



Final Report – Draft B

**Inter-laboratory calibration comparison
of the turbine gas meter G650**

**REGIONAL KEY COMPARISON
EUROMET**

EUROMET Project No. 862



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“Wherefore I perceive that there is nothing better, than that a man should rejoice in his own works”

Ecclesiastes [3:22]

Acknowledgements

We would like to express our gratitude to the company PREMAGAS which lent the turbine gas meter for this project and which cooperated with us during the stability tests of the meter.

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1. Introduction

The project EUROMET no.862 for the comparison of the axial turbine gas meter G650 officially started in March 2006 and was concluded in October 2006. The time schedule is shown in *table 1*. Each country took 1.5 week to perform the calibration of the turbine gas meter G650 with air in the pressure which is close to barometric pressure. The range of flow rates was from 100 m³/h to 1000 m³/h. The participating laboratories used their usual calibration procedure. The comparison was conducted with respect to guidelines^{1) 2)}.

In the moment when this report is issued no CIPM key comparison was finished in the field of low pressure gas flow in relevant flow rates. Three participant of this project Germany (PTB), Netherlands (NMi) and United Kingdom (NEL) are also participants in the running CIPM key comparison CCM.FF-K6 which covers flow rates only up to 260 g/min (approximately 18.7 m³/h). It can be assumed that relevant CIPM key comparison will take place in near future and that is why the “key comparison reference values” in 8 flow rates mentioned in this report can be regarded as “regional key comparison reference values”. The “regional key comparison reference values” will be linked to CIPM key comparison as soon as it will be possible.

Table 1 – Time schedule and participants

Country	Laboratory	Address of the Place of calibration	Date of calibration	Responsible
Czech Republic (PILOT LAB)	CMI Czech Metrology Institute	CMI Regional Inspectorate Průmyslová 455 530 03 Pardubice Czech Republic	27.3.- 5.4. 2006	Tomas Valenta
Austria	BEV Bundesamt für Eich- und Vermessungswesen	BEV Arltgasse 35 A 1160 Wien Austria	6.4. - 16.4. 2006	Manfred Macek
Hungary	OMH Országos Mérésügyi Hivatal	OMH Országos Mérésügyi Hivatal H-1124 Budapest Nemetvolgyi ut 37. Hungary	17.4.- 26.4. 2006	Csaba Czibulka
Germany	PTB Physikalisch- Technische Bundesanstalt	PTB Bundesallee 100 38116 Braunschweig Germany	27.4.-7.5. 2006	Bodo Mickan
Netherlands	NMi VSL Nederlands Meetinstituut Van Swinden Laboratorium	NMi VSL Flow Thijsseweg 11 2629JA Delft The Netherlands	8.5.-17.5. 2006	Mijndert P. van der Beek

¹⁾ EUROMET Guide No.3 - "Guidelines on Conducting Comparisons"
http://www.euromet.org/docs/guides/docs/E-G03-v02_7.pdf

²⁾ Guidelines for CIPM key comparisons
<http://www.bipm.org/utis/en/pdf/guidelines.pdf>

United Kingdom	NEL National Engineering Laboratory	NEL East Kilbride, Glasgow, Scotland, UK. G75 0QU	18.5.-28.5. 2006	Jeff Gibson
Denmark	FORCE Technology	FORCE Technology Vejen, Navervej 1 6600 Vejen Denmark	29.5.-7.6. 2006	Kurt Rasmussen
Poland	GUM Główny Urząd Miar (Central Office of Measures)	Central Office of Measures 00-950 Warszawa P-10 ul. Elektoralna 2 Poland	8.6.-18.6. 2006	Monika Kusyk-Ring
Lithuania	Lithuanian Energy Institute	Lithuanian Energy Institute Heat Equipment Research and Testing Laboratory Breslaujos str. 3, LT-44403 Kaunas-35 Lithuania	19.6.-28.6. 2006	Jurij Tonkonogij
Slovak Republic	SMU Slovak Institute of Metrology	PREMAGAS s.r.o. Nám. Dr. A. Schweitzera 194 916 01 Stará Turá Slovak Republic	29.6.-9.7. 2006	Stefan Makovnik
Czech Republic (PILOT LAB)	CMI Czech Metrology Institute	CMI Regional Inspectorate Pardubice Průmyslová 455 530 03 Pardubice Czech Republic	10.7.-19.7. 2006	Tomas Valenta
Switzerland <i>(ATA-CARNET)</i>	METAS Metrology and Accreditation Switzerland	Swiss Federal Office of Metrology and Accreditation Lindenweg 50, CH-3003 Bern-Wabern Switzerland	20.7.-30.7. 2006	Henri Baumann
Turkey <i>(ATA-CARNET)</i>	TUBITAK – UME National Metrology Institute of Turkey	TUBITAK-UME Anibal Cad. MAM Kampusu PK54 - 41470 Gebze- Kocaeli / TURKEY	31.7.-9.8. 2006	Vahit Ciftci
Czech Republic (PILOT LAB)	CMI Czech Metrology Institute	CMI Regional Inspectorate Pardubice Průmyslová 455 530 03 Pardubice Czech Republic	21.8.-3.9. 2006	Tomas Valenta

France	LNE-LADG Laboratoire Associé de Débitmétrie Gazeuse	LNE-LADG 43 route de l'Aérodrome 86000 POTIERS FRANCE	4.9.-17.9. 2006	Christophe Windenberger
Spain	CEM (Centro Español de Metrología) Enagas S.A.	Laboratorio Central Enagas Carretera de Madrid, km 306,4 50012 Zaragoza Spain	18.9.-1.10. 2006	Terradillos González
Czech Republic (PILOT LAB)	CMI Czech Metrology Institute	CMI Regional Inspectorate Pardubice Průmyslová 455 530 03 Pardubice Czech Republic	2.10.-14.10. 2006	Tomas Valenta

2. The instrument

The axial turbine gas meter (*Fig. 1*) was used for the comparison. The description of this meter is mentioned down.

Manufacturer: PREMAGAS s.r.o., Nám. Dr. A. Schweitzera 194, 916 01 Stará Turá,
Slovak Republic (<http://www.premagas.sk>)

Type: DAE

Size: G650

Serial number: 0004442

Q_{\min} : 100 m³/h

Weight: 45 kg

Maximum pressure loss in Q_{\max} with air ($\rho=1.2$ kg/m³) : 1400 Pa

P_{\max} : 16 bar

Inside diameter: DN 150

Pulse number: 4566.49 imp/m³

Q_{\max} : 1000 m³/h

Figure 1 – Axial turbine gas meter, type DAE

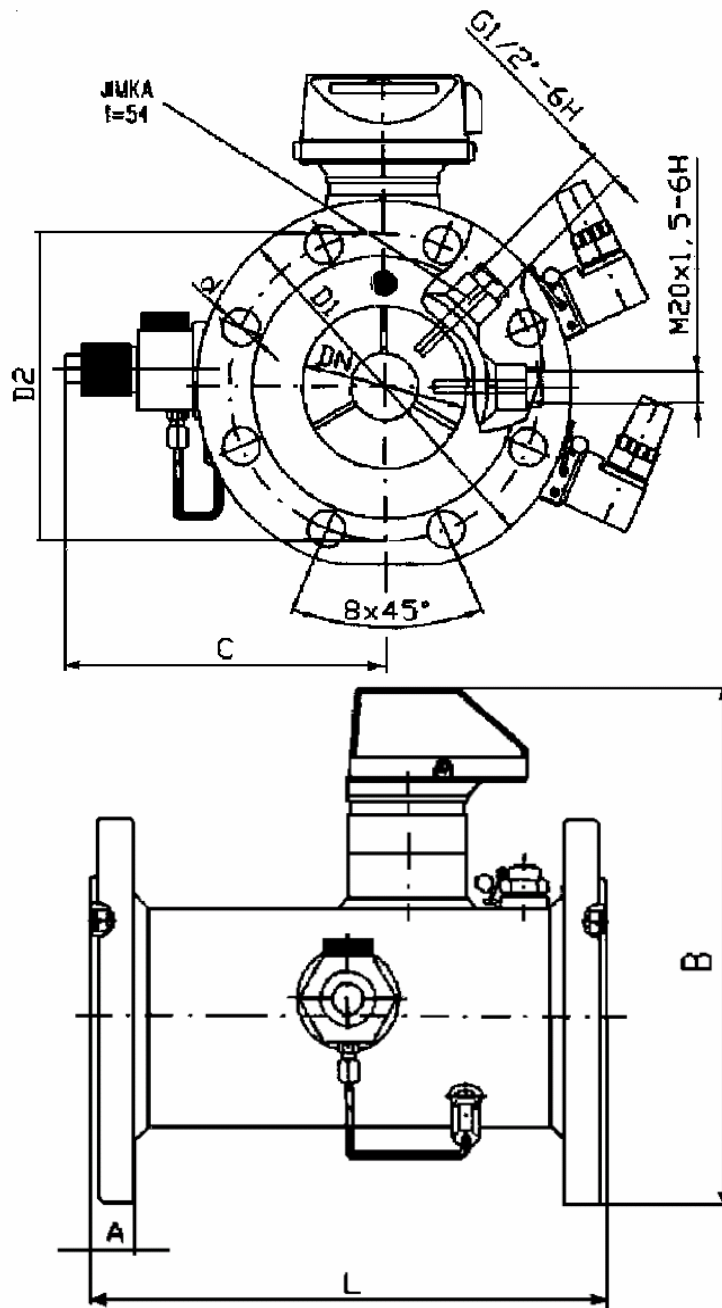


The dimensions of the meter are mentioned in *table 2* and in the *figure 2*.

Table 2 - Dimensions of the meter

L	D1	D2	D	A	B	C
450 mm	280 mm	240 mm	23 mm	22 mm	340 mm	195 mm

Figure 2 - Dimensions of the meter



The high frequency pulse emitter A1S was used. This emitter A1S was made according to DIN EN 50227 (NAMUR).

3. Calibration procedure

The turbine gas meter G650 was tested with air in the pressure which is close to barometric pressure. The meter was tested in horizontal position in each laboratory. For the tests it was necessary to use the upstream straightening pipe that was long at least 5x DN and the downstream straightening pipe that was long at least 3x DN. The reference pressure from the turbine gas meter was measured from the output “p_r”. The reference temperature from the turbine gas meter was measured in the distance (2÷3) x DN downstream of the turbine gas meter.

The pulse emitter A1S with the pulse number 4566.49 pulses/m³ was used for the tests. The calibration had to be performed in the laboratory where the temperature was from 19.5°C to 23.5°C. No oil lubrication was used.

The turbine gas meter was tested in 8 flow rates:

1000 m³/h, 800 m³/h, 650 m³/h, 500 m³/h, 400 m³/h, 300 m³/h, 200 m³/h, 100 m³/h.

The test was repeated at least 3 times in each flow rate and then the means of values in the *table 3* mentioned down were calculated. The flow rate had to be in the interval ± 3% of the required value.

Table 3 - Required table of results

Flow rate in the meter (m ³ /h)	Absolute pressure in the meter (Pa)	Temperature in the meter (°C)	Pressure loss of the meter (Pa)	Error of the meter (%)	Uncertainty of the error U(k=2) (%)
1000					
800					
650					
500					
400					
300					
200					
100					

Error of the meter is value which shows the relationship in percentage terms of the difference between the volume indicated by the meter and the volume which has actually flowed through the meter, to the later value.

$$E = \frac{V_i - V_c}{V_c} \cdot 100 \quad (\%) \quad [1]$$

where *E* is the error of the meter
V_i is the indicated volume by the meter (m³)
V_c is the real volume which has actually flowed through the meter (m³)

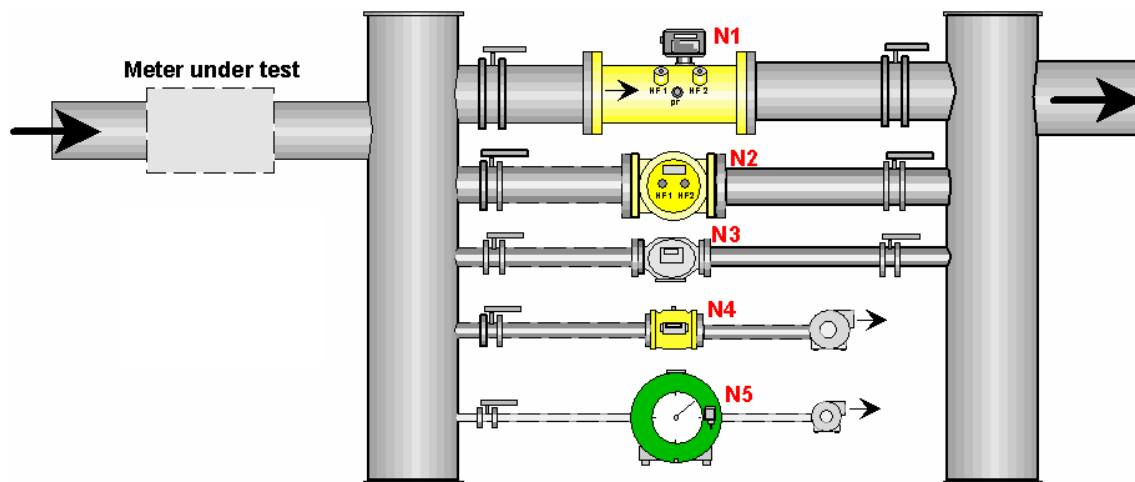
4. Equipment and obtained results

4.1. Austria

Description of the test bench (Fig.3) :

Maximum flow rate:	1000 m ³ /h
Minimum flow rate:	0.1 m ³ /h
Working pressure:	atmospheric conditions
Uncertainty (k=2):	0.30 %

Figure 3 - BEV test bench for industrial gas meters



Standard meters are mentioned in the *table 4*.

Table 4 - Standard meters in test bench of BEV

	Type	Size	used range	Manufacturer
N1	Rotary piston meter (DUO)	G650	10 to 1000 m ³ /h	Instromet
N2	Rotary piston meter (DUO)	G250	4 to 400 m ³ /h	Instromet
N3	Rotary piston meter (DUO)	G40	1 to 65 m ³ /h	Instromet
N4	Rotary piston meter	G16	0.5 to 25 m ³ /h	Instromet
N6	Wet drum meter	NB3	0.1 to 3 m ³ /h	Ester

Location:

Bundesamt für Eich- und Vermessungswesen (BEV)
Arltgasse 35
A-1160 Wien, Austria

Traceability:

For flow rates between 1000 m³/h and 25 m³/h, the normal meters are traceable to the NMI (Netherlands). For flow rates between 25 m³/h and 0.1 m³/h, the normal meters are traceable to the BEV (bell prover).

Description of the test procedure:

The meter was installed with an upstream straightening pipe (L = 750 mm) and a downstream straightening pipe (L = 600 mm) according to the 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 “pr”, the meter temperatures were measured downstream of the meters.

The duration of each test was min. 180 seconds (3 minutes). The indicated volume for the meters were 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.

Results of Austria:

Flow rate in the meter	Abs. pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U(k=2)
m ³ /h	Pa	°C	Pa	%	%
998.2	96920	21.8	861	0.09	0.30
801.0	97500	21.9	559	0.31	0.30
650.2	97830	21.9	377	0.36	0.30
500.5	98100	21.9	233	0.27	0.30
398.8	98250	21.8	151	0.22	0.30
299.7	98350	21.8	89	0.21	0.30
200.8	98430	21.8	42	0.42	0.30
101.0	98470	21.8	13	1.20	0.30

4.2. Hungary

The address of the laboratory:

Instromet Hungary-TWT Kft., H-2310 Szigetszentmiklós, Wesselényi u. 14.

Date of calibration: 20.04.2006

The Description of the Test Facility:

The Test Facility is type Instromet ITF-4000 for gas meters for the capacity of 0.5 to 4000 m³/h.

Standard meters:

- 1 x rotary displacement gas meter, type Instromet IRM-A, size G 16
- 4 x rotary displacement gas meter, type Instromet IRM-3-DUO, size G 650

The installation operates on the master meter principle, comparing the output of a Meter-under-Test is connected in series with the reference meter. The quantity of gas flowing through both meters is identical by taking pressure and temperature in both meters into account the volumetric flow rates can be compared. The Meter-under-Test is downstream of the reference meter. This principle grants the opportunity for testing dirty meters.

Traceability:

The standard meters are traceable to the primary standards of the Dutch institute of measurements the NMI.

Recalibration interval of the meters: 5 years

The barometer, the pressure transmitters and the temperature sensors are calibrated.

Description of the test procedure:

The transfer meter was installed according to the laboratory normal practice and according to the instructions of Project No. 862. The meter was calibrated against the standard meters Nr.4 and Nr.5 at eight different flow rates.

Pressure was measured at the point marked ‘P_r’ on the transfer meter. The temperature was measured downstream of the transfer meter. The duration of each test was min. 180 seconds.

The true volume flow rate at the transfer meter was obtained by correcting the volume flow rate measured by the standard meters to the conditions at the transfer meter. The indicated volume flow rate from the transfer meter was calculated from the pulses of pulse emitter AIS, time and the nominal K-factor ($K=4566.49 \text{ imp/m}^3$) of the meter.

Results of Hungary:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U(k=2)
(m ³ /h)	(Pa)	(°C)	(Pa)	(%)	(%)
1000	98494	22.0	850	0.66	0.26
800	99059	22.1	560	0.58	0.26
650	99093	23.8	380	0.53	0.26
500	99540	24.4	240	0.47	0.26
400	99783	24.9	160	0.38	0.26
300	99979	24.8	90	0.26	0.26
200	100120	24.6	40	0.52	0.26
100	100219	24.6	10	1.24	0.27

4.3. Germany

Place of calibration: Physikalisch-Technische Bundesanstalt (PTB)

Bundesallee 100, D-38116 Braunschweig, Germany

The nozzle test rig (*Fig. 5*) for large gas meters (2 – 5600 m³/h) was used for the calibration of the turbine meter G650.

Figure 5 - PTB test bench for large gas meters



The computer-controlled nozzle test rig consists of an echelon of 16 Venturi nozzles connected in parallel and operated at sound velocity. This mode of operation guarantees a very high stability of the flow rate selected, with short-term reproducibilities of 0,002%. The uncertainty of measurement amounts to $u < 0,08\%$.

The sonic nozzle test bench is a secondary standard with traceability to the bell prover (1 - 60 m³/h). A bell prover which allows volume flow rates of air at atmospheric pressure to be realized with a measurement uncertainty of $u < 0,06\%$ serves as the primary standard in Germany.

Results of Germany:

Flow rate in the meter	True flow rate	Absolute pressure in the meter	Temperature in the meter	Error of the meter	Uncertainty of the error U(k=2)
(m ³ /h)	(m ³ /h)	(Pa)	(°C)	(%)	(%)
1000	1036.989	98885	22.26	0.108	0.08
800	826.700	99599	22.29	0.342	0.08
650	672.748	99983	22.32	0.398	0.08
500	516.124	100284	22.33	0.330	0.08
400	413.281	100457	22.35	0.268	0.08
300	309.085	100582	22.34	0.232	0.08
200	205.763	100670	22.35	0.408	0.08
100	104.921	100721	22.37	1.140	0.08

4.4. Netherlands

The turbine meter used for this inter-comparison has been calibrated on the ‘Big Installation’ of NMi VSL, located in our lab in Delft, Thijsseweg 11. The installation is made up of two axial blowers, one for low flow rates (up to 4000 m³/h) and one for high flow rates (up to 15000 m³/h), a regulated heat exchanger after the blowers, data acquisition system, piping, pressure and temperature sensors and five reference meters. The reference meters are described in *table 5*:

Table 5: Reference meters in big installation in NMi

Standard nr	Type	Manufacturer	Range
2	G250 IRM-A-DUO rotor meter	Instromet	28 - 400 m ³ /h
3	G650 CVM38M rotor meter	IGA	150 - 1200 m ³ /h
4	G2500 SM-RI-D turbine meter	Instromet	800 – 4000 m ³ /h
5	G4000 SM-RI-D turbine meter	Instromet	1500 – 6500 m ³ /h
6	G6500 SM-RI-D Turbine meter	Instromet	2000 – 9500 m ³ /h

In this inter comparison meter numbers 2, 3 and 4 are used within the range of the Premagas turbine meter. When possible overlap measurements between two NMi reference meters has been performed.

The reference meters are all traceable to primary and/or (inter) nationally accepted measurement standards. The CMC of the installation within the range of 100 – 1000 m³/h is 0.15 %. The test procedure used by NMi is the test procedure as outlined in the Technical Protocol for EUROMET Project No. 862. As an addition to this procedure the temperature of the reference meters and the meter under test is monitored for each flow rate. Once stabilization has occurred, the measurement is started.

Results of Netherlands:

Indicated Flow rate	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U(k=2)
(m ³ /h)	(Pa)	(°C)	(Pa)	(%)	(%)
1000	101186	20.08	-564	0.26	0.15
801	101417	20.03	-333	0.43	0.15
650	101537	20.02	-213	0.46	0.15
500	101628	20.00	-122	0.37	0.15
399	101675	19.92	-74.7	0.32	0.15
300	101709	19.91	-40.7	0.26	0.15
200	101732	19.91	-18.3	0.45	0.15
100	101745	19.92	-5.1	1.18	0.15

4.5. United Kingdom

Place of calibration: TUV NEL Ltd, East Kilbride, Glasgow G75 OQU

The details of the meter and calibrations are shown below.

Date received: 19 May 2006

Date(s) calibrated: 23 — 24 May 2006

Calibration fluid: Dry air

Calibration range: 100 to 1000 m³/hr (actual)

Lab temperature: 20°C

Test pressure: Atmospheric

Reference mass flow rate: The reference flow rate was established using an ISO 9300 compliant sonic nozzle.

The calibration was performed using the high-pressure gravimetric airflow rig, with the flow rate being controlled using a set of pressure regulators (*figure 6*). The Gravirig is a blow-down test facility whereby air is compressed into a storage volume, dried to a dew point of -40°C and vented through the test line to atmosphere via a silencer. The reference mass flow rate is controlled and measured via a set of sonic nozzles, which are installed individually in one of two holders located upstream or downstream of the test section. The nozzles are pre-calibrated against a primary weighbridge — the flow being diverted into the vessel via two coupled ball valves located downstream of the nozzle holder. For the current tests, the reference nozzle was installed in the upstream holder as the line pressure was to be atmospheric.

Figure 7 shows a schematic of the test line, with dimensions of the pipe spools and positions of the temperature and pressure measurements relative to the inlet and outlet flanges of the turbine meter indicated also. The test line was open to atmosphere in the current tests so as to keep the line pressure as near-atmospheric as possible. There was 40D of undisturbed 6-inch, sch. 40 pipework upstream of the turbine and 15D downstream. The test pressure, P , was measured off a tapping located on the meter body. The test temperature was measured 2.3D downstream of the meter outlet flange.

Two additional pressure taps were used for the purposes of determining the pressure drop across the turbine meter. The upstream pressure, P , was measured 4.5D upstream of the meter inlet, whilst the downstream pressure, P_d , (which was close to zero) was measured at the downstream tapping, located about 1 D downstream of the meter outlet flange. These pressures were not logged by the data acquisition system. The variation in pressure was such that it was not possible to get a reasonable spot reading below $200\text{ m}^3/\text{hr}$ where the dp was tending to zero.

