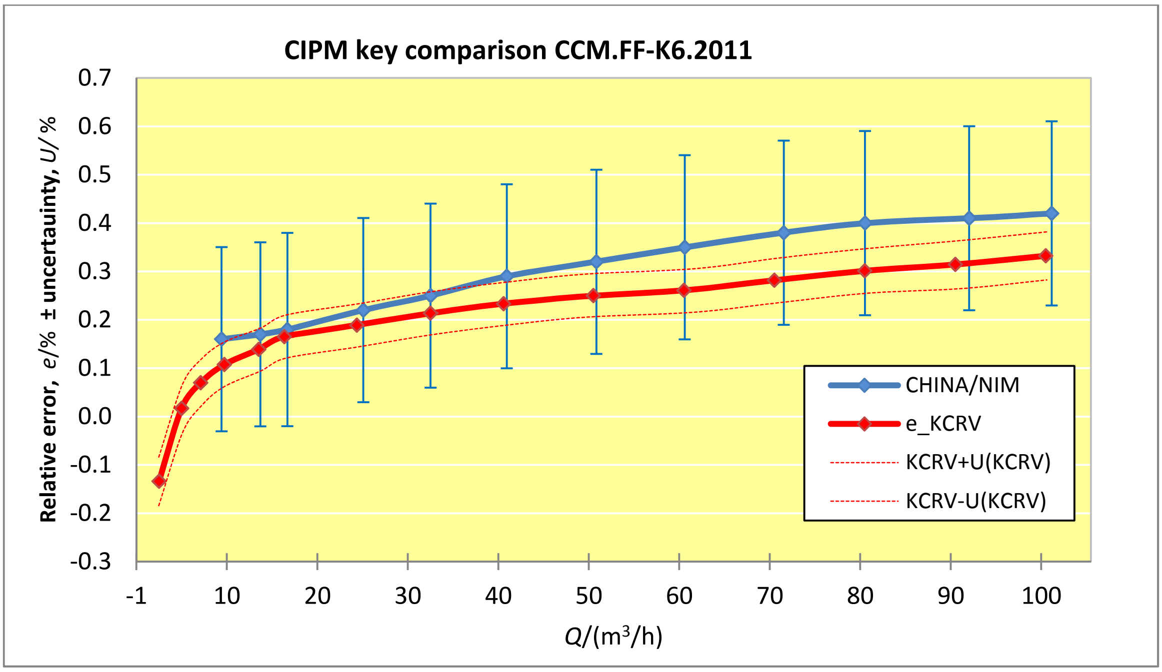
Mexico/CENAM					
Flow of the transfer standard, $Q/(\mathrm{m}^3/\mathrm{h})$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, $U_{xi}/$ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
2.00	-0.22	0.17	0.181	-0.09	0.49
4.50	-0.02	0.16	0.172	-0.04	0.22
6.60	0.02	0.16	0.172	-0.05	0.30
9.22	0.09	0.16	0.172	-0.02	0.11
13.02	0.14	0.15	0.162	0.00	0.01
15.84	0.23	0.15	0.162	0.06	0.42
23.86	0.27	0.15	0.162	0.08	0.52
32.00	0.27	0.15	0.162	0.06	0.36
40.08	0.30	0.15	0.162	0.07	0.43
50.00	0.31	0.15	0.162	0.06	0.39
60.01	0.30	0.15	0.162	0.04	0.25
70.00	0.31	0.15	0.162	0.03	0.18
80.01	0.32	0.15	0.162	0.02	0.12
90.00	0.32	0.15	0.162	0.01	0.04
100.00	0.33	0.15	0.162	0.00	0.01



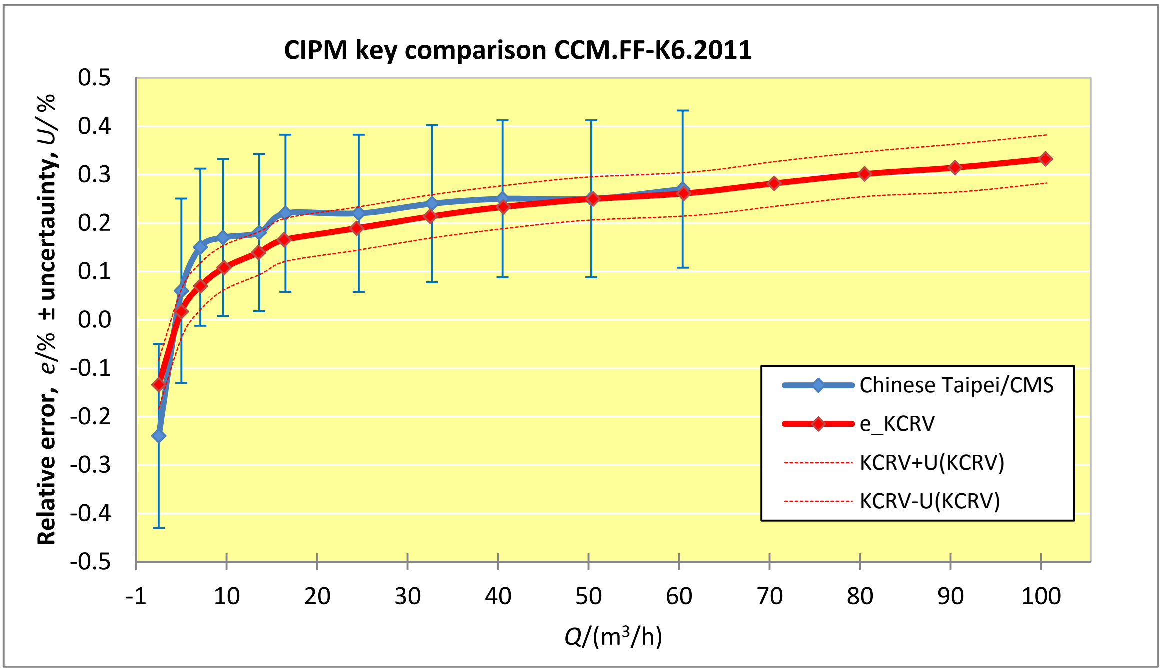
Korea/KRISS					
Flow of the transfer standard, $Q/(m^3/h)$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
9.11	0.02	0.18	0.190	-0.08	0.46
13.11	0.07	0.18	0.190	-0.07	0.35
16.02	0.16	0.18	0.190	0.00	0.01
24.04	0.18	0.18	0.190	-0.01	0.07
32.01	0.26	0.18	0.190	0.04	0.23
40.01	0.25	0.18	0.190	0.02	0.11
50.02	0.27	0.18	0.190	0.02	0.09
60.03	0.28	0.18	0.190	0.02	0.10
70.02	0.30	0.18	0.190	0.02	0.12
80.03	0.30	0.18	0.190	0.00	0.01
90.04	0.32	0.18	0.190	0.00	0.01
100.01	0.30	0.18	0.190	-0.03	0.16



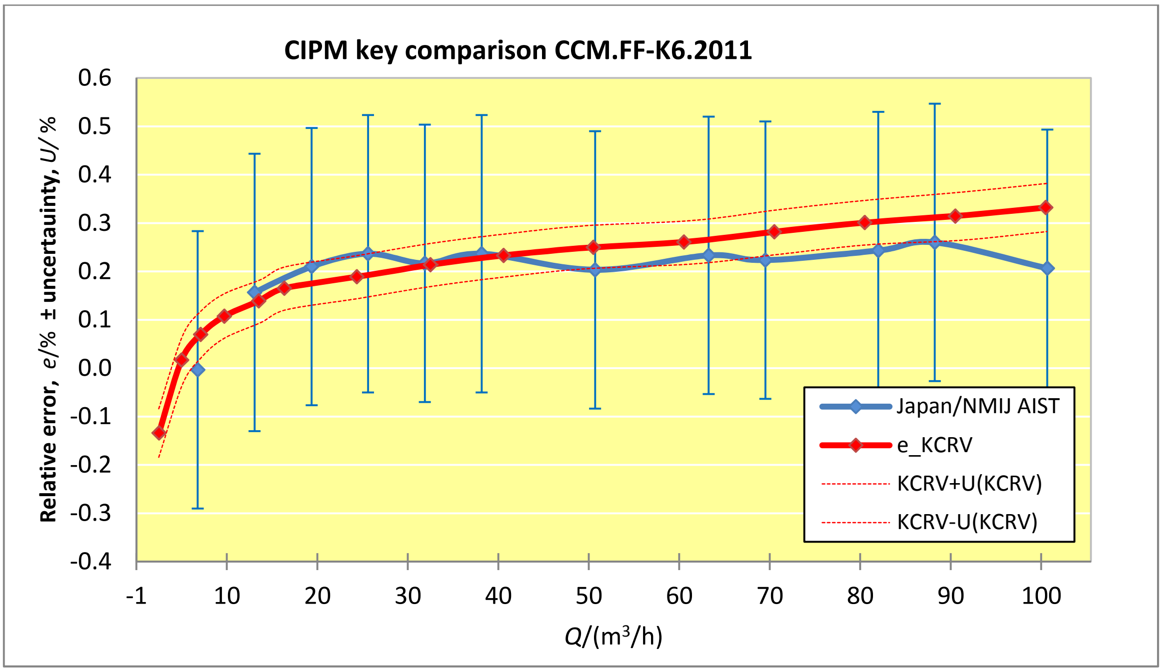
China/NIM					
Flow of the transfer standard, $Q/(m^3/h)$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, $U_{xi}/\%$	Expanded uncertainty of measurement extended by stability, $U_{TS}/\%$	$d_i/\%$	En_i
8.9	0.16	0.18	0.190	0.05	0.28
13.2	0.17	0.18	0.190	0.03	0.17
16.2	0.18	0.19	0.190	0.01	0.08
24.6	0.22	0.18	0.190	0.03	0.17
32.0	0.25	0.18	0.190	0.04	0.20
40.4	0.29	0.18	0.190	0.06	0.31
50.3	0.32	0.18	0.190	0.07	0.38
60.11	0.35	0.18	0.190	0.09	0.48
71.05	0.38	0.18	0.190	0.10	0.53
80.03	0.40	0.18	0.190	0.10	0.54
91.54	0.41	0.18	0.190	0.10	0.52
100.66	0.42	0.18	0.190	0.09	0.48