Figure 6 – Schematic of NEL’s air flow test facility

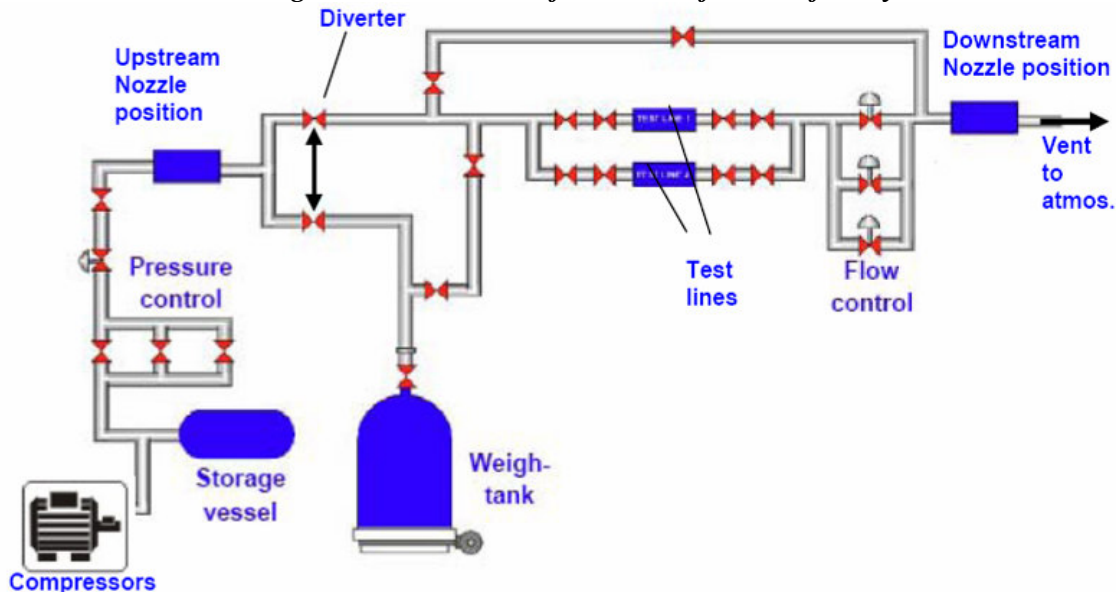
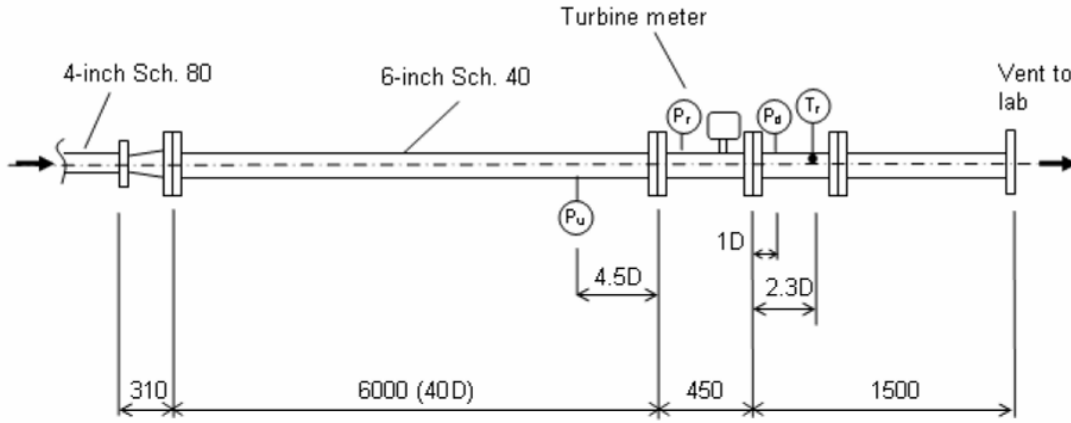


Figure 7 – Schematic of EUROMET 862 turbine installed NEL’s gas flow test facility (not to scale)



The indicated volumetric flow rate was calculated from the reference mass flow rate (kg/s) and the density was determined using the measurements of P_r and T_r and the equation of state for compressibility, Z . Thus

$$V_c = \frac{\dot{m}}{\rho} = \frac{\dot{m}ZRT_r}{p_r} \quad [2]$$

The meter error was determined as the difference between the indicated flow rate, based on a nominal k-factor of 4566.49 impulses per m^3 and measured frequency, and the actual volumetric flow rate determined at the meter

$$E = \frac{V_i - V_c}{V_c} \times 100 \quad [3]$$

The uncertainty of the measurement was $U(k=2)=0.25\%$.

The nozzle reference and meter temperatures were measured using PT100 Platinum Resistance Thermometers (PRT5) via a Solartron Scorpio data logger. The PRTs are calibrated in NEL’s Hetofrig temperature bath against a reference PRT and thermometry bridge which are calibrated once a year. The barometric pressure and the nozzle and meter gauge pressures were measured using Mensor precision gauges. These gauges are traceable to a Desgranges et Huot deadweight tester, for pressures from 2 — 70 bar g, a CEC deadweight tester for pressures 2,000 — 20,000 Pa g and an FRS-4 low pressure standard over the range 50 — 2000 Pa g. All pressure gauges are calibrated once a year. The meter test frequency was logged using a Philips Counter/Timer. The timer is calibrated once a year against an RIS reference frequency source.

Results of Great Britain:

NEL expressed doubts about the results obtained in NEL and subsequently NEL asked for the withdrawal of the results. No results of NEL are presented here now because it was approved by the majority of participants.

4.6. Denmark

Description of the test facilities

The tests were performed at the Danish National Reference Laboratory for volume gas measurement located at:

FORCE Technology
Navervej 1
DK-6600 Vejen
Denmark

The tests were performed on test line FORCE no.C02-003 which consists of standards

- rotary meter (10-100) m³/h
- turbine meter (80-400) m³/h
- turbine meter (200-1000) m³/h
- turbine meter (800-4000) m³/h

During the tests the meter is placed before the working standard (upstream). The air is sucked through the meter and the working standard. The pressure at the meter during test and at the working standard is measured at the P_r , and the temperatures at both meters are measured 2D downstream. The test line consists of 4 working standards in parallel, which are one rotary meter and 3 turbine meters (only one working standard is operating at a time). The test line can operate at a flow from 10 m³/h to 4000 m³/h. The temperature is measured with thermistors, and the pressure is measured with a differential pressure meter between the meter during test and the working standard, and the pressure difference between the working standard and the barometer reading.

Traceability of the working standards and other equipment:

The working standards are traceable to the NMI in Delft in Holland, and are being recalibrated every second year. The thermistors are traceable to NPL in England. The differential pressure meters are traceable to the National Reference Laboratory in Denmark.

Uncertainty:

The uncertainty of the calibration is in accordance with EA-4/02 “Expression of the Uncertainty of Measurement In Calibration“, December 1999, and is as the following, for each test line:

Atmospheric test line C02-003;

10 < Q < 400 m³/h $U_a \pm 0.18\%$

400 < Q < 4000 m³/h $U_a = \pm 0.22\%$

Results of Denmark:

Flow rate	Abs. pressure at the meter	Temperature at the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U(k=2)
[m ³ /h]	[Pa]	[°C]	[Pa]	[%]	[%]
1000	100673	19.88	850	0.23	± 0.22
800	101232	19.88	565	0.37	± 0.22
650	101562	19.90	399	0.39	± 0.22
500	101878	19.90	230	0.33	± 0.22
400	102036	19.87	149	0.28	± 0.18
300	102145	19.83	88	0.21	± 0.18
200	102231	19.82	39	0.38	± 0.18
100	102268	19.81	9	1.14	± 0.18

4.7. Poland

Address of the laboratory:

Central Office of Measures (GUM)
Gas Meters Testing Laboratory
ul. Elektoralna 2
00-950 Warsaw, P-10
Poland

Test facility: bell prover

$$Q_{\min} = 9 \text{ m}^3/\text{h}, Q_{\max} = 7000 \text{ m}^3/\text{h}$$

$$V_n = 65 \text{ m}^3,$$

situated at Central Office of Measures (GUM), Gas Meters Testing Laboratory, ul. Elektoralna 2, 00-950 Warsaw P-10, Poland.

Traceability: The standard is related to national standards of length, time, pressure, temperature.

Test procedure: The calibration of gas meter is carried out by determination of the error-flow rate relationship. Errors of gas meter calibrating are determined by increase of volume measured by gas meter and measurement dose related to gas meter conditions. The volume of gas measured by a gas meter is calculated by multiplying number of high frequency pulses by pulse generator constant.

Results of Poland:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U (k=2)
m ³ /h	Pa	°C	Pa	%	%
1000	103242	21.47	733	0.04	0.25
800	104070	21.82	493	0.18	0.25
650	104410	21.68	352	0.18	0.25
500	104637	21.54	217	0.16	0.25
400	104744	21.53	139	0.05	0.25
300	104818	21.53	73	-0.02	0.25
200	104877	21.65	41	0.05	0.26
100	104815	21.60	12	0.83	0.26

4.8. Lithuania

Place of the test:

Heat equipment research and testing laboratory of Lithuanian energy institute, 3 Breslaujos str. LT-44403 Kaunas-35, Lithuania

The test method:

During the test the turbine gas meter was calibrated by the method of comparison the meter's readings with readings of a standard gas meter. The calibration was carried out according to the document KM-2E/3-MP01:2004 «Air (gases) volume and flow rate meters, (1 – 9700) m³/h. Methods of calibration».

According to the document «The Technical Protocol for EUROMET Project No. 862. Inter-laboratory Calibration Comparison of the Turbine Gas Meter G650» the gas meter has been calibrated at 8 flow rates: (1000, 800, 650, 500, 400, 300, 200 and 100) m³/h.

The test at each flow rate was repeated 3 times and then the means were calculated. The deviation of real flow rate values did not exceed ± 3% of the required values.

The tests were carried out without lubrication of the turbine bearings.

The test facility:

The standard facility No. 2E/3 with reference gas meters was used for calibration. The main characteristics of the facility: measurement range is (1 – 9700) m³/h, the best measurement capability in the range of flow rate (1 – 1600) m³/h is ± 0,25 %.

The facility was calibrated 09.12.2004, certificate of calibration No. 118/04-L. The general view of the facility is presented at *figure 8*.

Figure 8 - The general view of the standard facility



Round tubes of diameter DN150 were used as straight pipes. The length of upstream straight pipe was $L_1=1.8$ m (12 DN), downstream – $L_2=1$ m (6.6 DN). The scheme of the facility is presented at *figure 9*.

Ambient conditions:

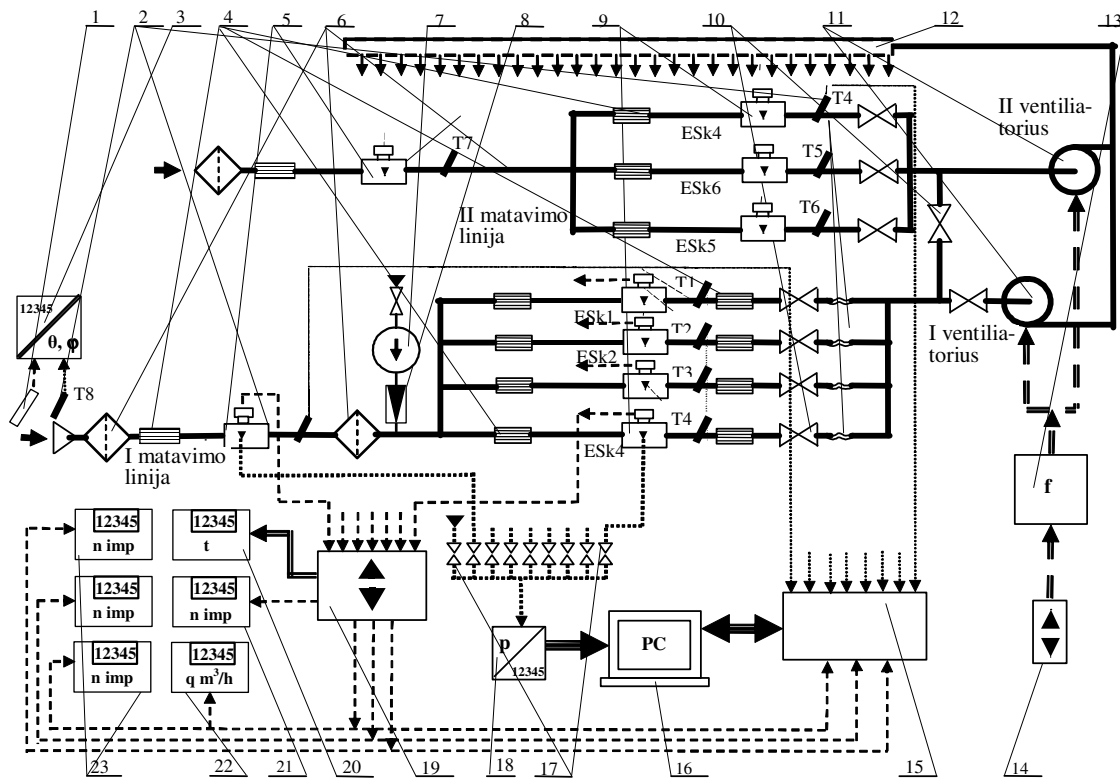
Atmospheric pressure (1005 ± 8) mbar; temperature (20.5 ± 0.5)°C; relative air humidity (36 ± 2) %.

Traceability:

The reference gas meter of CGT-2 type, G650, DN150, production of the company “COMMON” (Poland), S/N 450116 was used for calibration. The meter was calibrated by PTB (Germany), calibration certificate No.06/028/03 of 19.04.2006.

The temperature, pressure and time measurement devices are traceable to the Lithuanian national standards.

Figure 9 - The scheme of the standard facility. 1 – humidity sensor; 2 – thermometers; 3 – temperature and humidity transducer; 4 – flow straightener; 5 – meter under calibration; 6 – air filter; 7 – compressor; 8 – pressure reducer; 9 – reference gas meters; 10 – valves; 11 – fans; 12 – distributing air collector; 13 – frequency converter; 14 – controller of frequency converter; 15 – data acquisition and measurement device; 16 – personal computer ; 17 – pressure tapping connecting valves; 18 – absolute pressure meter; 19 – device of synchronization of time measurement and pulses counting; 20 – timer; 21 –; 22 – electronic flow rate indicator; 23 – reference meters pulses counters.



Results of Lithuania:

Flow rate in the meter	Absolute pressure in the meter	Air temperature downstream	Pressure loss of the meter	Error of the meter	Expanded uncertainty of the error U (k=2)
[m ³ /h]	[kPa]	[°C]	[Pa]	[%]	[%]
998.8	99.5±5	20.9	Not measured	0.10	± 0.31%
798.5		20.7		0.27	± 0.31%
648.4		20.5		0.32	± 0.31%
498.9		20.4		0.23	± 0.31%
400.2		20.3		0.15	± 0.31%
299.2		20.2		0.09	± 0.31%
199.6		20.1		0.29	± 0.31%
100.3		20.1		1.13	± 0.31%

4.9. Slovak Republic

The comparison measurement was realised in the authorised metrological centre - Premagas, Ltd. Stará Turá, in July 06, 2006. Tests were performed at the standard equipment of TRZ, ZP 7630 type with the production number 279/1985. A producer of the equipment is: J.B.Rombach, Karlsruhe and Brehm & Jung electronic, Darmstadt, Germany. The test fluid: air under atmospheric conditions. The test equipment works in a flow range (0.25 - 4000) m³.h⁻¹.

The following standard gas meters have taken part in the measurement:

- Rotary gas meter – a gas meter with rotating chambers, of CVM system, with size G 100, produced by: Rockwell, Du Bois, USA, measuring range (16 - 160) m³.h⁻¹, production number 5170521, date of production 1984. Traceability: In 2005 an indirect comparison of a gas meter was realised, (by rotary gas meter G100, produced by Elster AG Mainz – Kastel, Germany) with critical nozzles, produced by Elster AG Mainz – Kastel, Germany. The expanded uncertainty of a measuring is U=0.20% (k=2). Traceability of the equipment is to the Primary standard for Gas Flow SMU.
- Turbine gas meter of the TRZ G650 DN150 type, produced by: Elster, Germany, measuring range (100 - 1000) m³.h⁻¹, production number 83026952, date of production 1998. Traceability: In 2005 a direct comparison of the standard gas meter with a standard turbine gas meter type TRZ size G650 production number 83036233/2004 produced by Elster GmbH, in 2004 a traceability of a Standard for Gas Flow PTB was realised. The expanded uncertainty of a measuring is U=0.20% (k=2) from a measured value of flow.
- Turbine gas meter of the TZ 300 size G 2500, produced by: J. B. Rombach, Germany, measuring range (400 - 4000) m³.h⁻¹, production number 1700035. Traceability: In 2005 was realised a direct comparison of the standard gas meter with a standard turbine gas meters which were installed in standard equipment CMI, Pardubice. A traceability of standard turbine gas meters of a National standard CMI type EZKUM and Standards PTB was realised. The expanded uncertainty of a measuring is U=0.18% (k=2) from a measured value of flow.

The comparison measurement was realised according to the SMU working procedure No. 11/230, Version 1 and according to the working procedure No. GAS MS/05 from 2002 authorised by a metrological centre - Premagas, Ltd. Stará Turá. The SMU title of the working procedure: „Working procedure for calibration, verification and tests for type approvals working on a principle of volume measurement“. The title of the Premagas working procedure: „Procedure for verification of turbine gas meters G100 - G 2500“.

The test equipment type TRZ, ZP 7630 during the measurement of comparison is on the following *figure 10*.

Figure 10 --Test bench in Premagas



Place of measurement: Premagas, s.r.o. Stará Turá
 Testing facility: TRZ, ZP 7630
 Date of measurement: 06.07.2006
 Atmospheric pressure: 98800 Pa

Results of Slovak Republic:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U (k=2)
[m ³ /h]	[Pa]	[°C]	[Pa]	[%]	[%]
1000	97250	22.41	858	0.19	0.25
800	97838	22.38	540	0.27	0.25
650	98153	22.46	368	0.29	0.20
500	98413	22.40	228	0.22	0.20
400	98550	22.46	150	0.13	0.20
300	98658	22.48	83	0.08	0.20
200	98730	22.55	40	0.25	0.20
100	98780	22.48	10	1.10	0.25

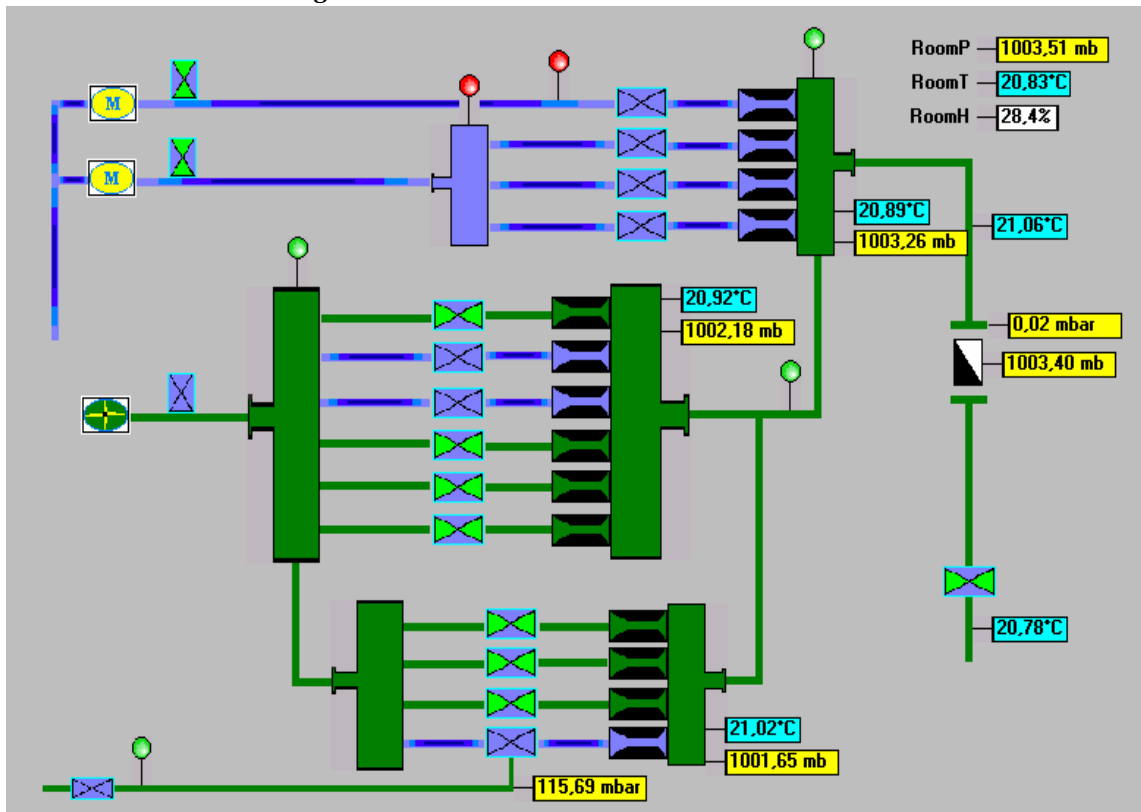
4.10. Czech Republic

The test bench with sonic nozzles consists of 14 nozzles which are situated in three blocks. The vacuum is generated by two centrifugal fans and by one vacuum pump. The clamping system of gas meter is pneumatic. There are one barometric pressure meter and six gauge pressure sensors in the test bench.

Three of gauge pressure sensors measure the negative pressures in blocks of nozzles, one of them measures the tightness of lines which are out of operation, one measures the negative pressure in gas meter (p_r) and the last one measures the pressure loss of gas meter.

Five temperature sensors measure the temperature in blocks of nozzles, in the gas meter and in the input of air to the test bench. Besides the humidity in the input of air to the test bench and the time of test are measured, too. The *figure 11* of the test bench is mentioned down.

Figure 11 – Test bench with sonic nozzles in CMI



This test bench is controlled by PC and the one works fully automatically. It is only necessary to clamp the gas meter to the test bench. Then the operator inputs the data of the gas meter and defines the required sequence of the flow rates. The measurement starts with the leakage test. The comparison of all pulse emitters of the gas meter follows. Until these two exams are successful the determination of error of the gas meter in the sequence of flow rates does not begin. The measurement runs independently by automatically adjusting of the flow rates.

During the test the temperature in the blocks of nozzles and in the gas meter, the pressure in the blocks of nozzles and in the gas meter and the humidity are measured once per 2 seconds. The time of test is measured, too. The time of test in one flow rate is at least 60 seconds.

The test bench with sonic nozzles was made by Schlumberger Industries, Calibration Equipments Division, Barcelona, Spain in 1998. The type designation is SONICAL SN-1000, serial number of the bench is 330. On December, 1998 during the installation in Czech Metrology Institute (local inspectorate Pardubice) all sonic nozzles were calibrated by

Mr. Bernhardt Jarosch from regional German metrological office Baden-Wurttemberg (Landesgewerbeamt Baden-Württemberg Eichdirektion). Mr Jarosch has used standards with the traceability to Physikalisch-Technische Bundesanstalt (PTB). In January 2004 the sonic nozzles up to the nominal flow rate 2.0 m³/h were calibrated by wet drum gas meter EP2 which is traceable to PTB.

The 6 pieces of temperature sensors Pt100 DESIN, 6 pieces of gauge pressure sensors FEDISA, barometric pressure sensor DRUCK, pulse timer and humidity sensor VAISALA are calibrated regularly with standards that are traceable Czech national standards.

Results of Czech Republic:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U (k=2)
[m ³ /h]	[Pa]	[°C]	[Pa]	[%]	[%]
1000	97738	22.69	891	0.10	0.25
800	98346	22.67	570	0.31	0.25
650	98651	22.54	403	0.39	0.25
500	98946	22.41	242	0.31	0.25
400	99104	22.36	159	0.27	0.25
300	99199	22.33	94	0.28	0.25
200	99276	22.42	54	0.42	0.25
100	99321	22.42	16	1.19	0.25

4.11. Switzerland

Description of the test facility (Fig. 12):

- Bell prover: 10 m³
- Calibrated volume: 10 m³
- Displacement measure: electro-optic ruler
- Flow range: (1.0 – 1000) m³/h
- Uncertainty (CMC): 0.15 %
- Location: Federal Office of Metrology METAS
Lindenweg 50
3003 Bern-Wabern

Figure 12 – Bell prover in METAS



Test procedure:

For each flow rate the meter error have been measured 6 times. The absolute pressure was measured on the meter output ' p_r '. The pressure loss of the meter was measured between the inlet and the outlet pipes of the meter.

Results of Switzerland:

Flow rate in the meter (m ³ /h)	Absolute pressure in the meter (mbar)	Temperature in the meter (°C)	Pressure loss of the meter (mbar)	Error of the meter (%)	Uncertainty of the error U(k=2) (%)
100	975.047	20.819	0.10	1.29	0.08
200	974.639	20.806	0.38	0.52	0.08
300	976.726	20.798	0.81	0.30	0.08
400	975.927	20.829	1.40	0.29	0.08
500	972.379	20.865	2.13	0.34	0.08
650	970.107	20.922	3.45	0.42	0.08
800	966.707	20.849	5.08	0.39	0.08
1000	961.788	20.825	7.90	0.20	0.08

4.12. Turkey

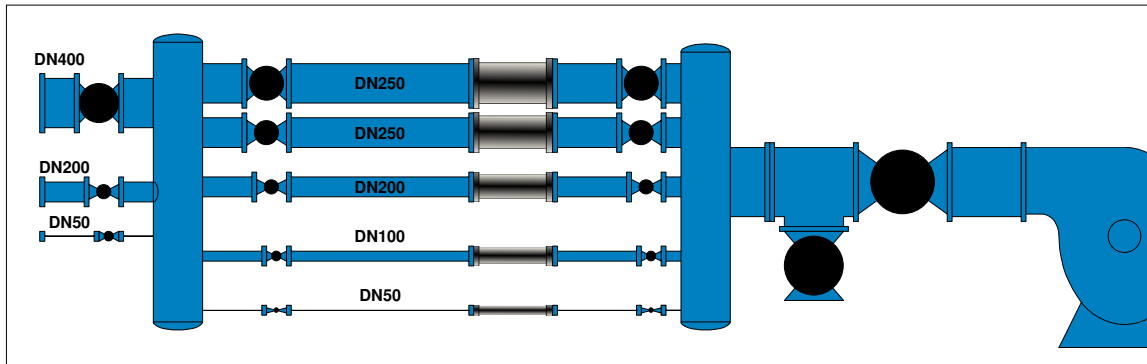
UME - Medium Flow Gas Measurement System Description

As seen from the *figure 13*, UME Medium Gas Flow rate Measurement system was designed to operate in the range of 5-4800 m³/h for gas flow meter calibrations. It consists of one flow computer, two suction fans with frequency controller, five reference flow meters with a different measuring capacity and upstream and downstream of each flow meter has pressure-actuated ball valves. Time measurement, pulse counts, temperature and pressure at upstream of each flow meters are made by UME flow computer.

Flow meters are traceable to NMi and UME. UME Medium Gas Flow rate Measurement system's total uncertainty is about 0.18 % (for k=2).

Figure 13 – Test bench in UME





Uncertainty Budget:

Uncertainty of calibration measurements is computed in accordance with Guide to the Expression of Uncertainty in Measurement (GUM, ISO 1993) and ISO 5168 documents. The reported uncertainties corresponds to the expended uncertainty with the coverage factor $k=2$. Confidence level is 95%.

Uncertainty budget consists of the following components:

- Uncertainty of Medium Gas Flow Test Rig
- Error of Repeatability
- Error of Resolution
- Flow computer time count
- Flow computer pulse count

Results of Turkey:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error $U(k=2)$
(m^3/h)	(Pa)	($^{\circ}C$)	(Pa)	(%)	(%)
1001.906	97000	21.4	481	0.58	0.18
814.541	97500	21.5	290	0.68	0.18
664.883	97800	21.6	189	0.72	0.18
503.883	98300	21.1	103	0.68	0.18
402.672	98400	21.4	62	0.62	0.19
306.673	98500	21.6	34	0.45	0.19
203.064	98600	21.8	13	0.73	0.20
104.500	98600	21.8	3	0.96	0.25

4.13. France

The pressure test bench (*Fig. 14*) for medium and high flow rates at Poitiers can generate flow rates from $8 m^3/h$ to $90000 m^3/h$ (standard conditions). A set of 12 Venturi nozzles (nominal flow rate: 1.5 to $1000 m^3 \cdot h^{-1} \cdot bar^{-1}$) operating in sonic conditions is used for

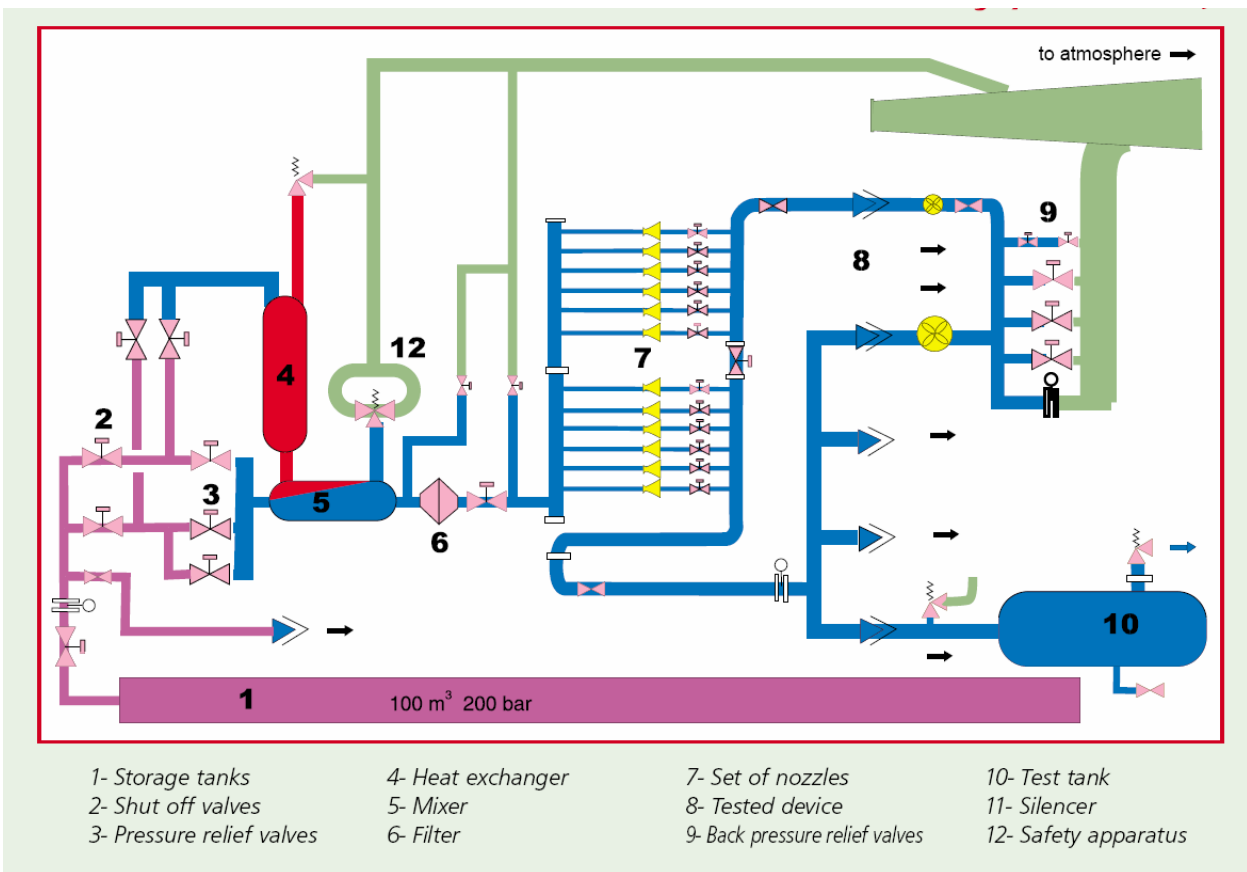
the determination of the standard mass flow rate. The longest testing pipeline is 50 m long with nominal diameters from DN25 up to DN300. The test pressure range is from 1 bar up to 50 bar (absolute). Compressed dry air stored in a 110 m³ vessel under 200 bar is used as the test fluid. Possibilities of testing pressure from 50 to 150 bar are also available on request.

The meter under test is placed on a pipeline downstream 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 in test in order to determine the volumetric flow rate going through.

The air coming from a storage vessel (200 bar-110 m³) goes through the valves and the heating control system. This adjusts the suitable temperature and pressure upstream the nozzles automatically. The pipe lines bear the reference nozzles chosen according to the flow patterns to be generated for the tests.

These nozzles are traceable to National Standards since they are calibrated with the GDF "Pisc" facility (PVT, time method). In addition, nozzles for flow, pressures determination are measured using Desgranges & Huot weight testers and temperatures are measured using PT100 and thermocouples probes. All the instruments and probes used are traceable to national standards (LNE for pressure and temperature, LCIE for Voltage).

Figure 14 – Test bench in Poitiers



Place of calibration: CESAME LNE ouest - 43, route de l'aérodrome - F - 86036 Poitiers
Cedex

Results of France:

Reference Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Error of the meter	Uncertainty
m ³ /h	bar	°C	%	%
997.4	1.002	17.45	-0.10	0.24
799.0	1.004	15.86	0.13	0.24
648.0	1.007	18.33	0.28	0.24
500.2	1.007	17.71	0.36	0.24
400.0	1.008	17.98	0.39	0.24
298.7	1.008	18.69	0.21	0.24
199.4	1.008	18.80	0.31	0.24
98.8	1.009	19.87	0.87	0.24

4.14. Spain

The calibration has been performed in the Enagás Central Laboratory (Gas Meter Laboratory) sited in the following address:

Enagás, S.A.
 LABORATORIO DE CONTADORES DE GAS
 Autovía A-2, km. 306,4. 50012 – ZARAGOZA (SPAIN)
 Phone No.: 976 469826 / 976 469837 - Fax No.: 976 349398

The test bench (as shown in *figures 15 & 16*) consists of five working standard meters, which are periodically calibrated by means of three reference standard meters (with traceability to international standards). Both working and reference meters are described in the following *table 6*:

Table 6 – Standard meters in Enagás, S.A.

Working Standard Meters			Reference Standard Meters		
Item	Type	Size	Item	Type	Size
1	Turbine	G 6500	1	Turbine	G 6500
2	Turbine	G 2500			
3	Turbine	G 650	2	Turbine	G 650
4	Turbine	G 250			
5	Rotary displacement	G 65	3	Rotary displacement	G 65

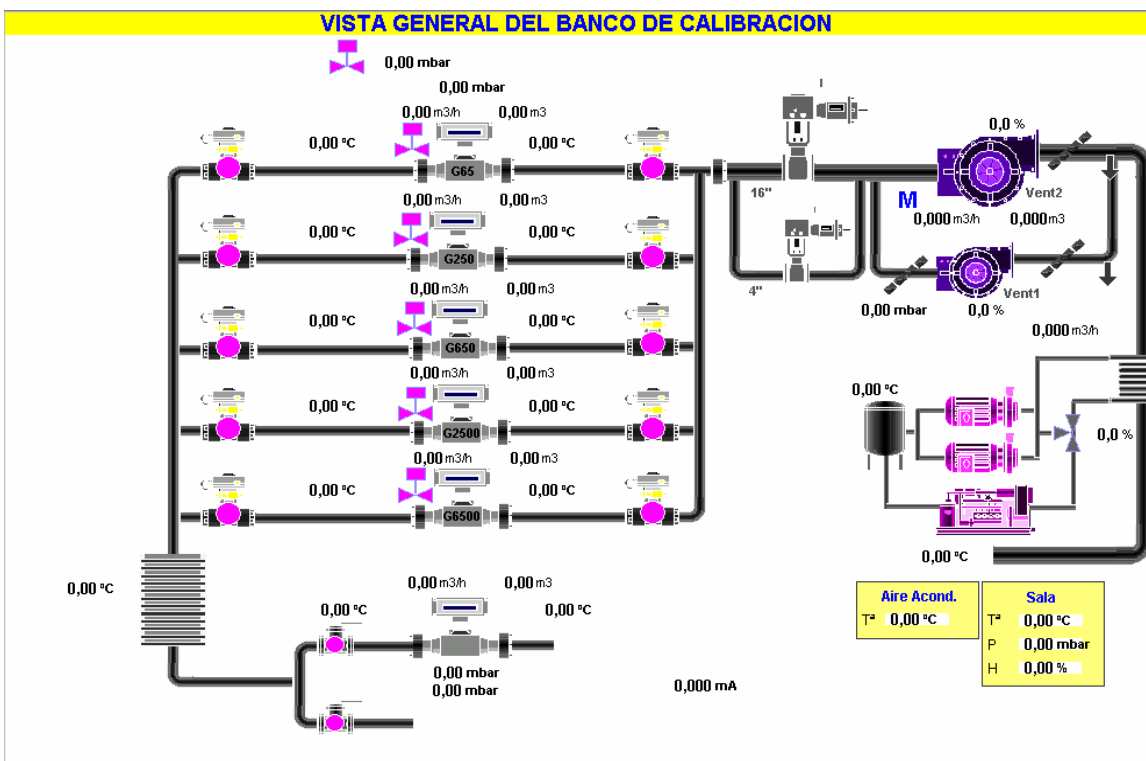
The flow rate range covered with these standard meters is 5 - 10000 m³/h.
The fluid used for calibration is air at a pressure close to atmospheric pressure. The laboratory air temperature is within the range 20 °C ± 1 °C.

The facility is equipped with the necessary equipment for the measurement of gauge and barometric pressure [mbar], temperature [°C], and pulses (high and low frequency). All this instruments are also calibrated by means of internal procedures and its measurements are traceable to national standards.

Figure 15 – Test facility in Zaragoza



Figure 16 – Calibration bench diagram



The results of the calibration services of Enagás (Laboratorio de Contadores de Gas) are traceable to primary and/or (inter)nationally accepted measurement standards.

The traceability of the working standard meters and other measuring instruments which were used during the test, as well as their corresponding recalibration intervals, are shown in the following *table 7*:

Table 7 - Recalibration intervals in Enagás, S.A.

Item	Traceability	Recalibration Intervals
Working standard meter G 6500	NMi	1 year
Working standard meter G 2500	NMi	1 year
Working standard meter G 650	NMi	1 year
Working standard meter G 250	NMi	1 year
Working standard meter G 65	NMi	1 year
Temperature meters	ENAC	2 years
Gauge pressure meters	ENAC	2 years
Barometric pressure meter	ENAC	2 years
Pulse counter	ENAC	1 year

Test procedure:

The calibration has been performed according to the following procedure:

- Meter reception, registration and previous inspection.
- Temperature conditioning: before calibration the meter has remained a minimum of 24 hours in the test facilities for temperature conditioning (20 ± 1 °C).
- Leakage test: the test facility (including the meter) has been tested for leakage previous to calibration.
- K factor test: the pulse number per m^3 (K) has been checked before calibration.
- Run-in-period: the meter has undergone a run-in-period of not less than 30 minutes at the flow rate Q_{max} before calibration.
- Calibration:
 - Calibration has been carried out with air at a pressure close to atmospheric pressure. The laboratory air temperature was from 19 °C to 21 °C.
 - The determination of the error of the meter is based on the comparison of the volume of the air indicated by standard meter and of the volume which was indicated by the meter under test after calculations of corrections concerning different temperatures and pressures in the standard meter and in the meter under test.
 - The reference pressure from the turbine gas meter has been measured from the output “ p_F ”.
 - Calibration has been performed by means of the A1S high frequency pulse emitter.
 - The minimum test time was 108 seconds.
 - Deviation between nominal test flow rates and real test flow rates has been less than ± 3 %.
 - At each flow rate the error has been determined three times without changing the flow rate.
- Determination of the error of the meter (average of three values obtained at each flow rate) and the uncertainty of the error.
- Data recording: test data sheet and certificate of calibration have been issued.

Date/s of calibration: 27.09.2006

Results of Spain:

Flow rate in the meter	Absolute pressure in the meter	Temperature in the meter	Pressure loss of the meter	Error of the meter	Uncertainty of the error U (k=2)
(m ³ /h)	(Pa)	(°C)	(Pa)	(%)	(%)
1000	95.927	19.98	495	0.34	0.28
800	96.439	19.95	299	0.54	0.28
650	96.740	19.92	190	0.59	0.28
500	96.988	19.95	106	0.52	0.28
400	97.115	20.00	64	0.48	0.28
300	97.222	20.04	33	0.34	0.28
200	97.285	20.05	13	0.62	0.28
100	97.321	20.09	2	1.28	0.28

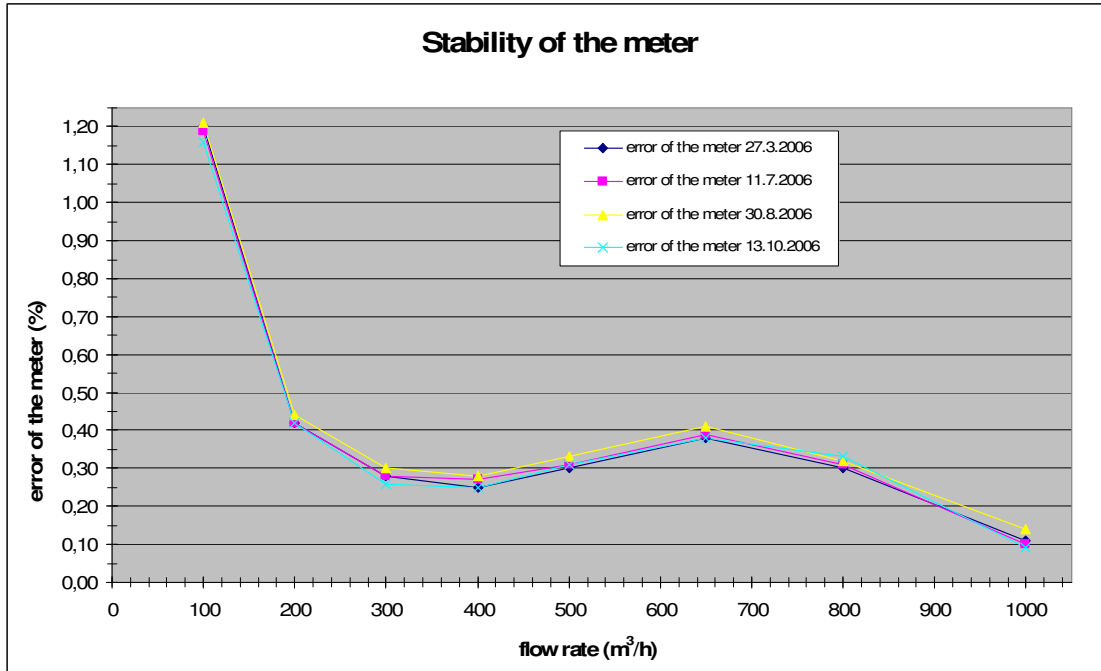
The reported uncertainty of the measurement is based on a standard uncertainty multiplied by a coverage factor k, which for T-student distribution corresponds to a coverage probability of approximately 95.5%. The standard uncertainty had been determined in accordance with EA international norms, in particular as stated in the publication EA-4/02 “Expression of the uncertainty of measurement in calibration” (December 1999).

5. Stability of the meter and the dependency of laboratories

During the project the turbine gas meter was tested four times in the pilot laboratory (CMI). Obtained results are mentioned down.

flow rate (m ³ /h)	error of the meter 27.3.2006	error of the meter 11.7.2006	error of the meter 30.8.2006	error of the meter 13.10.2006	maximum difference
(m ³ /h)	(%)	(%)	(%)	(%)	(%)
1000	0.11	0.10	0.14	0.09	0.05
800	0.30	0.31	0.32	0.33	0.03
650	0.38	0.39	0.41	0.38	0.03
500	0.30	0.31	0.33	0.31	0.03
400	0.25	0.27	0.28	0.25	0.03
300	0.28	0.28	0.30	0.26	0.04
200	0.42	0.42	0.44	0.42	0.02
100	1.20	1.19	1.21	1.16	0.05

The estimated expanded uncertainty caused by the stability (reproducibility) of the turbine meter is approximately $U_{tm}=0.03\%$. In this case the uniform distribution between minimal value and maximal value is assumed.



In this project there were 6 independent laboratories:

Germany, Netherlands, Poland, France, Switzerland and Great Britain(results withdrawn)

In this project there were 5 laboratories traceable to Netherlands (NMI):

Austria, Hungary, Denmark, Turkey and Spain

In this project there were 3 laboratories traceable to Germany (PTB):

Czech Republic, Slovak Republic, Lithuania

6. Determination of the reference values in determined flow rates

6.1. Description of the method

The reference value was determined in each flow rate separately. The method of determination of the reference value in each flow rate corresponds to the procedure A presented by M.G.Cox³⁾. Only results from independent laboratories were taken into account for the determination of the key comparison reference value (KCRV) and of the uncertainty

³⁾ Cox M.G., *Evaluation of key comparison data*, Metrologia, 2002, **39**, 589-595

of the key comparison reference value. Then the results from dependent laboratories were compared with the key comparison reference value and with the uncertainty of the key comparison reference value.

6.1.1. The determination of the Key Comparison Reference Value (KCRV) and its uncertainty

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

$$y = \frac{\frac{x_1}{u_{x1}^2} + \frac{x_2}{u_{x2}^2} + \dots + \frac{x_n}{u_{xn}^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots + \frac{1}{u_{xn}^2}}, \quad [4]$$

where x_1, x_2, \dots, x_n are errors of the meter in one flow rate in different independent laboratories $1, 2, \dots, n$
 $u_{x1}, u_{x2}, \dots, u_{xn}$ are standard uncertainties (not expanded) of the error in different independent laboratories $1, 2, \dots, n$ including the uncertainty caused by stability of the meter

The standard uncertainties (not expanded) of the error in different laboratories $u_{x1}, u_{x2}, \dots, u_{xn}$ (equation [4]) include the stability of the meter. These uncertainties were calculated by

$$u_{xi} = \sqrt{\left(\frac{U_{xi_lab}}{2}\right)^2 + \left(\frac{U_{im}}{2}\right)^2} \quad [5]$$

where U_{xi_lab} is the expanded uncertainty ($k=2$) determined by laboratory i and presented in results of laboratory i
 U_{im} is estimated expanded uncertainty caused by the stability (reproducibility) of the turbine gas meter (see chapter 5)

The standard uncertainty of the reference value u_y is given by

$$\frac{1}{u_y^2} = \frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots + \frac{1}{u_{xn}^2} \quad [6]$$

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

$$U(y) = 2 \cdot u_y \quad [7]$$

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

$$\chi_{obs}^2 = \frac{(x_1 - y)^2}{u_{x1}^2} + \frac{(x_2 - y)^2}{u_{x2}^2} + \dots + \frac{(x_n - y)^2}{u_{xn}^2} \quad [8]$$

The degrees of freedom ν were assigned

$$\nu = n - 1 \quad [9]$$

where n is number of evaluated laboratories.