Chinese Taipei/CMS					
Flow of the transfer standard, $Q/(\mathrm{m}^3/\mathrm{h})$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
2.0	-0.24	0.18	0.190	-0.11	0.58
4.5	0.06	0.18	0.190	0.04	0.24
6.6	0.15	0.15	0.162	0.08	0.52
9.1	0.17	0.15	0.162	0.06	0.40
13.1	0.18	0.15	0.162	0.04	0.26
16.0	0.22	0.15	0.162	0.05	0.35
24.1	0.22	0.15	0.162	0.03	0.20
32.2	0.24	0.15	0.162	0.03	0.17
40.0	0.25	0.15	0.162	0.02	0.11
49.8	0.25	0.15	0.162	0.00	0.00
59.9	0.27	0.15	0.162	0.01	0.06



Japan/NMIJ AIST					
Flow of the transfer standard, Q/(m^3/h)	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS} /%	d_i/%	En_i
6.28	0.00	0.28	0.287	-0.07	0.26
12.57	0.16	0.28	0.287	0.02	0.06
18.87	0.21	0.28	0.287	0.04	0.16
25.11	0.24	0.28	0.287	0.05	0.17
31.38	0.22	0.28	0.287	0.00	0.01
37.66	0.24	0.28	0.287	0.00	0.01
50.20	0.20	0.28	0.287	-0.05	0.16
62.75	0.23	0.28	0.287	-0.03	0.10
69.02	0.22	0.28	0.287	-0.06	0.21
81.50	0.24	0.28	0.287	-0.06	0.20
87.74	0.26	0.28	0.287	-0.05	0.19
100.17	0.21	0.28	0.287	-0.13	0.44



France/LNE-LADG					
Flow of the transfer standard, $Q/(m^3/h)$	Relative error of the transfer standard, e/%	Expanded uncertainty of measurement declared by laboratory, U_{xi}/ %	Expanded uncertainty of measurement extended by stability, U_{TS}/%	d_i/%	En_i
13.16	0.11	0.25	0.258	-0.03	0.11
15.87	0.15	0.25	0.258	-0.02	0.06
24.42	0.17	0.25	0.258	-0.02	0.09
32.56	0.21	0.25	0.258	-0.01	0.03
40.22	0.23	0.25	0.258	0.00	0.00
50.39	0.25	0.25	0.258	0.00	0.01
60.57	0.26	0.25	0.258	0.00	0.01
70.53	0.25	0.25	0.258	-0.03	0.13
80.46	0.29	0.25	0.258	-0.01	0.04
90.30	0.27	0.25	0.258	-0.05	0.19
100.44	0.28	0.25	0.258	-0.05	0.21