The consistency check was failing if

$$Pr\{\chi_{\nu}^2 > \chi_{obs}^2\} < 0,05 \quad [10]$$

(The function $CHINV(0,05;\nu)$ in MS Excel was used. The consistency check was failing if $CHINV(0,05;\nu) < \chi_{obs}^2$)

If the consistency check did not fail 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_{obs}^2 were calculated again without the values of excluded laboratory. The consistency check was calculated again, too. This procedure was repeated till the consistency check passed.

6.1.2. The determination of the differences “Lab to KCRV” and “Lab to Lab” as well as their uncertainties and Degrees of Equivalence

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

$$di = x_i - x_{ref} \quad [11]$$

$$dij = x_i - x_j \quad [12]$$

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

$$Ei = \left| \frac{di}{U(di)} \right| \quad [13]$$

and $Eij = \left| \frac{dij}{U(dij)} \right|$, respectively. [14]

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 is *equivalent (passed) if E_i or $E_{ij} \leq 1$* .
- The laboratory was determined as *not equivalent (failed) if E_i or $E_{ij} > 1.2$* .
- For values of *DoE* in the range $1 < E_i$ or $E_{ij} \leq 1.2$ we define “warning level” were actions to check is recommended to the laboratory.

The reason for such “warning level” is that we have to consider the confidence in the determination of the uncertainties (for the results of labs as well the KCRV). Conventionally we work at a 95% confidence level. Therefore in some comparisons a range up to $E < 1.5$ is used for these “warnings”⁴⁾. This is a reasonable value where stochastic influences dominate the uncertainty budgets. In the case of comparisons for gas flow, the smaller value 1.2 was chosen, which reflects the dominance of non-stochastic parts of uncertainty compared to the stochastic parts. (The reproducibility is usually much better than the total uncertainty of a laboratory).⁵⁾

The calculation of the *DoE* needs the information about the uncertainty of the differences d_i and d_{ij} (equations [11] and [12]). To make statements about this, let us 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:

$$u_{x_1-x_2}^2 = \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} & \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} \begin{pmatrix} u_1^2 & \text{cov} \\ \text{cov} & u_2^2 \end{pmatrix} \begin{pmatrix} \frac{\partial(x_1-x_2)}{\partial x_1} \\ \frac{\partial(x_1-x_2)}{\partial x_2} \end{pmatrix} = u_1^2 + u_2^2 - 2 \cdot \text{cov} \quad [15]$$

Simply spoken, 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 we have to look to the different cases in this comparison:

A) Differences to the KCRV

A1) *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.³⁾

⁴⁾ C. Ullner et al., *Special features in proficiency tests of mechanical testing laboratories*, and P. Robouch et al., *The „Naji Plot“, a simple graphical tool for the evaluation of inter-laboratory comparisons*,

Both in: D. Richter, W. Wöger, W. Hässelbarth (ed.) *Data analysis of key comparisons*, 178. PTB-Seminar/International Workshop, ISBN 3-89701-933-3.

⁵⁾ D. Doppeide, B. Mickan, R. Kramer, H.-J. Hotze, J.-P. Vallet, M.R. Harris, Jiunn-Haur Shaw, Kyung-Am Park, *CIPM Key Comparisons for Compressed Air and Nitrogen, CCM.FF-5.b – Final Report*, 07/09/2006
http://kcdb.bipm.org/appendixB/appbresults/ccm.ff-k5.b/ccm.ff-k5.b_final_report.pdf

³⁾ Cox M.G., *Evaluation of key comparison data*, *Metrologia*, 2002, **39**, 589-595

$$\Rightarrow u(di) = \sqrt{u_{xi}^2 + u_{xref}^2 - 2 \cdot u_{xref}^2} = \sqrt{u_{xi}^2 - u_{xref}^2} \quad [16]$$

A2) *Independent laboratories without contribution to the KCRV*

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

$$\Rightarrow u(di) = \sqrt{u_{xi}^2 + u_{xref}^2} \quad [17]$$

A3) *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 lab from its source (which is the lab contributing to the KCRV). Then the results of the lab 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 A1. In any case of additional uncertainty caused stochastically the correlation and consequently the covariance is smaller.

$$\Rightarrow u(di) = \sqrt{u_{xi}^2 + u_{xref}^2 - 2u_{xref}^2} = \sqrt{u_{xi}^2 - u_{xref}^2} \quad [18]$$

B) Differences Lab to Lab

B1) *Independent laboratories*

There is no covariance between the results of two independent laboratory i and j

$$\Rightarrow u(dij) = \sqrt{u_{xi}^2 + u_{xj}^2} \quad [19]$$

B2) *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 traceabilities of both labs are derived. Again we can determine a conservative upper limit of the covariance for the same reason as in A3 as $\text{cov} = u_{\text{SourceLab}}^2$.

$$\Rightarrow u(dij) = \sqrt{u_{xi}^2 + u_{xj}^2 - 2 \cdot u_{\text{SourceLab}}^2} \quad [20]$$

The equations from [16] to [20] use the standard uncertainties ($k = 1$). The expanded uncertainties $U(di)$ and $U(dij)$ (see equations [13],[14]) are determined by

$$U(di) = 2 \cdot u(di) \quad [21]$$

$$U(dij) = 2 \cdot u(dij) \quad [22]$$

6.2. Flow rate 1000 m³/h

The first and last round of evaluation in 1000 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x^*(1/u)^2$
	(%)	(%)			
Germany	0.10800	0.08544	0.914	547.9452	59.178
Netherlands	0.25610	0.15347	1.954	169.8315	43.494
Poland	0.04000	0.25179	0.747	63.0915	2.524
Switzerland	0.20000	0.08544	1.435	547.9452	109.589
France	-0.10000	0.24187	4.234	68.3761	-6.838

$$x_{ref} = y = 0.148832774$$

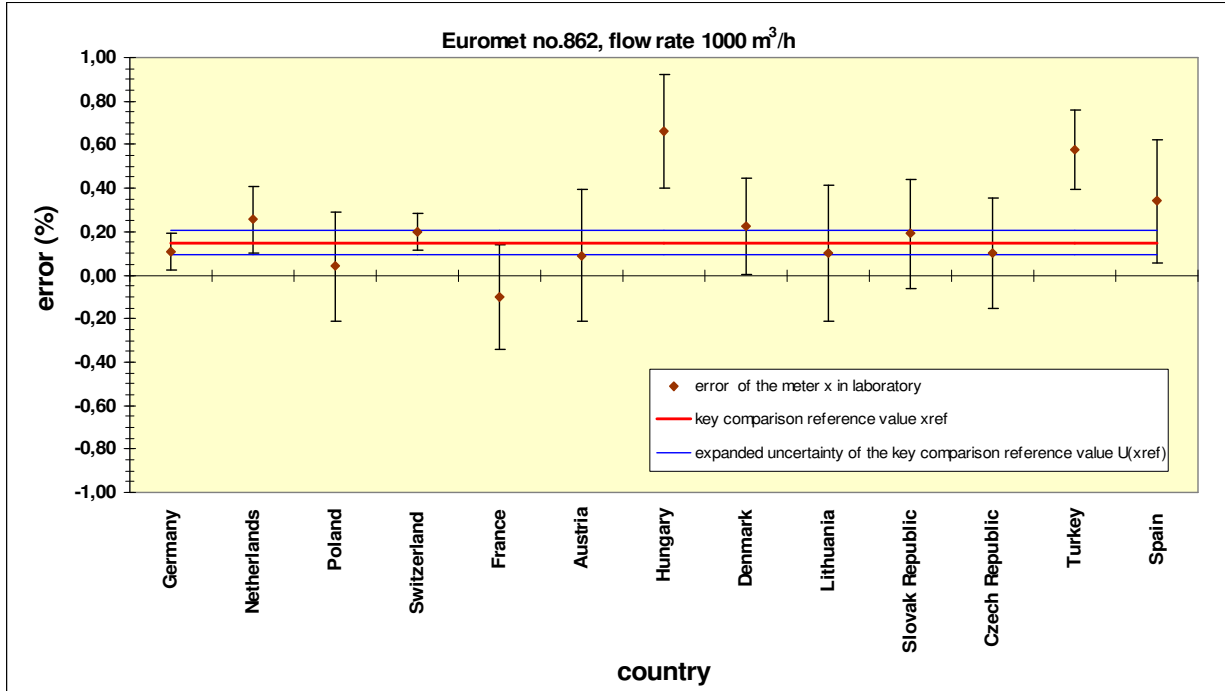
$$U(x_{ref}) = 0.053505983$$

$$CHIINV \ 9.487729037$$

$$\chi_{obs}^2 = 9.2834$$

The consistency check passed because $CHIINV > \chi_{obs}^2$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.11	0.08544	-0.04	0.067	0.61
Netherlands	0.26	0.15297	0.11	0.143	0.75
Poland	0.04	0.25179	-0.11	0.246	0.44
Switzerland	0.20	0.08544	0.05	0.067	0.77
France	-0.10	0.24187	-0.25	0.236	1.05
Austria	0.09	0.30150	-0.06	0.297	0.20
Hungary	0.66	0.26173	0.51	0.256	2.00
Denmark	0.23	0.22204	0.08	0.215	0.36
Lithuania	0.10	0.31145	-0.05	0.307	0.16
Slovak Republic	0.19	0.25179	0.04	0.246	0.17
Czech Republic	0.10	0.25179	-0.05	0.246	0.20
Turkey	0.58	0.18373	0.43	0.176	2.44
Spain	0.34	0.28160	0.19	0.276	0.69



6.3. Flow rate 800 m³/h

The first and last round of evaluation in 800 m³/h:

Country	Error of the meter x (%)	Uncertainty $U(k=2)$ (%)	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
Germany	0.34	0.085440	0.075	547.95	187.40
Netherlands	0.43	0.153407	0.997	169.97	73.14
Poland	0.18	0.251794	1.904	63.09	11.36
Switzerland	0.39	0.085440	0.721	547.95	213.70
France	0.13	0.241868	3.515	68.38	8.68

$$x_{ref} = y = 0.353730408$$

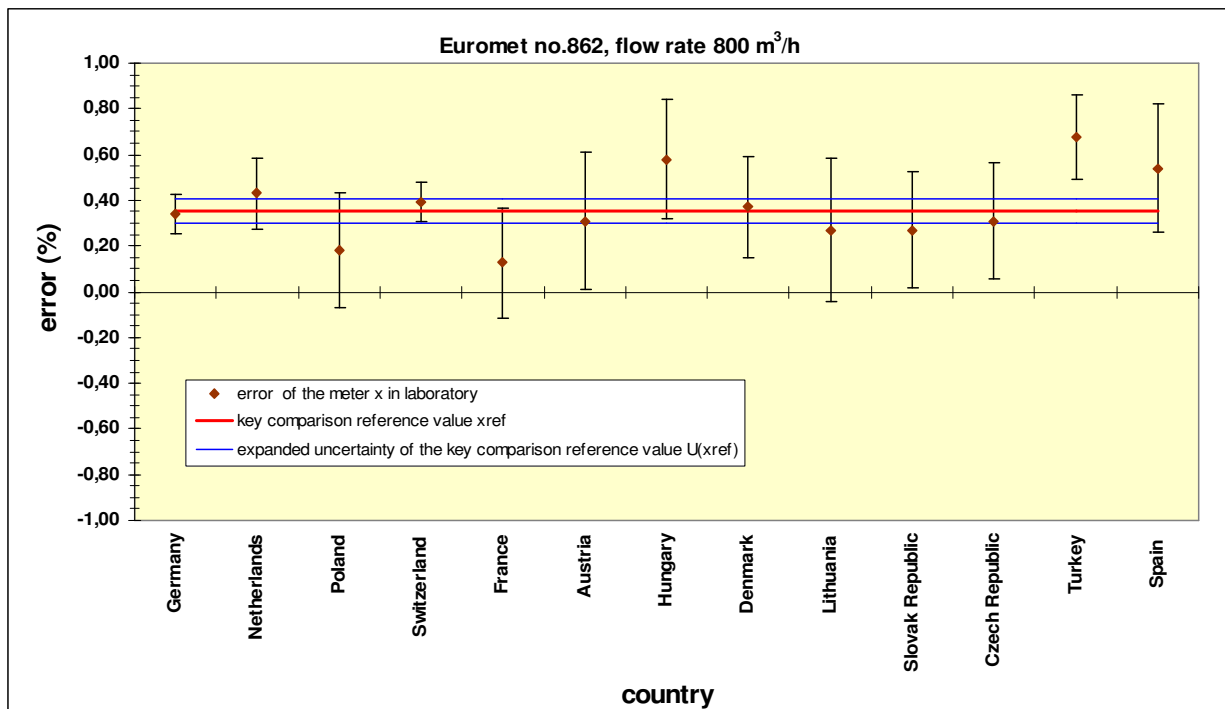
$$U(x_{ref}) = 0.053503357$$

$$CHIINV = 9.487729037$$

$$\chi_{obs}^2 = 7.2125$$

The consistency check passed because $CHIINV > \chi_{obs}^2$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.34	0.08544	-0.0117	0.067	0.18
Netherlands	0.43	0.15341	0.0766	0.144	0.53
Poland	0.18	0.25179	-0.1737	0.246	0.71
Switzerland	0.39	0.08544	0.0363	0.067	0.54
France	0.13	0.24187	-0.2267	0.236	0.96
Austria	0.31	0.30150	-0.0437	0.297	0.15
Hungary	0.58	0.26173	0.2263	0.256	0.88
Denmark	0.37	0.22204	0.0163	0.215	0.08
Lithuania	0.27	0.31145	-0.0837	0.307	0.27
Slovak Republic	0.27	0.25179	-0.0837	0.246	0.34
Czech Republic	0.31	0.25179	-0.0437	0.246	0.18
Turkey	0.68	0.18379	0.3221	0.176	1.83
Spain	0.54	0.28160	0.1863	0.276	0.67



6.4. Flow rate 650 m³/h

The first and last round of evaluation in 650 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	0.40	0.085440	0.000	547.95	218.08
Netherlands	0.46	0.152976	0.560	170.93	77.82
Poland	0.18	0.251794	3.000	63.09	11.36
Switzerland	0.42	0.085440	0.264	547.95	230.14
France	0.28	0.241868	0.937	68.38	19.21

$$x_{ref} = y = 0.39806712$$

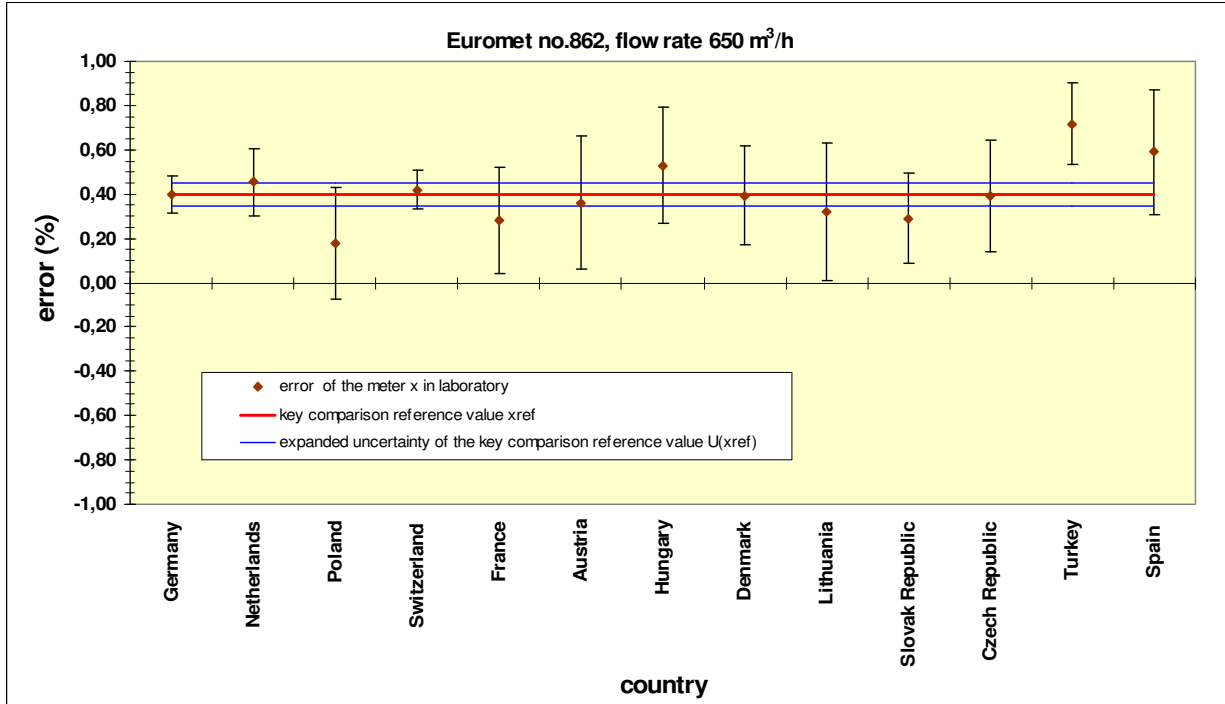
$$U(x_{ref}) = 0.053485007$$

$$CHIINV = 9.487729037$$

$$\chi^2_{obs} = 4.7606$$

The consistency check passed because $CHIINV > \chi^2_{obs}$

Country	Error of the meter x	Uncertainty $U(k=2)$	di	$U(di)$	Ei
	(%)	(%)	(%)	(%)	
Germany	0.40	0.08544	-0.0001	0.067	0.00
Netherlands	0.46	0.15298	0.0572	0.143	0.40
Poland	0.18	0.25179	-0.2181	0.246	0.89
Switzerland	0.42	0.08544	0.0219	0.067	0.33
France	0.28	0.24187	-0.1171	0.236	0.50
Austria	0.36	0.30150	-0.0381	0.297	0.13
Hungary	0.53	0.26173	0.1319	0.256	0.51
Denmark	0.39	0.22204	-0.0047	0.215	0.02
Lithuania	0.32	0.31145	-0.0781	0.307	0.25
Slovak Republic	0.29	0.20224	-0.1081	0.195	0.55
Czech Republic	0.39	0.25179	-0.0081	0.246	0.03
Turkey	0.72	0.18446	0.3197	0.177	1.81
Spain	0.59	0.28160	0.1919	0.276	0.69



6.5. Flow rate 500 m³/h

The first and last round of evaluation in 500 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x^*(1/u)^2$
	(%)	(%)			
Germany	0.33	0.0854400	0.003	547.95	180.82
Netherlands	0.37	0.1532683	0.207	170.28	62.53
Poland	0.16	0.2517936	1.874	63.09	10.09
Switzerland	0.34	0.0854400	0.032	547.95	186.30
France	0.36	0.2418677	0.060	68.38	24.75

$$x_{ref} = y = 0.332347059$$

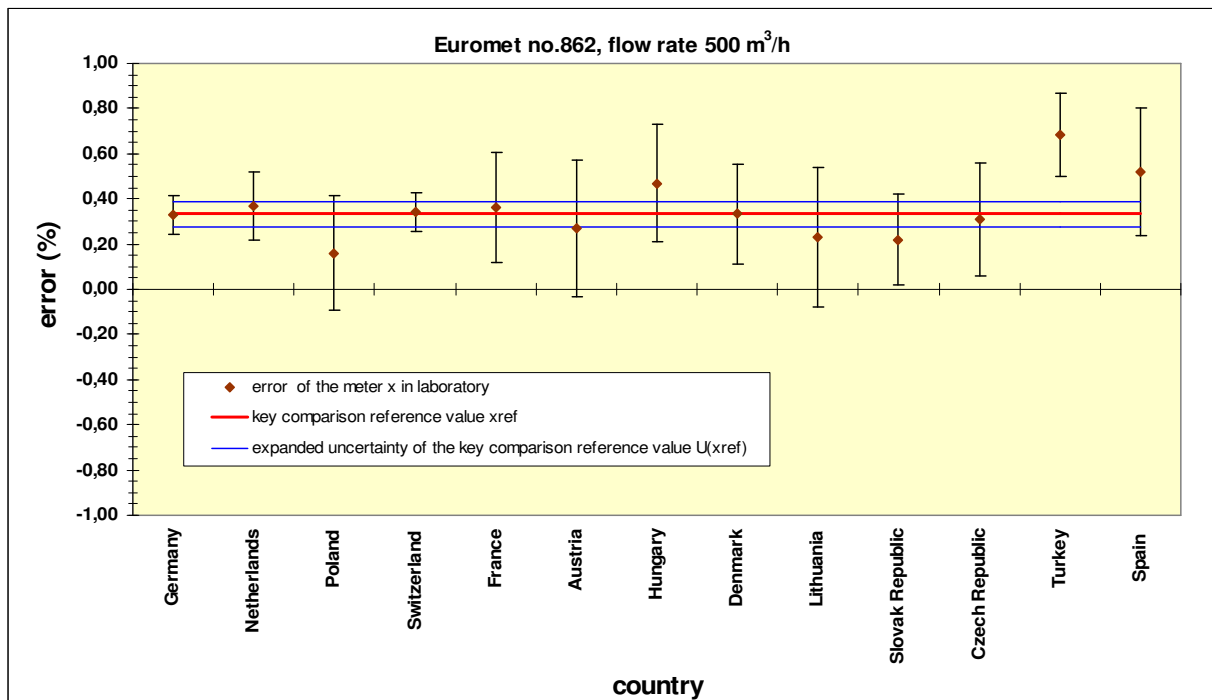
$$U(x_{ref}) = 0.053497461$$

$$CHIINV = 9.487729037$$

$$\chi^2_{obs} = 2.1764$$

The consistency check passed because $CHIINV > \chi^2_{obs}$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.33	0.0854400	-0.0023	0.067	0.04
Netherlands	0.37	0.1532683	0.0349	0.144	0.24
Poland	0.16	0.2517936	-0.1723	0.246	0.70
Switzerland	0.34	0.0854400	0.0077	0.067	0.11
France	0.36	0.2418677	0.0297	0.236	0.13
Austria	0.27	0.3014963	-0.0623	0.297	0.21
Hungary	0.47	0.2617250	0.1377	0.256	0.54
Denmark	0.33	0.2220360	0.0010	0.215	0.00
Lithuania	0.23	0.3114482	-0.1023	0.307	0.33
Slovak Republic	0.22	0.2022375	-0.1123	0.195	0.58
Czech Republic	0.31	0.2517936	-0.0223	0.246	0.09
Turkey	0.68	0.1857973	0.3508	0.178	1.97
Spain	0.52	0.2816026	0.1877	0.276	0.68



6.6. Flow rate 400 m³/h

The first and last round of evaluation in 400 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	0.27	0.08544	0.067	547.95	146.85
Netherlands	0.32	0.15313	0.284	170.59	54.57
Poland	0.05	0.25179	3.311	63.09	3.15
Switzerland	0.29	0.08544	0.065	547.95	158.90
France	0.39	0.24187	0.841	68.38	26.67

$$x_{ref} = y = 0.279082442$$

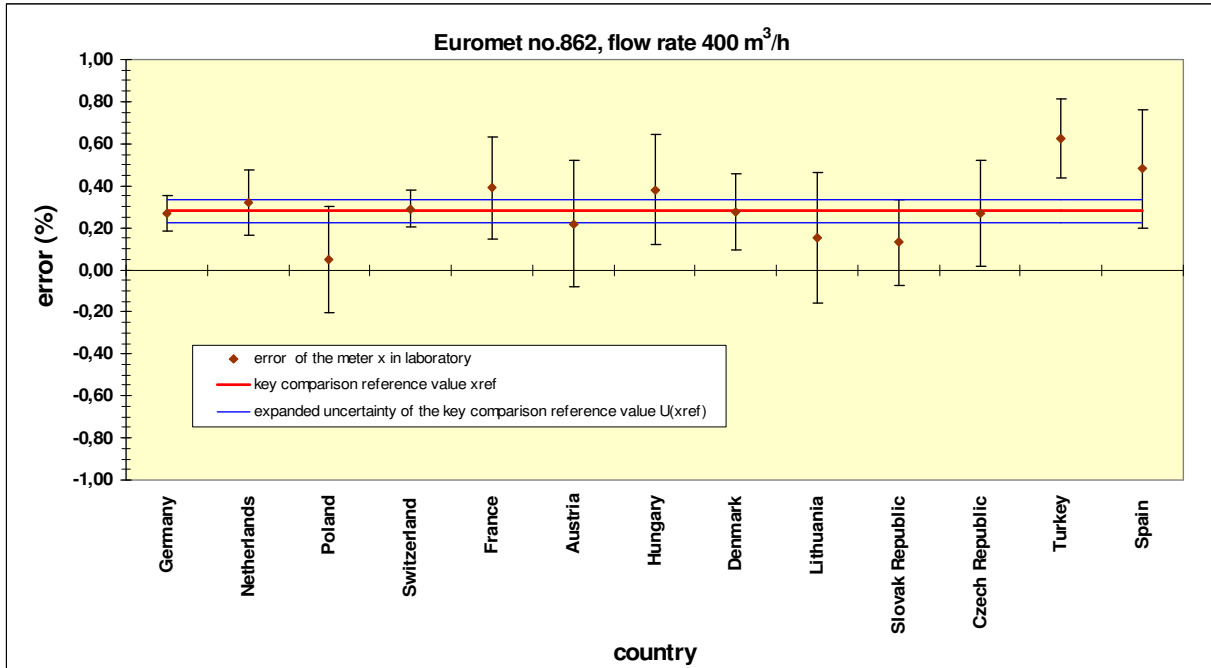
$$U(x_{ref}) = 0.053491425$$

$$CHIINV 9.487729037$$

$$\chi^2_{obs} = 4.5687$$

The consistency check passed because $CHIINV > \chi^2_{obs}$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.27	0.08544	-0.0111	0.067	0.17
Netherlands	0.32	0.15313	0.0408	0.143	0.28
Poland	0.05	0.25179	-0.2291	0.246	0.93
Switzerland	0.29	0.08544	0.0109	0.067	0.16
France	0.39	0.24187	0.1109	0.236	0.47
Austria	0.22	0.30150	-0.0591	0.297	0.20
Hungary	0.38	0.26173	0.1009	0.256	0.39
Denmark	0.28	0.18248	-0.0024	0.174	0.01
Lithuania	0.15	0.31145	-0.1291	0.307	0.42
Slovak Republic	0.13	0.20224	-0.1491	0.195	0.76
Czech Republic	0.27	0.25179	-0.0091	0.246	0.04
Turkey	0.62	0.18839	0.3456	0.181	1.91
Spain	0.48	0.28160	0.2009	0.276	0.73



6.7. Flow rate 300 m³/h

The first and last round of evaluation in 300 m³/h:

Country	Error of the meter x (%)	Uncertainty $U(k=2)$ (%)	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x^*(1/u)^2$
Germany	0.23	0.08544	0.170	547.95	127.12
Netherlands	0.26	0.15318	0.026	170.48	44.65
Poland	-0.02	0.25179	4.586	63.09	-1.26
Switzerland	0.30	0.08544	1.391	547.95	164.38
France	0.21	0.24187	0.136	68.38	14.02

$$x_{ref} = y = 0.249612137$$

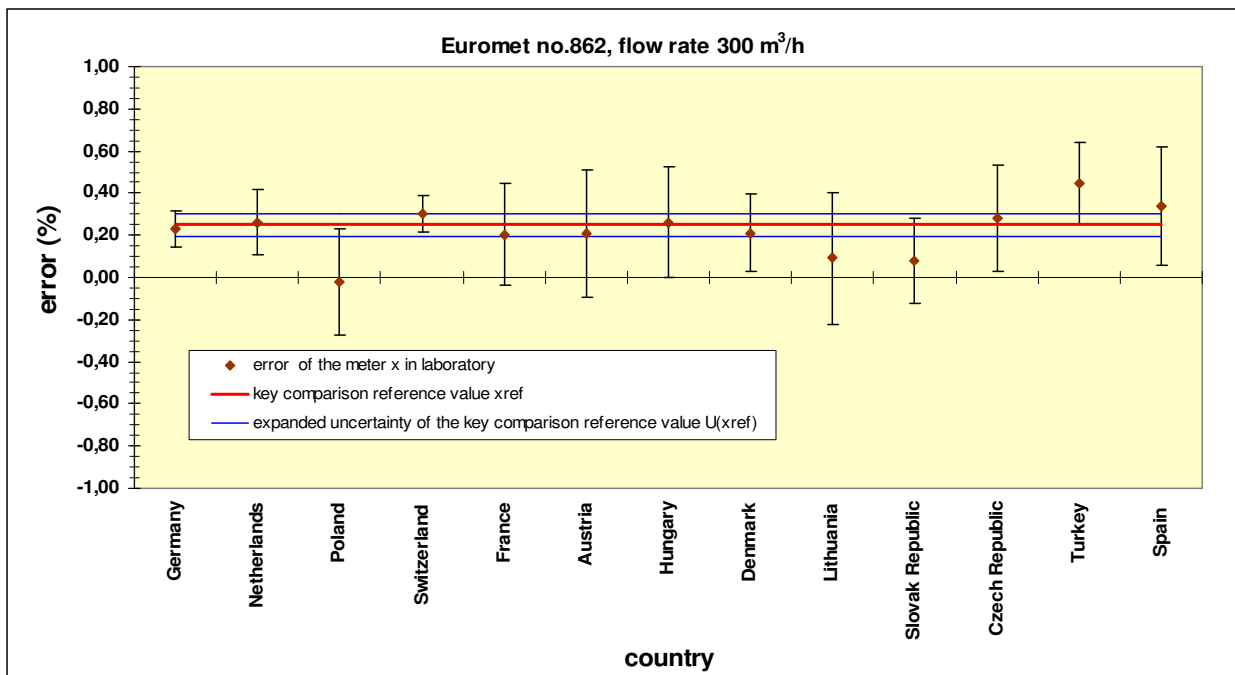
$$U(x_{ref}) = 0.053493603$$

$$CHIINV = 9.487729037$$

$$\chi^2_{obs} = 6.3093$$

The consistency check passed because $CHIINV > \chi^2_{obs}$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.23	0.085440	-0.0176	0.067	0.26
Netherlands	0.26	0.153178	0.0123	0.144	0.09
Poland	-0.02	0.251794	-0.2696	0.246	1.10
Switzerland	0.30	0.085440	0.0504	0.067	0.76
France	0.21	0.241868	-0.0446	0.236	0.19
Austria	0.21	0.301496	-0.0396	0.297	0.13
Hungary	0.26	0.261725	0.0104	0.256	0.04
Denmark	0.21	0.182483	-0.0396	0.174	0.23
Lithuania	0.09	0.311448	-0.1596	0.307	0.52
Slovak Republic	0.08	0.202237	-0.1696	0.195	0.87
Czech Republic	0.28	0.251794	0.0304	0.246	0.12
Turkey	0.45	0.191391	0.1963	0.184	1.07
Spain	0.34	0.281603	0.0904	0.276	0.33



6.8. Flow rate 200 m³/h

The first round of evaluation in 200 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x^*(1/u)^2$
	(%)		(%)		
Germany	0.41	0.085440	0.486	547.95	223.56
Netherlands	0.45	0.153227	0.041	170.37	77.22
Poland	0.05	0.261725	8.780	58.39	2.92
Switzerland	0.52	0.085440	3.705	547.95	284.93
France	0.31	0.241868	1.116	68.38	21.20

$$\begin{aligned} \text{WME} = y &= 0.4377706 \\ U(y) &= 0.05358582 \\ \text{CHIINV} &= 9.487729037 \\ \chi_{obs}^2 &= 14.1282 \end{aligned}$$

The consistency check failed because $\text{CHIINV} < \chi_{obs}^2$
The result of Poland was excluded for the next round of evaluation.

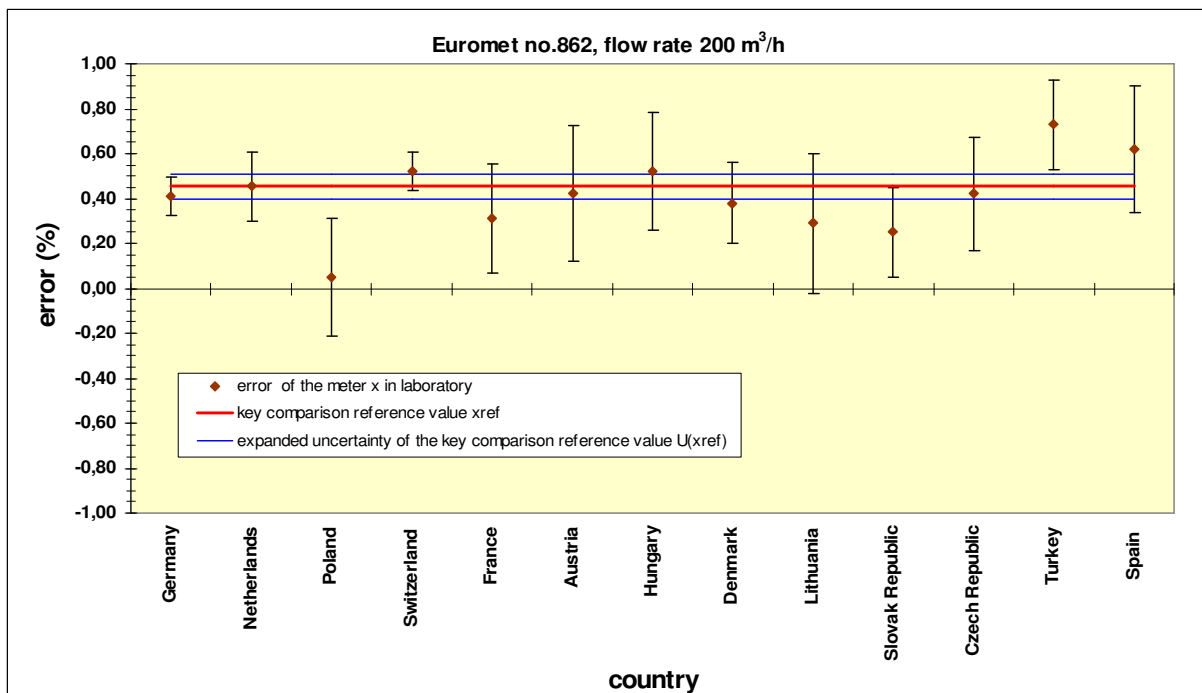
The second and last round of evaluation in 200 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x^*(1/u)^2$
	(%)		(%)		
Germany	0.41	0.085440	0.486	547.95	223.56
Netherlands	0.45	0.153227	0.041	170.37	77.22
Switzerland	0.52	0.085440	3.705	547.95	284.93
France	0.31	0.241868	1.116	68.38	21.20

$$\begin{aligned} x_{ref} = y &= 0.45473669 \\ U(x_{ref}) &= 0.054745538 \\ \text{CHIINV} &= 7.814727764 \\ \chi_{obs}^2 &= 5.3477 \end{aligned}$$

The consistency check passed because $\text{CHIINV} > \chi_{obs}^2$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	0.41	0.085440	-0.0467	0.066	0.71
Netherlands	0.45	0.153227	-0.0015	0.143	0.01
Poland	0.05	0.261725	-0.4047	0.267	1.51
Switzerland	0.52	0.085440	0.0653	0.066	0.99
France	0.31	0.241868	-0.1447	0.236	0.61
Austria	0.42	0.301496	-0.0347	0.296	0.12
Hungary	0.52	0.261725	0.0653	0.256	0.25
Denmark	0.38	0.182483	-0.0747	0.174	0.43
Lithuania	0.29	0.311448	-0.1647	0.307	0.54
Slovak Republic	0.25	0.202237	-0.2047	0.195	1.05
Czech Republic	0.42	0.251794	-0.0347	0.246	0.14
Turkey	0.73	0.200312	0.2733	0.193	1.42
Spain	0.62	0.281603	0.1653	0.276	0.60



6.9. Flow rate 100 m³/h

The first round of evaluation in 100 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	1.14	0.085440	0.774	547.95	624.66
Netherlands	1.18	0.155427	0.001	165.58	195.39
Poland	0.83	0.261725	7.055	58.39	48.47
Switzerland	1.29	0.085440	6.924	547.95	706.85
France	0.87	0.241868	6.511	68.38	59.42

$$WME = y = 1.17759026$$

$$U(y) = 0.053678151$$

$$CHIINV = 9.487729037$$

$$\chi_{obs}^2 = 21.2655$$

The consistency check failed because $CHIINV < \chi_{obs}^2$

The result of Poland was excluded for the next round of evaluation.

The second round of evaluation in 100 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	1.14	0.085440	0.774	547.95	624.66
Netherlands	1.18	0.155427	0.001	165.58	195.39
Switzerland	1.29	0.085440	6.924	547.95	706.85
France	0.87	0.241868	6.511	68.38	59.42

$$WME = y = 1.192853101$$

$$U(y) = 0.054844006$$

$$CHIINV = 7.814727764$$

$$\chi_{obs}^2 = 14.2104$$

The consistency check failed because $CHIINV < \chi_{obs}^2$

The result of Switzerland was excluded for the next round of evaluation.

The third round of evaluation in 100 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	1.14	0.085440	0.774	547.95	624.66
Netherlands	1.18	0.155427	0.001	165.58	195.39
France	0.87	0.241868	6.511	68.38	59.42

$$WME = y = 1.124773984$$

$$U(y) = 0.071524349$$

$$CHIINV = 5.991464547$$

$$\chi_{obs}^2 = 7.2865$$

The consistency check failed because $CHIINV < \chi_{obs}^2$

The result of France was excluded for the next round of evaluation.

The fourth and last round of evaluation in 100 m³/h:

Country	Error of the meter x	Uncertainty $U(k=2)$	$\frac{(x_i - y)^2}{\left(\frac{U(x_i)}{2}\right)^2}$	$1/u^2$	$x*(1/u)^2$
	(%)	(%)			
Germany	1.14	0.085440	0.774	547.95	624.66
Netherlands	1.18	0.155427	0.001	165.58	195.39

$$x_{ref} = y = 1.149284413$$

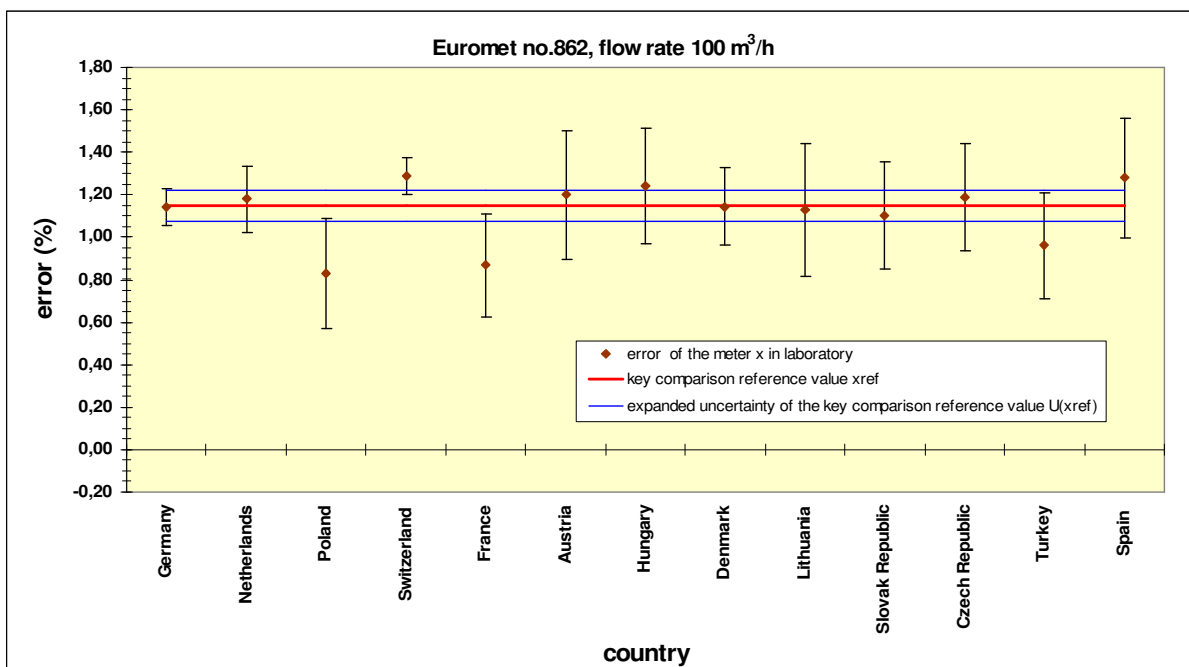
$$U(x_{ref}) = 0.074872995$$

$$CHIINV = 3.841459149$$

$$\chi_{obs}^2 = 0.7752$$

The consistency check passed because $CHIINV > \chi_{obs}^2$

Country	Error of the meter x	Uncertainty $U(k=2)$	d_i	$U(d_i)$	E_i
	(%)	(%)	(%)	(%)	
Germany	1.14	0.085440	-0.0093	0.041	0.23
Netherlands	1.18	0.155427	0.0307	0.136	0.23
Poland	0.83	0.261725	-0.3193	0.272	1.17
Switzerland	1.29	0.085440	0.1407	0.114	1.24
France	0.87	0.241868	-0.2803	0.253	1.11
Austria	1.20	0.301496	0.0507	0.292	0.17
Hungary	1.24	0.271662	0.0907	0.261	0.35
Denmark	1.14	0.182483	-0.0060	0.166	0.04
Lithuania	1.13	0.311448	-0.0193	0.302	0.06
Slovak Republic	1.10	0.251794	-0.0493	0.240	0.21
Czech Republic	1.19	0.251794	0.0407	0.240	0.17
Turkey	0.96	0.251794	-0.1858	0.240	0.77
Spain	1.28	0.281603	0.1307	0.271	0.48

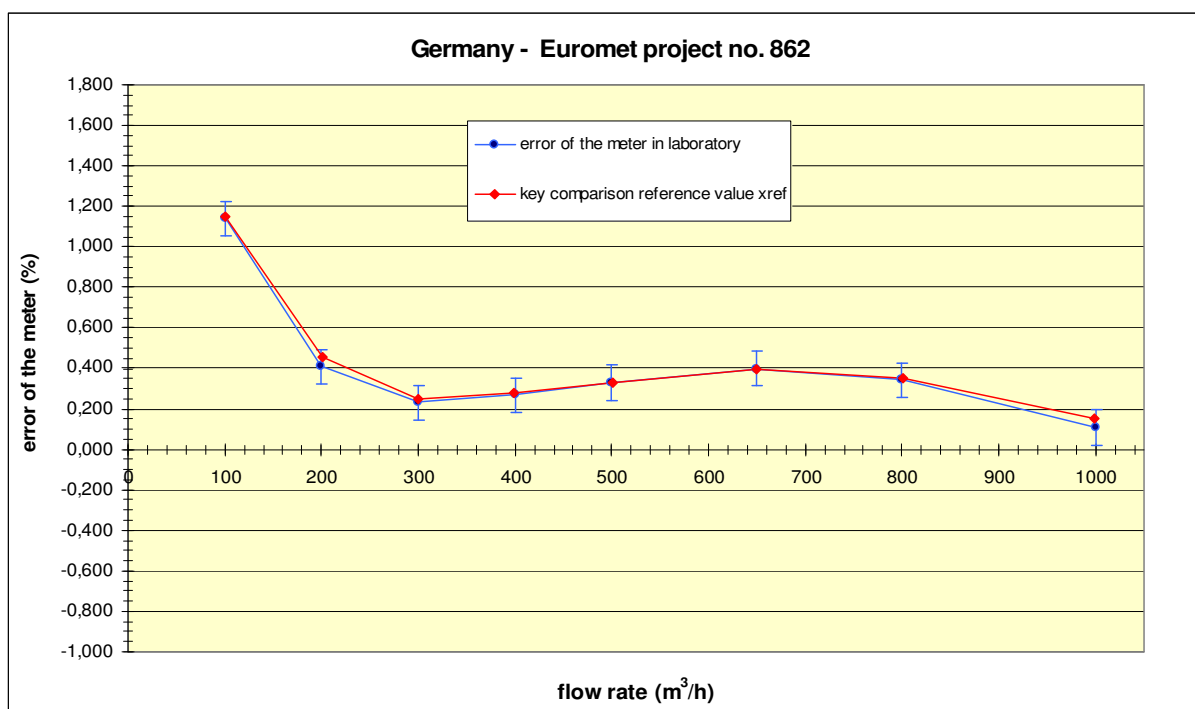


7. Results

7.1. Independent laboratories

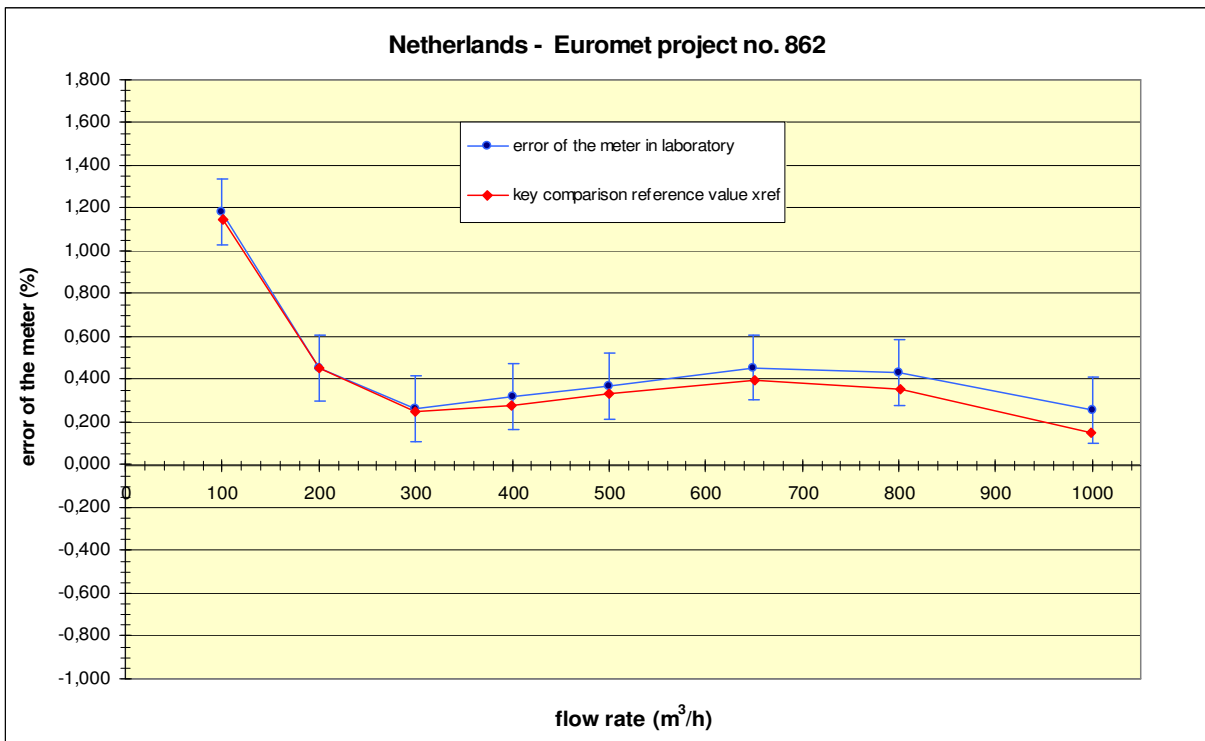
7.1.1. Germany

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	consistency check	di	Ei	result
m^3/h	%	%	%	%				
1000.00	0.108	0.085	0.149	0.054	inside	-0.04	0.61	passed
800.00	0.342	0.085	0.354	0.054	inside	-0.01	0.18	passed
650.00	0.398	0.085	0.398	0.053	inside	0.00	0.00	passed
500.00	0.330	0.085	0.332	0.053	inside	0.00	0.04	passed
400.00	0.268	0.085	0.279	0.053	inside	-0.01	0.17	passed
300.00	0.232	0.085	0.250	0.053	inside	-0.02	0.26	passed
200.00	0.408	0.085	0.455	0.055	inside	-0.05	0.71	passed
100.00	1.140	0.085	1.149	0.075	inside	-0.01	0.23	passed
mean						-0.02	0.27	passed



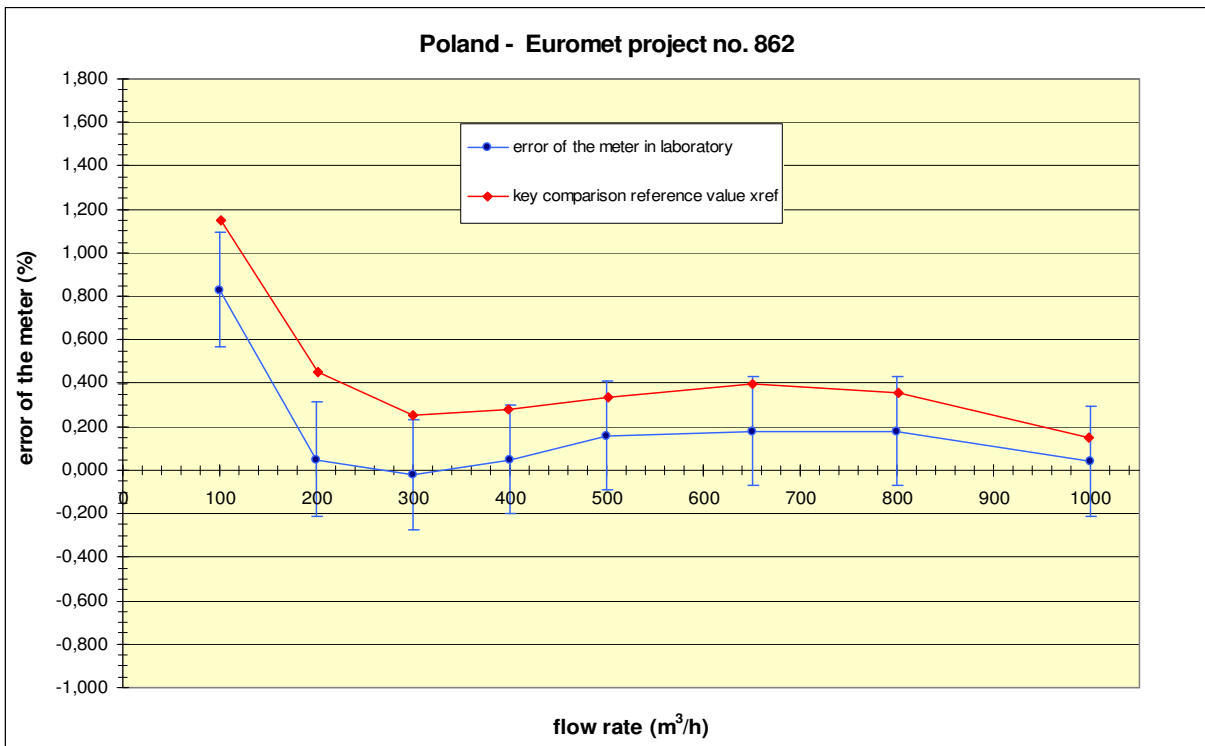
7.1.2. Netherlands

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	consistency check	di	Ei	result
m^3/h	%	%	%	%				
1000.00	0.256	0.153	0.149	0.054	inside	0.11	0.75	passed
800.00	0.430	0.153	0.354	0.054	inside	0.08	0.53	passed
650.00	0.455	0.153	0.398	0.053	inside	0.06	0.40	passed
500.00	0.367	0.153	0.332	0.053	inside	0.03	0.24	passed
400.00	0.320	0.153	0.279	0.053	inside	0.04	0.28	passed
300.00	0.262	0.153	0.250	0.053	inside	0.01	0.09	passed
200.00	0.453	0.153	0.455	0.055	inside	0.00	0.01	passed
100.00	1.180	0.155	1.149	0.075	inside	0.03	0.23	passed
mean						0.04	0.32	passed



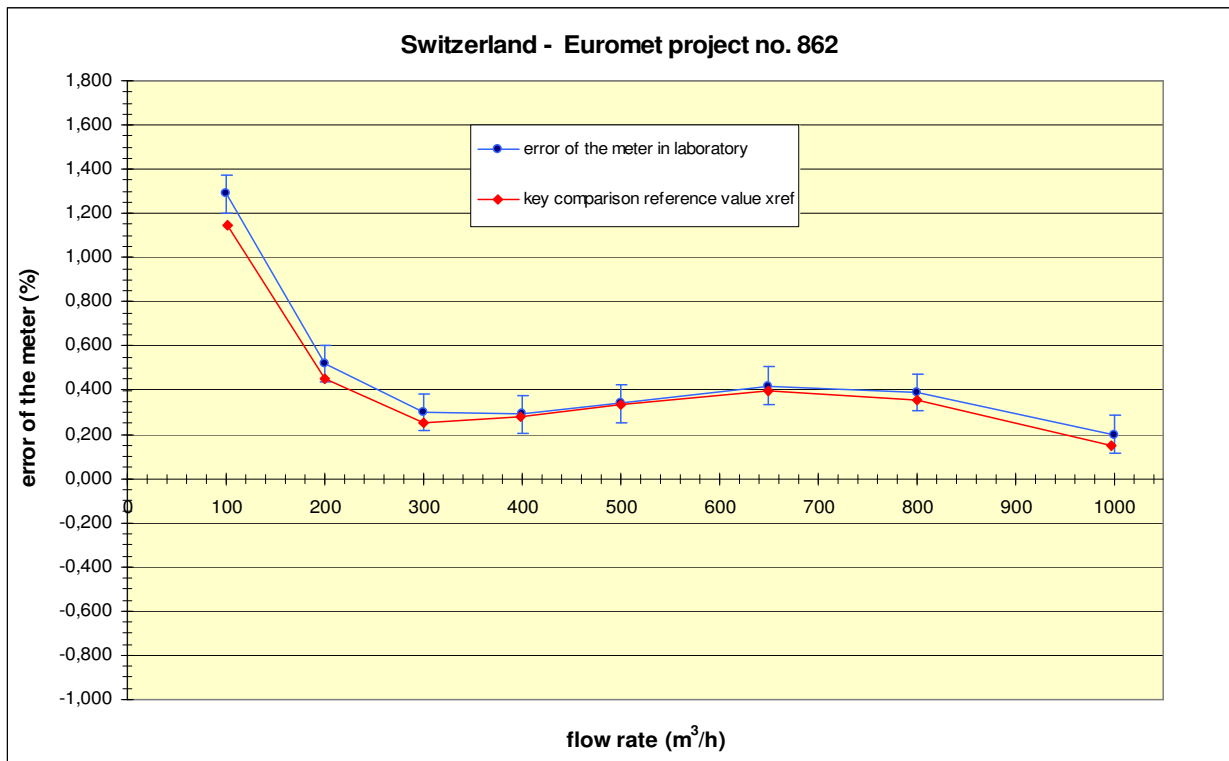
7.1.3. Poland

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	consistency check	di	Ei	result
m^3/h	%	%	%	%				
1000.00	0.040	0.252	0.149	0.054	inside	-0.11	0.44	passed
800.00	0.180	0.252	0.354	0.054	inside	-0.17	0.71	passed
650.00	0.180	0.252	0.398	0.053	inside	-0.22	0.89	passed
500.00	0.160	0.252	0.332	0.053	inside	-0.17	0.70	passed
400.00	0.050	0.252	0.279	0.053	inside	-0.23	0.93	passed
300.00	-0.020	0.252	0.250	0.053	inside	-0.27	1.10	warning
200.00	0.050	0.262	0.455	0.055	outside	-0.40	1.51	failed
100.00	0.830	0.262	1.149	0.075	outside	-0.32	1.17	warning
mean						-0.24	0.93	passed



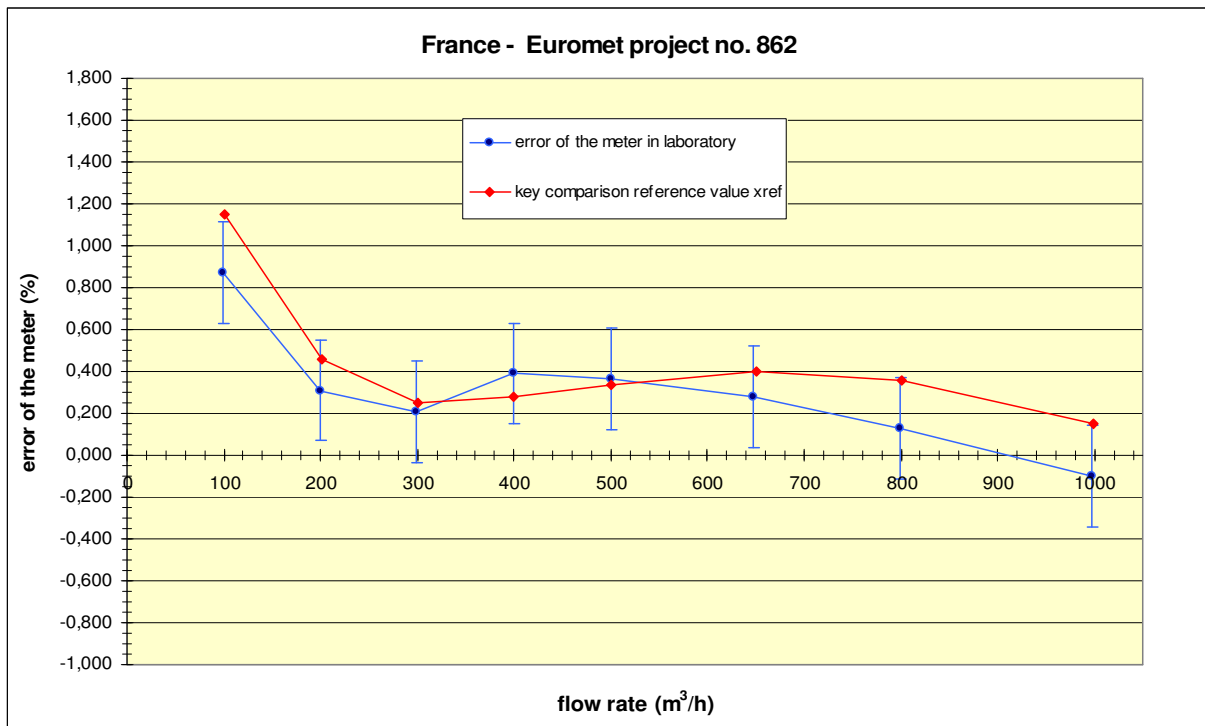
7.1.4. Switzerland

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value U(x_{ref})	consistency check	Di	Ei	result
m ³ /h	%	%	%	%				
1000.00	0.200	0.085	0.149	0.054	inside	0.05	0.77	passed
800.00	0.390	0.085	0.354	0.054	inside	0.04	0.54	passed
650.00	0.420	0.085	0.398	0.053	inside	0.02	0.33	passed
500.00	0.340	0.085	0.332	0.053	inside	0.01	0.11	passed
400.00	0.290	0.085	0.279	0.053	inside	0.01	0.16	passed
300.00	0.300	0.085	0.250	0.053	inside	0.05	0.76	passed
200.00	0.520	0.085	0.455	0.055	inside	0.07	0.99	passed
100.00	1.290	0.085	1.149	0.075	outside	0.14	1.24	failed
mean	0.05	0.61						passed



7.1.5. France

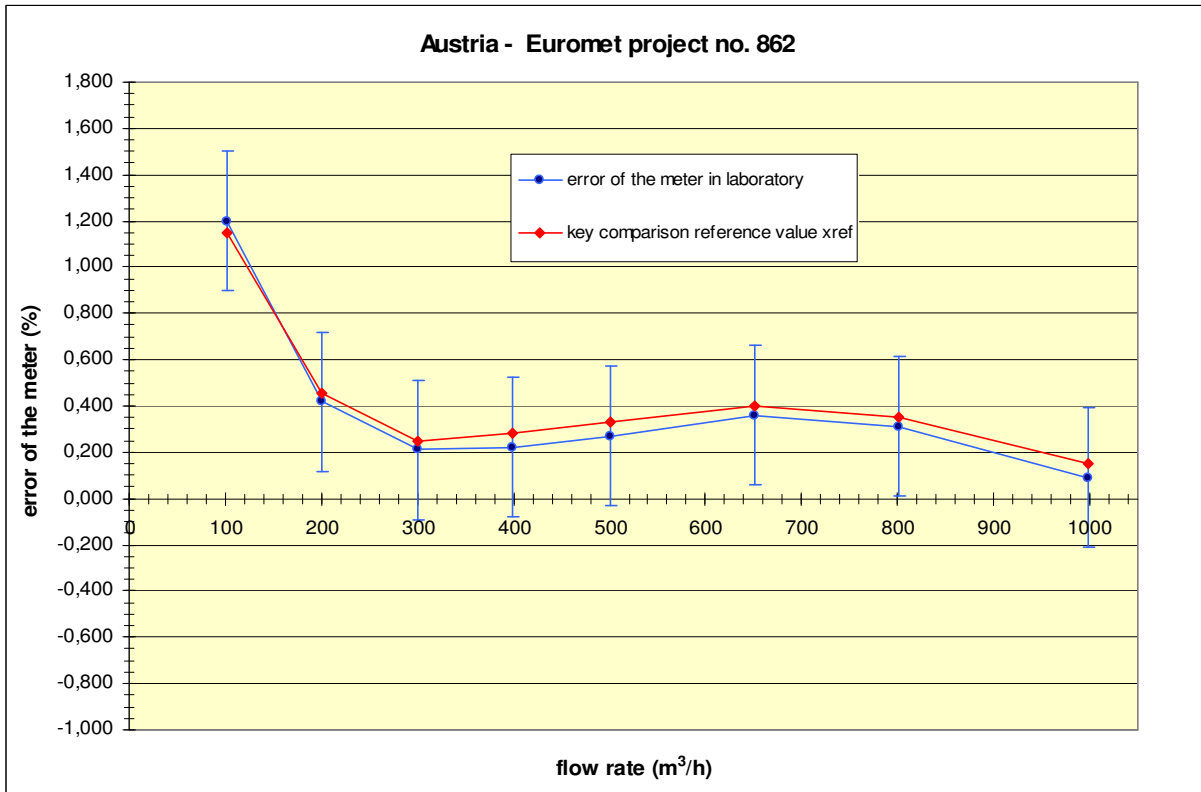
flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	consistency check	di	Ei	result
m^3/h	%	%	%	%				
997.37	-0.100	0.242	0.149	0.054	inside	-0.25	1.05	warning
799.04	0.127	0.242	0.354	0.054	inside	-0.23	0.96	passed
648.00	0.281	0.242	0.398	0.053	inside	-0.12	0.50	passed
500.16	0.362	0.242	0.332	0.053	inside	0.03	0.13	passed
400.01	0.390	0.242	0.279	0.053	inside	0.11	0.47	passed
298.70	0.205	0.242	0.250	0.053	inside	-0.04	0.19	passed
199.43	0.310	0.242	0.455	0.055	inside	-0.14	0.61	passed
98.82	0.869	0.242	1.149	0.075	outside	-0.28	1.11	warning
mean						-0.12	0.63	passed



7.2. Dependent laboratories

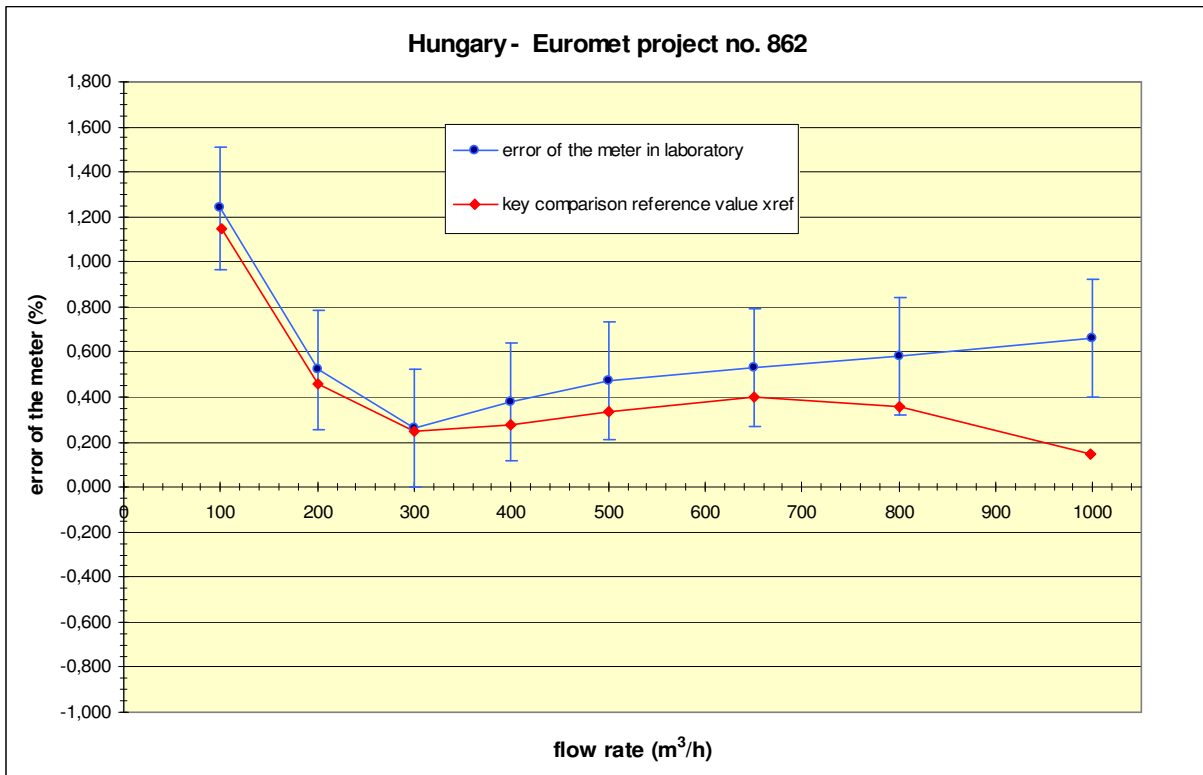
7.2.1. Austria

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	d_i	E_i	result
m^3/h	%	%	%	%			
998.20	0.090	0.301	0.149	0.054	-0.06	0.20	passed
801.00	0.310	0.301	0.354	0.054	-0.04	0.15	passed
650.20	0.360	0.301	0.398	0.053	-0.04	0.13	passed
500.50	0.270	0.301	0.332	0.053	-0.06	0.21	passed
398.80	0.220	0.301	0.279	0.053	-0.06	0.20	passed
299.70	0.210	0.301	0.250	0.053	-0.04	0.13	passed
200.80	0.420	0.301	0.455	0.055	-0.03	0.12	passed
101.00	1.200	0.301	1.149	0.075	0.05	0.17	passed
mean					-0.04	0.16	passed



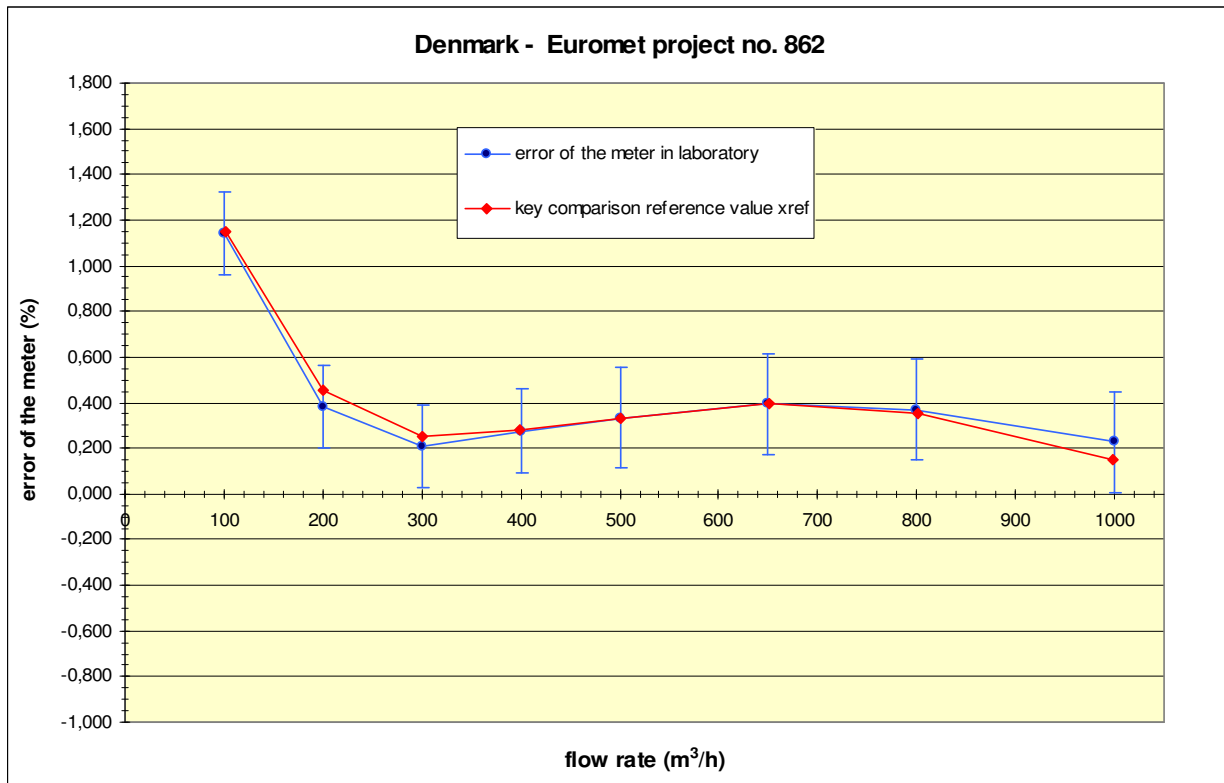
7.2.2. Hungary

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	d_i	E_i	result
m^3/h	%	%	%	%			
1000.00	0.660	0.262	0.149	0.054	0.51	2.00	failed
800.00	0.580	0.262	0.354	0.054	0.23	0.88	passed
650.00	0.530	0.262	0.398	0.053	0.13	0.51	passed
500.00	0.470	0.262	0.332	0.053	0.14	0.54	passed
400.00	0.380	0.262	0.279	0.053	0.10	0.39	passed
300.00	0.260	0.262	0.250	0.053	0.01	0.04	passed
200.00	0.520	0.262	0.455	0.055	0.07	0.25	passed
100.00	1.240	0.272	1.149	0.075	0.09	0.35	passed
mean					0.16	0.62	passed



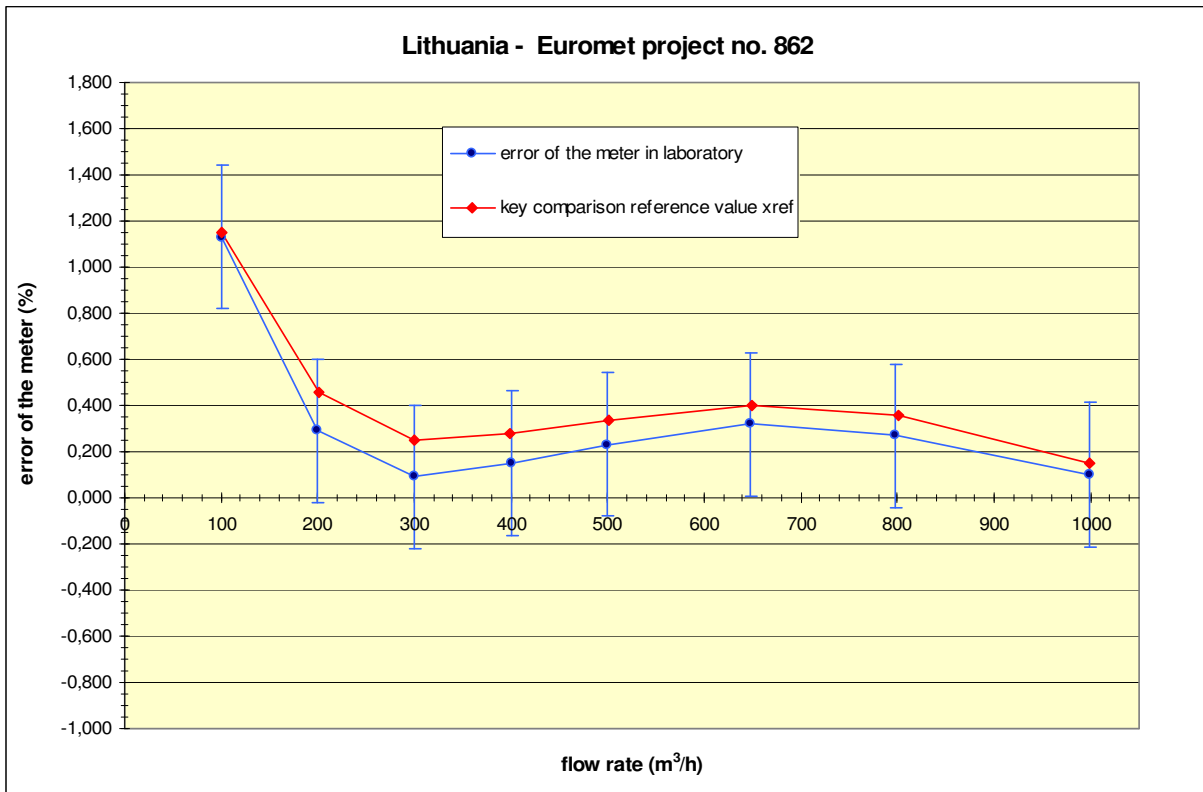
7.2.3. Denmark

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	di	Ei	result
m ³ /h	%	%	%	%			
1000.00	0.227	0.222	0.149	0.054	0.08	0.36	passed
800.00	0.370	0.222	0.354	0.054	0.02	0.08	passed
650.00	0.393	0.222	0.398	0.053	0.00	0.02	passed
500.00	0.333	0.222	0.332	0.053	0.00	0.00	passed
400.00	0.277	0.182	0.279	0.053	0.00	0.01	passed
300.00	0.210	0.182	0.250	0.053	-0.04	0.23	passed
200.00	0.380	0.182	0.455	0.055	-0.07	0.43	passed
100.00	1.143	0.182	1.149	0.075	-0.01	0.04	passed
mean					0.00	0.15	passed



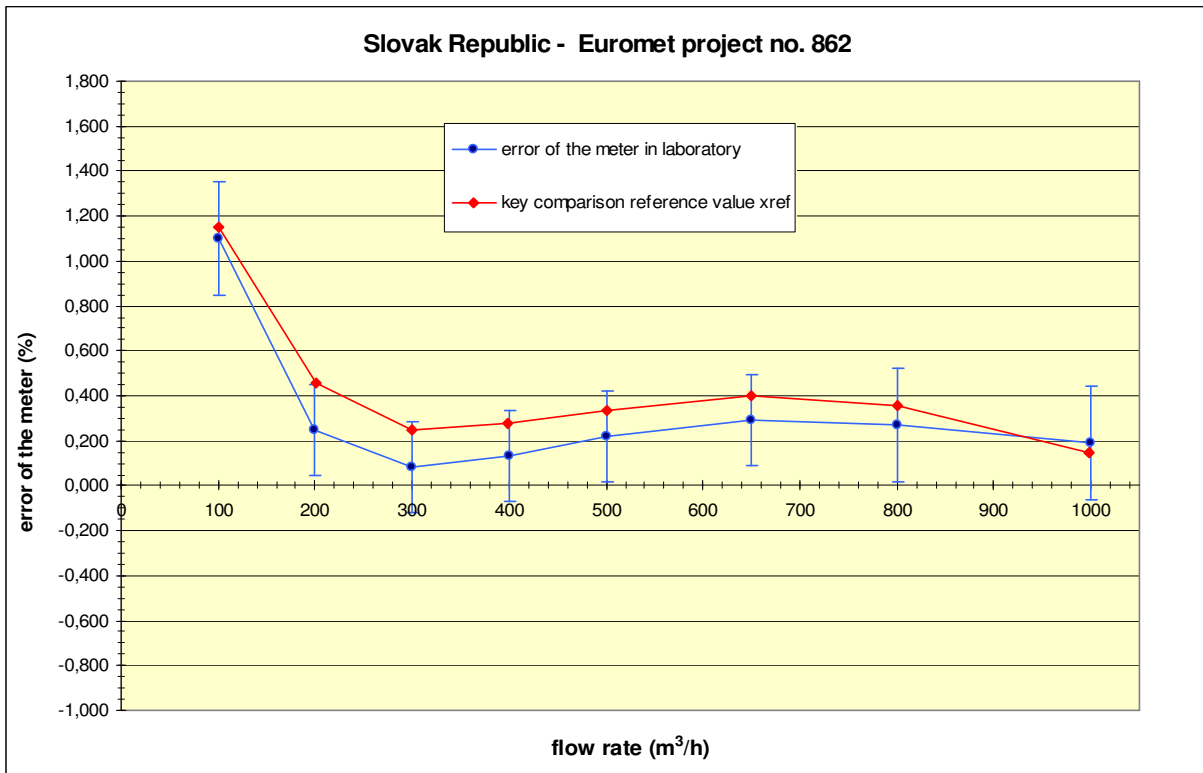
7.2.4. Lithuania

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	di	Ei	result
m ³ /h	%	%	%	%			
998.80	0.100	0.311	0.149	0.054	-0.05	0.16	passed
798.50	0.270	0.311	0.354	0.054	-0.08	0.27	passed
648.40	0.320	0.311	0.398	0.053	-0.08	0.25	passed
498.90	0.230	0.311	0.332	0.053	-0.10	0.33	passed
400.20	0.150	0.311	0.279	0.053	-0.13	0.42	passed
299.20	0.090	0.311	0.250	0.053	-0.16	0.52	passed
199.60	0.290	0.311	0.455	0.055	-0.16	0.54	passed
100.30	1.130	0.311	1.149	0.075	-0.02	0.06	passed
mean					-0.10	0.32	passed



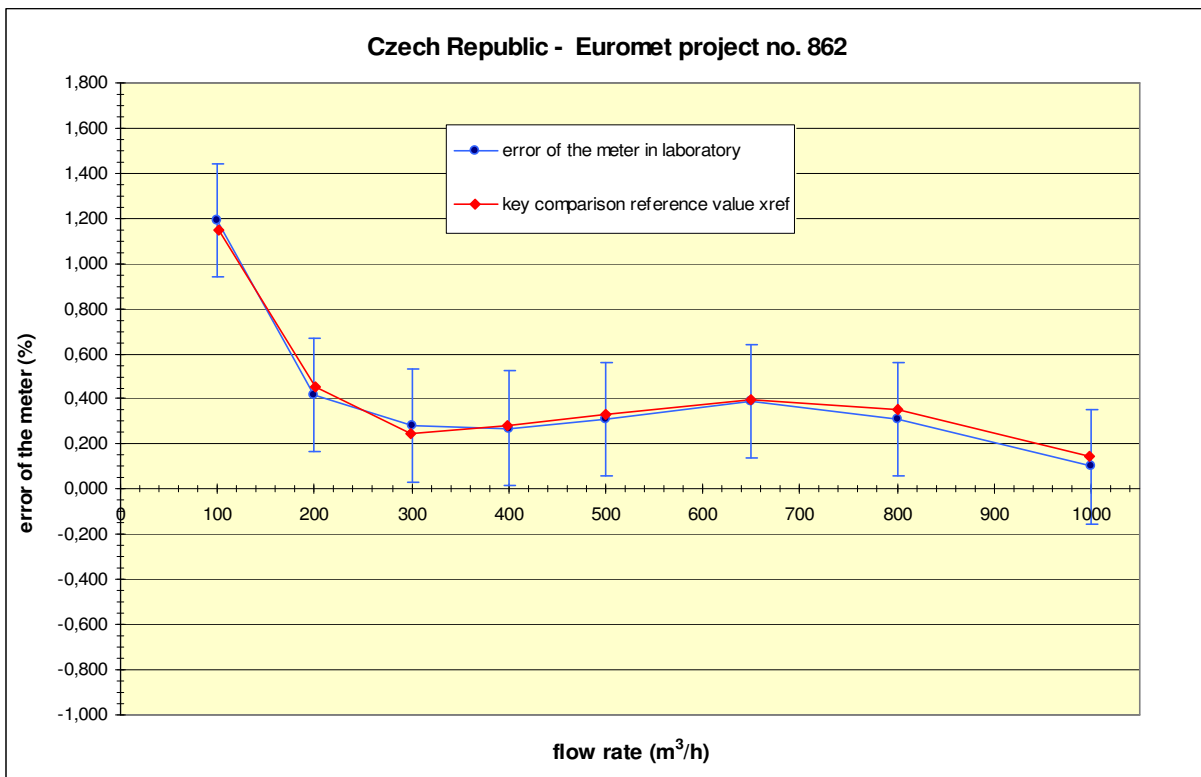
7.2.5. Slovak Republic

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	di	Ei	result
m ³ /h	%	%	%	%			
1000.00	0.190	0.252	0.149	0.054	0.04	0.17	passed
800.00	0.270	0.252	0.354	0.054	-0.08	0.34	passed
650.00	0.290	0.202	0.398	0.053	-0.11	0.55	passed
500.00	0.220	0.202	0.332	0.053	-0.11	0.58	passed
400.00	0.130	0.202	0.279	0.053	-0.15	0.76	passed
300.00	0.080	0.202	0.250	0.053	-0.17	0.87	passed
200.00	0.250	0.202	0.455	0.055	-0.20	1.05	warning
100.00	1.100	0.252	1.149	0.075	-0.05	0.21	passed
mean					-0.10	0.57	passed



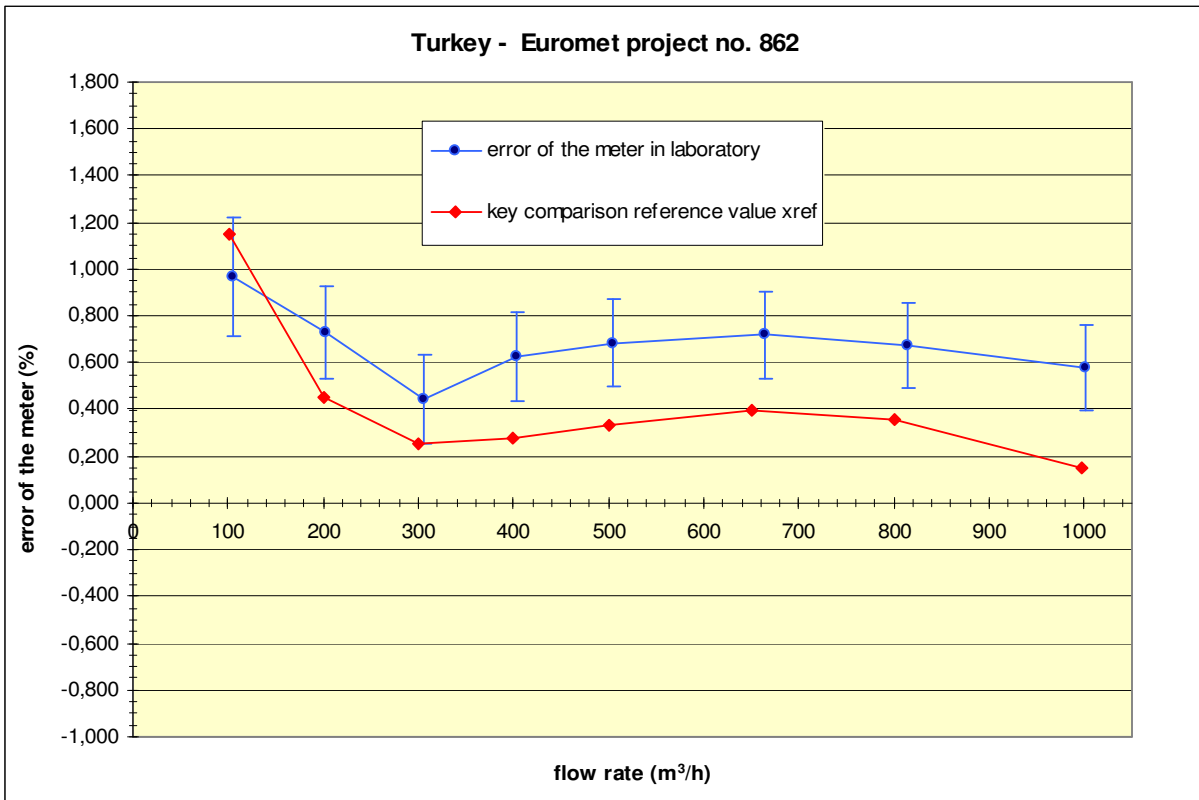
7.2.6. Czech Republic

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	di	Ei	result
m ³ /h	%	%	%	%			
1000.00	0.100	0.252	0.149	0.054	-0.05	0.20	passed
800.00	0.310	0.252	0.354	0.054	-0.04	0.18	passed
650.00	0.390	0.252	0.398	0.053	-0.01	0.03	passed
500.00	0.310	0.252	0.332	0.053	-0.02	0.09	passed
400.00	0.270	0.252	0.279	0.053	-0.01	0.04	passed
300.00	0.280	0.252	0.250	0.053	0.03	0.12	passed
200.00	0.420	0.252	0.455	0.055	-0.03	0.14	passed
100.00	1.190	0.252	1.149	0.075	0.04	0.17	passed
mean					-0.01	0.12	passed



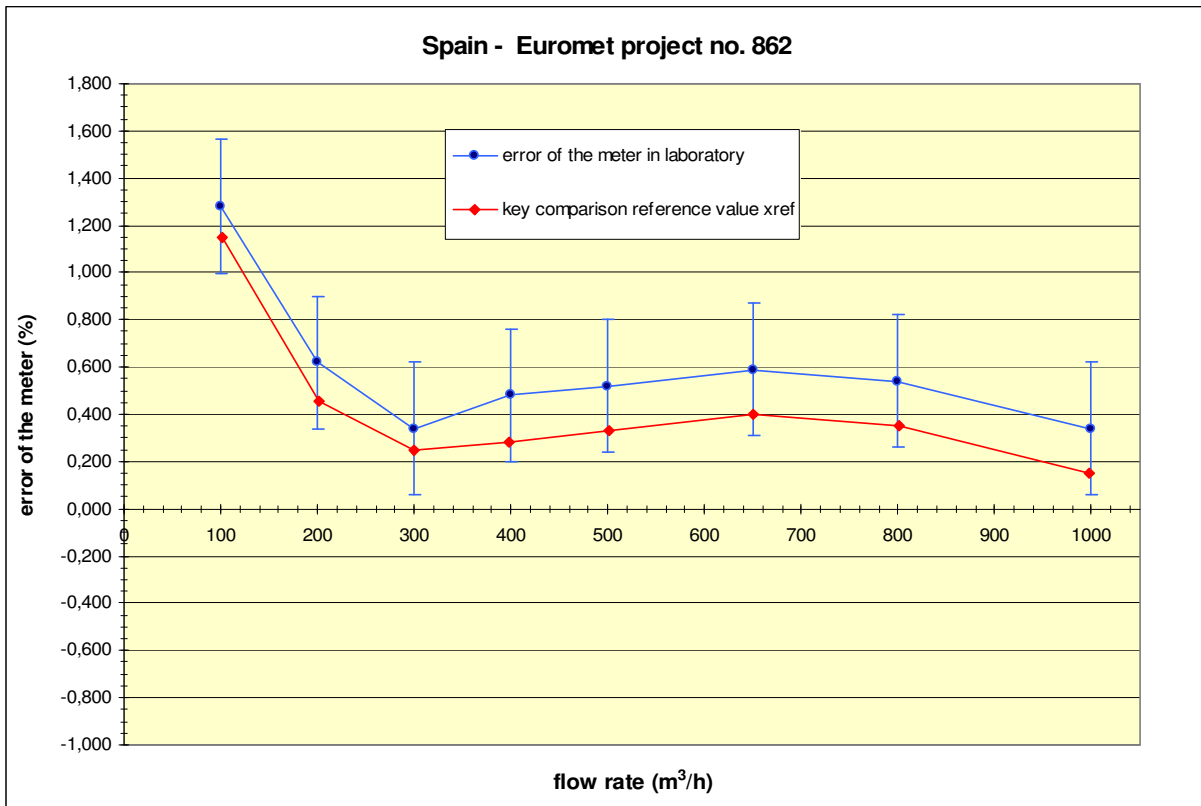
7.2.7. Turkey

flow rate in the meter	error of the meter in laboratory	uncertainty of the error U(k=2)	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	d_i	E_i	result
m^3/h	%	%	%	%			
1001.91	0.578	0.184	0.149	0.054	0.43	2.44	failed
814.54	0.676	0.184	0.354	0.054	0.32	1.83	failed
664.88	0.718	0.184	0.398	0.053	0.32	1.81	failed
503.88	0.683	0.186	0.332	0.053	0.35	1.97	failed
402.67	0.625	0.188	0.279	0.053	0.35	1.91	failed
306.67	0.446	0.191	0.250	0.053	0.20	1.07	warning
203.06	0.728	0.200	0.455	0.055	0.27	1.42	failed
104.50	0.963	0.254	1.149	0.075	-0.19	0.77	passed
mean					0.26	1.65	failed



7.2.8. Spain

flow rate in the meter	error of the meter in laboratory	uncertainty of the error $U(k=2)$	key comparison reference value x_{ref}	expanded uncertainty of the key comparison reference value $U(x_{ref})$	di	Ei	result
m ³ /h	%	%	%	%			
1000.00	0.340	0.282	0.149	0.054	0.19	0.69	passed
800.00	0.540	0.282	0.354	0.054	0.19	0.67	passed
650.00	0.590	0.282	0.398	0.053	0.19	0.69	passed
500.00	0.520	0.282	0.332	0.053	0.19	0.68	passed
400.00	0.480	0.282	0.279	0.053	0.20	0.73	passed
300.00	0.340	0.282	0.250	0.053	0.09	0.33	passed
200.00	0.620	0.282	0.455	0.055	0.17	0.60	passed
100.00	1.280	0.282	1.149	0.075	0.13	0.48	passed
mean					0.17	0.61	passed



8. Degree of equivalence between laboratories

As it was mentioned above in this project there were 6 independent laboratories (---):
Germany, Netherlands, Poland, France, Switzerland and Great Britain(results withdrawn)

In this project there were 5 laboratories traceable to Netherlands (NMi):
Austria, Hungary, Denmark, Turkey and Spain

In this project there were 3 laboratories traceable to Germany (PTB):
Czech Republic, Slovak Republic, Lithuania

The degree of equivalence between laboratory *i* and laboratory *j* was calculated as the pair of values *dij* and *Eij* (equations [12], [14], [19], [20], [22], see chapter 6.1.2.). The calculated pairs of values *dij* and *Eij* are mentioned down in tables.

The pair of values is red if *Eij* is higher than 1.2. It means that the mutual degree of equivalence of laboratories *i* and *j* failed.

The pair of values is light orange if *Eij* is higher than 1 and equal or less than 1.2. It means that the mutual degree of equivalence of laboratories *i* and *j* is in warning level.

The pair of values is black if *Eij* is equal or less than 1. It means that there is satisfactory mutual degree of equivalence of laboratories *i* and *j*.

Flow rate	Austria-Hungary (NMi/NMi)		Austria-Germany (NMi/---)		Austria-Netherlands (NMi/NMi)		Austria-Denmark (NMi/NMi)		Austria-Poland (NMi/---)		Austria-Lithuania (NMi/PTB)		Austria-Slovak Rep. (NMi/PTB)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
<i>Q</i>														
1000	-0.57	1.69	-0.02	0.06	-0.17	0.63	-0.14	0.31	0.05	0.13	-0.01	0.02	-0.10	0.25
800	-0.27	0.80	-0.03	0.10	-0.12	0.46	-0.06	0.31	0.13	0.33	0.04	0.09	0.04	0.10
650	-0.17	0.50	-0.04	0.12	-0.10	0.36	-0.03	0.31	0.18	0.46	0.04	0.09	0.07	0.19
500	-0.20	0.59	-0.06	0.19	-0.10	0.37	-0.06	0.31	0.11	0.28	0.04	0.09	0.05	0.14
400	-0.16	0.47	-0.05	0.15	-0.10	0.38	-0.06	0.28	0.17	0.43	0.07	0.16	0.09	0.25
300	-0.05	0.15	-0.02	0.07	-0.05	0.20	0.00	0.28	0.23	0.59	0.12	0.28	0.13	0.36
200	-0.10	0.30	0.01	0.04	-0.03	0.13	0.04	0.28	0.37	0.93	0.13	0.30	0.17	0.47
100	-0.04	0.12	0.06	0.19	0.02	0.08	0.06	0.28	0.37	0.93	0.07	0.16	0.10	0.25
Mean	-0.20	0.58	-0.02	0.12	-0.08	0.32	-0.03	0.29	0.20	0.51	0.06	0.15	0.07	0.25

Flow rate	Austria-Czech Rep. (NMi/PTB)		Austria-Switzerland (NMi/---)		Austria-Turkey (NMi/NMi)		Austria-France (NMi/---)		Austria-Spain (NMi/NMi)		Hungary-Germany (NMi/---)		Hungary-Netherlands (NMi/---)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
<i>Q</i>														
1000	-0.01	0.03	-0.11	0.35	-0.49	1.73	0.19	0.49	-0.25	0.71	0.55	2.00	0.40	1.86
800	0.00	0.00	-0.08	0.26	-0.37	1.30	0.18	0.47	-0.23	0.65	0.24	0.86	0.15	0.69
650	-0.03	0.08	-0.06	0.19	-0.36	1.27	0.08	0.20	-0.23	0.65	0.13	0.48	0.07	0.34
500	-0.04	0.10	-0.07	0.22	-0.41	1.46	-0.09	0.24	-0.25	0.71	0.14	0.51	0.10	0.47
400	-0.05	0.13	-0.07	0.22	-0.40	1.42	-0.17	0.44	-0.26	0.73	0.11	0.41	0.06	0.28
300	-0.07	0.18	-0.09	0.29	-0.24	0.82	0.01	0.01	-0.13	0.37	0.03	0.10	0.00	0.01
200	0.00	0.00	-0.10	0.32	-0.31	1.05	0.11	0.28	-0.20	0.57	0.11	0.41	0.07	0.31
100	0.01	0.03	-0.09	0.29	0.24	0.71	0.33	0.86	-0.08	0.23	0.10	0.35	0.06	0.26
Mean	-0.02	0.07	-0.08	0.27	-0.29	1.22	0.08	0.38	-0.20	0.58	0.18	0.64	0.11	0.53

Flow rate	Hungary-Denmark (NMi/NMi)		Hungary-Poland (NMi/---)		Hungary-Lithuania (NMi/PTB)		Hungary-Slovak Rep. (NMi/PTB)		Hungary-Czech Rep. (NMi/PTB)		Hungary-Switzerland (NMi/---)		Hungary-Turkey (NMi/NMi)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
<i>Q</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.43	1.61	0.62	1.71	0.56	1.38	0.47	1.29	0.56	1.54	0.46	1.67	0.08	0.34
800	0.21	0.78	0.40	1.10	0.31	0.76	0.31	0.85	0.27	0.74	0.19	0.69	-0.10	0.40
650	0.14	0.51	0.35	0.96	0.21	0.52	0.24	0.73	0.14	0.39	0.11	0.40	-0.19	0.78
500	0.14	0.51	0.31	0.85	0.24	0.59	0.25	0.76	0.16	0.44	0.13	0.47	-0.21	0.88
400	0.10	0.43	0.33	0.91	0.23	0.57	0.25	0.76	0.11	0.30	0.09	0.33	-0.24	1.01
300	0.05	0.21	0.28	0.77	0.17	0.42	0.18	0.54	-0.02	0.06	-0.04	0.15	-0.19	0.76
200	0.14	0.59	0.47	1.27	0.23	0.57	0.27	0.82	0.10	0.28	0.00	0.00	-0.21	0.82
100	0.10	0.39	0.41	1.09	0.11	0.27	0.14	0.38	0.05	0.13	-0.05	0.18	0.28	0.91
Mean	0.16	0.63	0.40	1.08	0.26	0.63	0.26	0.77	0.17	0.48	0.11	0.49	-0.10	0.74

Flow rate	Hungary-France (NMi/---)		Hungary-Spain (NMi/NMi)		Germany-Netherlands (---/---)		Germany-Denmark (---/NMi)		Germany-Poland (---/---)		Germany-Lithuania (---/PTB)		Germany-Slovak Rep. (---/PTB)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
<i>Q</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.76	2.13	0.32	0.83	-0.15	0.84	-0.12	0.50	0.07	0.26	0.01	0.03	-0.08	0.34
800	0.45	1.27	0.04	0.10	-0.09	0.50	-0.03	0.12	0.16	0.61	0.07	0.24	0.07	0.30
650	0.25	0.70	-0.06	0.16	-0.06	0.33	0.00	0.02	0.22	0.82	0.08	0.26	0.11	0.57
500	0.11	0.30	-0.05	0.13	-0.04	0.21	0.00	0.01	0.17	0.64	0.10	0.33	0.11	0.58
400	-0.01	0.03	-0.10	0.26	-0.05	0.30	-0.01	0.04	0.22	0.82	0.12	0.39	0.14	0.73
300	0.06	0.15	-0.08	0.21	-0.03	0.17	0.02	0.11	0.25	0.95	0.14	0.47	0.15	0.81
200	0.21	0.59	-0.10	0.26	-0.05	0.26	0.03	0.14	0.36	1.30	0.12	0.39	0.16	0.84
100	0.37	1.02	-0.04	0.10	-0.04	0.23	0.00	0.02	0.31	1.13	0.01	0.03	0.04	0.17
Mean	0.27	0.77	-0.01	0.26	-0.06	0.35	-0.01	0.12	0.22	0.81	0.08	0.27	0.09	0.54

Flow rate	Germany-Czech Rep. (---/PTB)		Germany-Switzerland (---/---)		Germany-Turkey (---/NMi)		Germany-France (---/---)		Germany-Spain (---/NMi)		Netherlands-Denmark (---/NMi)		Netherlands-Poland (---/---)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
<i>Q</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.01	0.03	-0.09	0.76	-0.47	2.32	0.21	0.81	-0.23	0.79	0.03	0.18	0.22	0.73
800	0.03	0.13	-0.05	0.40	-0.33	1.65	0.22	0.84	-0.20	0.67	0.06	0.36	0.25	0.85
650	0.01	0.03	-0.02	0.18	-0.32	1.57	0.12	0.46	-0.19	0.65	0.06	0.37	0.28	0.93
500	0.02	0.08	-0.01	0.08	-0.35	1.73	-0.03	0.12	-0.19	0.65	0.03	0.20	0.21	0.70
400	0.00	0.01	-0.02	0.18	-0.36	1.72	-0.12	0.48	-0.21	0.72	0.04	0.40	0.27	0.92
300	-0.05	0.20	-0.07	0.56	-0.21	1.02	0.03	0.11	-0.11	0.37	0.05	0.48	0.28	0.96
200	-0.01	0.05	-0.11	0.93	-0.32	1.47	0.10	0.38	-0.21	0.72	0.07	0.67	0.40	1.33
100	-0.05	0.21	-0.15	1.24	0.18	0.66	0.27	1.06	-0.14	0.48	0.04	0.33	0.35	1.15
Mean	-0.01	0.09	-0.07	0.54	-0.27	1.52	0.10	0.53	-0.19	0.63	0.05	0.37	0.28	0.95

Flow rate	Netherlands-Lithuania (---/PTB)		Netherlands-Slovak Rep. (---/PTB)		Netherlands-Czech Rep. (---/PTB)		Netherlands-Switzerland (---/---)		Netherlands-Turkey (---/NMi)		Netherlands-France (---/---)		Netherlands-Spain (---/NMi)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.16	0.45	0.07	0.22	0.16	0.53	0.06	0.32	-0.32	2.90	0.36	1.24	-0.08	0.35
800	0.16	0.46	0.16	0.54	0.12	0.41	0.04	0.23	-0.25	2.21	0.30	1.06	-0.11	0.46
650	0.14	0.39	0.17	0.65	0.07	0.22	0.04	0.20	-0.26	2.36	0.17	0.61	-0.13	0.56
500	0.14	0.40	0.15	0.58	0.06	0.19	0.03	0.16	-0.32	2.77	0.01	0.02	-0.15	0.64
400	0.17	0.49	0.19	0.75	0.05	0.17	0.03	0.17	-0.30	2.58	-0.07	0.24	-0.16	0.67
300	0.17	0.50	0.18	0.72	-0.02	0.06	-0.04	0.22	-0.18	1.50	0.06	0.20	-0.08	0.32
200	0.16	0.47	0.20	0.80	0.03	0.11	-0.07	0.38	-0.27	2.01	0.14	0.50	-0.17	0.69
100	0.05	0.14	0.08	0.27	-0.01	0.03	-0.11	0.62	0.22	1.04	0.31	1.08	-0.10	0.41
Mean	0.14	0.41	0.15	0.57	0.06	0.22	0.00	0.29	-0.21	2.17	0.16	0.62	-0.12	0.51

Flow rate	Denmark-Poland (NMi/---)		Denmark-Lithuania (NMi/PTB)		Denmark-Slovak Rep. (NMi/PTB)		Denmark-Czech Rep. (NMi/PTB)		Denmark-Switzerland (NMi/---)		Denmark-Turkey (NMi/NMi)		Denmark-France (NMi/---)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>dij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Eij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.19	0.56	0.13	0.33	0.04	0.11	0.13	0.38	0.03	0.11	-0.35	1.80	0.33	0.99
800	0.19	0.57	0.10	0.26	0.10	0.30	0.06	0.18	-0.02	0.08	-0.31	1.57	0.24	0.74
650	0.21	0.64	0.07	0.19	0.10	0.34	0.00	0.01	-0.03	0.11	-0.32	1.66	0.11	0.34
500	0.17	0.52	0.10	0.27	0.11	0.38	0.02	0.07	-0.01	0.03	-0.35	1.78	-0.03	0.09
400	0.23	0.73	0.13	0.35	0.15	0.54	0.01	0.02	-0.01	0.07	-0.35	2.26	-0.11	0.37
300	0.23	0.74	0.12	0.33	0.13	0.48	-0.07	0.23	-0.09	0.45	-0.24	1.49	0.01	0.02
200	0.33	1.03	0.09	0.25	0.13	0.48	-0.04	0.13	-0.14	0.69	-0.35	2.06	0.07	0.23
100	0.31	0.98	0.01	0.04	0.04	0.14	-0.05	0.15	-0.15	0.73	0.18	0.78	0.27	0.91
Mean	0.23	0.72	0.09	0.25	0.10	0.35	0.01	0.15	-0.05	0.28	-0.26	1.67	0.11	0.46

Flow rate	Denmark-Spain (NMi/NMi)		Poland-Lithuania (---/PTB)		Poland-Slovak Rep. (---/PTB)		Poland-Czech Rep. (---/PTB)		Poland-Switzerland (---/---)		Poland-Turkey (---/NMi)		Poland-France (---/---)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>Dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	-0.11	0.39	-0.06	0.15	-0.15	0.42	-0.06	0.17	-0.16	0.60	-0.54	1.73	0.14	0.40
800	-0.17	0.59	-0.09	0.22	-0.09	0.25	-0.13	0.37	-0.21	0.79	-0.50	1.59	0.05	0.15
650	-0.20	0.68	-0.14	0.35	-0.11	0.34	-0.21	0.59	-0.24	0.90	-0.54	1.72	-0.10	0.29
500	-0.19	0.65	-0.07	0.17	-0.06	0.19	-0.15	0.42	-0.18	0.68	-0.52	1.67	-0.20	0.58
400	-0.20	0.78	-0.10	0.25	-0.08	0.25	-0.22	0.62	-0.24	0.90	-0.57	1.83	-0.34	0.97
300	-0.13	0.50	-0.11	0.27	-0.10	0.31	-0.30	0.84	-0.32	1.20	-0.47	1.47	-0.23	0.64
200	-0.24	0.92	-0.24	0.59	-0.20	0.60	-0.37	1.02	-0.47	1.71	-0.68	2.06	-0.26	0.73
100	-0.14	0.53	-0.30	0.74	-0.27	0.74	-0.36	0.99	-0.46	1.67	-0.13	0.37	-0.04	0.11
Mean	-0.17	0.63	-0.14	0.34	-0.13	0.39	-0.23	0.63	-0.29	1.06	-0.49	1.55	-0.12	0.48

Flow rate	Poland-Spain (---/NMI)		Lithuania-Slovak Rep. (PTB/PTB)		Lithuania-Czech Rep. (PTB/PTB)		Lithuania-Switzerland (PTB/---)		Lithuania-Turkey (PTB/NMI)		Lithuania-France (PTB/---)		Lithuania-Spain (PTB/NMI)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	-0.30	0.79	-0.09	0.23	0.00	0.00	-0.10	0.31	-0.48	1.32	0.20	0.51	-0.24	0.57
800	-0.36	0.95	0.00	0.00	-0.04	0.10	-0.12	0.37	-0.41	1.12	0.14	0.36	-0.27	0.64
650	-0.41	1.09	0.03	0.08	-0.07	0.18	-0.10	0.31	-0.40	1.10	0.04	0.10	-0.27	0.64
500	-0.36	0.95	0.01	0.03	-0.08	0.21	-0.11	0.34	-0.45	1.25	-0.13	0.33	-0.29	0.69
400	-0.43	1.14	0.02	0.06	-0.12	0.31	-0.14	0.43	-0.47	1.30	-0.24	0.61	-0.33	0.79
300	-0.36	0.95	0.01	0.03	-0.19	0.49	-0.21	0.65	-0.36	0.97	-0.12	0.29	-0.25	0.60
200	-0.57	1.48	0.04	0.11	-0.13	0.34	-0.23	0.71	-0.44	1.18	-0.02	0.05	-0.33	0.79
100	-0.45	1.17	0.03	0.08	-0.06	0.16	-0.16	0.50	0.17	0.41	0.26	0.66	-0.15	0.36
Mean	-0.41	1.07	0.01	0.08	-0.09	0.22	-0.15	0.45	-0.35	1.08	0.02	0.36	-0.27	0.63

Flow rate	Slovak Rep.-Czech Rep. (PTB/PTB)		Slovak Rep.-Switzerland (PTB/---)		Slovak Rep.-Turkey (PTB/NMI)		Slovak Rep.-France (PTB/---)		Slovak Rep.-Spain (PTB/NMI)		Czech Rep.-Switzerland (PTB/---)		Czech Rep.-Turkey (PTB/NMI)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.09	0.27	-0.01	0.04	-0.39	1.24	0.29	0.83	-0.15	0.40	-0.10	0.38	-0.48	1.53
800	-0.04	0.12	-0.12	0.45	-0.41	1.30	0.14	0.41	-0.27	0.71	-0.08	0.30	-0.37	1.17
650	-0.10	0.33	-0.13	0.59	-0.43	1.56	0.01	0.03	-0.30	0.87	-0.03	0.11	-0.33	1.05
500	-0.09	0.30	-0.12	0.55	-0.46	1.69	-0.14	0.45	-0.30	0.87	-0.03	0.11	-0.37	1.19
400	-0.14	0.46	-0.16	0.73	-0.49	1.79	-0.26	0.82	-0.35	1.01	-0.02	0.08	-0.35	1.13
300	-0.20	0.66	-0.22	1.00	-0.37	1.31	-0.13	0.40	-0.26	0.75	-0.02	0.08	-0.17	0.52
200	-0.17	0.56	-0.27	1.23	-0.48	1.68	-0.06	0.19	-0.37	1.07	-0.10	0.38	-0.31	0.96
100	-0.09	0.27	-0.19	0.71	0.14	0.38	0.23	0.66	-0.18	0.48	-0.10	0.38	0.23	0.63
Mean	-0.09	0.37	-0.15	0.66	-0.36	1.37	0.01	0.47	-0.27	0.77	-0.06	0.23	-0.27	1.02

Flow rate	Czech Rep.-France (PTB/---)		Czech Rep.-Spain (PTB/NMI)		Switzerland-Turkey (---/NMI)		Switzerland-France (---/---)		Switzerland-Spain (---/NMI)		Turkey-France (NMI/---)		Turkey-Spain (NMI/NMI)	
	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>	<i>dij</i>	<i>Eij</i>
1000	0.20	0.57	-0.24	0.64	-0.38	1.87	0.30	1.17	-0.14	0.48	0.68	2.23	0.24	0.91
800	0.18	0.52	-0.23	0.61	-0.29	1.41	0.26	1.03	-0.15	0.51	0.55	1.81	0.14	0.52
650	0.11	0.31	-0.20	0.53	-0.30	1.46	0.14	0.54	-0.17	0.58	0.44	1.44	0.13	0.49
500	-0.05	0.15	-0.21	0.56	-0.34	1.68	-0.02	0.09	-0.18	0.61	0.32	1.05	0.16	0.62
400	-0.12	0.34	-0.21	0.56	-0.33	1.62	-0.10	0.39	-0.19	0.65	0.23	0.77	0.14	0.55
300	0.08	0.21	-0.06	0.16	-0.15	0.70	0.10	0.37	-0.04	0.14	0.24	0.78	0.11	0.40
200	0.11	0.32	-0.20	0.53	-0.21	0.96	0.21	0.82	-0.10	0.34	0.42	1.33	0.11	0.40
100	0.32	0.92	-0.09	0.24	0.33	1.22	0.42	1.64	0.01	0.03	0.09	0.27	-0.32	1.01
Mean	0.10	0.42	-0.18	0.48	-0.21	1.36	0.16	0.76	-0.12	0.42	0.37	1.21	0.09	0.61

Flow rate	France-Spain (---/NMI)	
	d_{ij}	E_{ij}
1000	-0.44	1.19
800	-0.41	1.11
650	-0.31	0.83
500	-0.16	0.43
400	-0.09	0.24
300	-0.14	0.36
200	-0.31	0.84
100	-0.41	1.11
Mean	-0.28	0.76

9. Summary and conclusion

The summary of results is mentioned down in the *tables 8, 9 and 10*. The independent laboratories are **light green**. The laboratories with traceability to Germany (PTB) are **light yellow**. The laboratories with traceability to Netherlands (NMI) are **light blue**.

The colour of letters and of numbers is red if there is the evaluation “failed” in tables. The colour of letters and of numbers is light orange if there is the evaluation “warning level” in tables. The colour of letters and of numbers is black if there is evaluation “passed” in tables.

The complete evaluation of each laboratory concerning the key comparison reference value in different flow rates is summarised in the *table 8*.

Table 8 – Evaluation summary of each laboratory from the point of view of key comparison reference values in different flow rates

Flow rate	Independent laboratories					Dependent laboratories							
	Germany	Netherlands	Poland	Switzerland	France	Austria	Hungary	Denmark	Lithuania	Slovak Rep.	Czech Rep.	Turkey	Spain
1000	passed	passed	passed	passed	warning	passed	failed	passed	passed	passed	passed	failed	passed
800	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	failed	passed
650	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	failed	passed
500	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	failed	passed
400	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	failed	passed
300	passed	passed	warning	passed	passed	passed	passed	passed	passed	passed	passed	warning	passed
200	passed	passed	failed	passed	passed	passed	passed	passed	passed	warning	passed	failed	passed
100	passed	passed	warning	failed	warning	passed	passed	passed	passed	passed	passed	passed	passed
Mean	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	passed	failed	passed

The complete evaluation of each laboratory concerning the mean coefficients E_i (equation [13]) and E_{ij} (equation [14]) is summarised in the *table 9*. In the **diagonal** there are the mean coefficients E_i which express the equivalence with the key comparison

reference value. In other cells there are coefficients E_{ij} which express the equivalence of one laboratory with another laboratory.

Table 9 -The complete evaluation of each laboratory concerning the mean coefficients E_i and E_{ij}

	Czech Rep.	Denmark	Austria	Germany	Netherlands	Lithuania	Slovak Rep.	Spain	Switzerland	Hungary	France	Poland	Turkey
Czech Rep.	0.12	0.15	0.07	0.09	0.22	0.22	0.37	0.48	0.23	0.48	0.42	0.63	1.02
Denmark	0.15	0.15	0.29	0.12	0.37	0.25	0.35	0.63	0.28	0.63	0.46	0.72	1.67
Austria	0.07	0.29	0.16	0.12	0.32	0.15	0.25	0.58	0.27	0.58	0.38	0.51	1.22
Germany	0.09	0.12	0.12	0.27	0.35	0.27	0.54	0.63	0.54	0.64	0.53	0.81	1.52
Netherlands	0.22	0.37	0.32	0.35	0.32	0.41	0.57	0.51	0.29	0.53	0.62	0.95	2.17
Lithuania	0.22	0.25	0.15	0.27	0.41	0.32	0.08	0.63	0.45	0.63	0.36	0.34	1.08
Slovak Rep.	0.37	0.35	0.25	0.54	0.57	0.08	0.57	0.77	0.66	0.77	0.47	0.39	1.37
Spain	0.48	0.63	0.58	0.63	0.51	0.63	0.77	0.61	0.42	0.26	0.76	1.07	0.61
Switzerland	0.23	0.28	0.27	0.54	0.29	0.45	0.66	0.42	0.61	0.49	0.76	1.06	1.36
Hungary	0.48	0.63	0.58	0.64	0.53	0.63	0.77	0.26	0.49	0.62	0.77	1.08	0.74
France	0.42	0.46	0.38	0.53	0.62	0.36	0.47	0.76	0.76	0.77	0.63	0.48	1.21
Poland	0.63	0.72	0.51	0.81	0.95	0.34	0.39	1.07	1.06	1.08	0.48	0.93	1.55
Turkey	1.02	1.67	1.22	1.52	2.17	1.08	1.37	0.61	1.36	0.74	1.21	1.55	1.65

The complete evaluation of each laboratory concerning the mean coefficients d_i (equation [11]) and d_{ij} (equation [12]) is summarised in the *table 10*. In the **diagonal** there are the mean coefficients d_i which express the equivalence with the key comparison reference value. In other cells there are coefficients d_{ij} which express the equivalence of one laboratory with another laboratory.

Table 10 -The complete evaluation of each laboratory concerning the mean coefficients d_i and d_{ij}

	Poland	France	Slovak Rep.	Lithuania	Austria	Germany	Czech Rep.	Denmark	Netherlands	Switzerland	Hungary	Spain	Turkey
Poland	-0.24	-0.12	-0.13	-0.14	-0.20	-0.22	-0.23	-0.23	-0.28	-0.29	-0.40	-0.41	-0.49
France	0.12	-0.12	-0.01	-0.02	-0.08	-0.10	-0.10	-0.11	-0.16	-0.16	-0.27	-0.28	-0.37
Slovak Rep.	0.13	0.01	-0.10	-0.01	-0.07	-0.09	-0.09	-0.10	-0.15	-0.15	-0.26	-0.27	-0.36
Lithuania	0.14	0.02	0.01	-0.10	-0.06	-0.08	-0.09	-0.09	-0.14	-0.15	-0.26	-0.27	-0.35
Austria	0.20	0.08	0.07	0.06	-0.04	-0.02	-0.02	-0.03	-0.08	-0.08	-0.20	-0.20	-0.29
Germany	0.22	0.10	0.09	0.08	0.02	-0.02	-0.01	-0.01	-0.06	-0.07	-0.18	-0.19	-0.27
Czech Rep.	0.23	0.10	0.09	0.09	0.02	0.01	-0.01	-0.01	-0.06	-0.06	-0.17	-0.18	-0.27
Denmark	0.23	0.11	0.10	0.09	0.03	0.01	0.01	0.00	-0.05	-0.05	-0.16	-0.17	-0.26
Netherlands	0.28	0.16	0.15	0.14	0.08	0.06	0.06	0.05	0.04	0.00	-0.11	-0.12	-0.21
Switzerland	0.29	0.16	0.15	0.15	0.08	0.07	0.06	0.05	0.00	0.05	-0.11	-0.12	-0.21
Hungary	0.40	0.27	0.26	0.26	0.20	0.18	0.17	0.16	0.11	0.11	0.16	-0.01	-0.10
Spain	0.41	0.28	0.27	0.27	0.20	0.19	0.18	0.17	0.12	0.12	0.01	0.17	-0.09
Turkey	0.49	0.37	0.36	0.35	0.29	0.27	0.27	0.26	0.21	0.21	0.10	0.09	0.26

The error curves of all participants and of the key comparison reference values are summarised in the graph mentioned down.

