EURAMET project No. 1046

Inter-comparison of water flow standards using electromagnetic flowmeters

Final report

Coordinators of the project

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Abstract

The Euramet comparison No. 1046 is a supplementary comparison of European national water flow laboratories. The comparison started in May 2008 and the measurements were finished in June 2009. Eleven laboratories took part in the comparison - namely: Austria (BEV), Bosnia and Herzegovina (IMBH), Czech Republic (CMI - pilot laboratory), France (CETIAT), Greece (EIM), Hungary (MKEH), Lithuania (VMT/LEI), Republic of Macedonia (BoM), Norway (Justervesenet), Slovakia (SMU) and Switzerland (METAS). Two electromagnetic flow-meters were used as transfer standards. Laboratories results were compared in a range of flow-rates between 1 m^3/h and 10 m^3/h with water at a temperature near to 20°C. The data were evaluated according to standard methods.

Contents

1. Introduction

At the beginning of the year 2008 European national water flow laboratories were invited to take part in an EURAMET supplementary inter-laboratory comparison which should verify their performance in the range of flows from 1 m^3/h to 10 m^3/h. Cold water with temperature near to 20°C was used. Laboratories of twelve European countries decided to take part in the comparison – namely: Austria (BEV), Bosnia and Herzegovina (IMBH), Czech Republic (CMI - pilot laboratory), France (CETIAT), Greece (EIM), Hungary (MKEH), Latvia (LNMC), Lithuania (VMT/LEI), Republic of Macedonia (BoM), Norway (Justervesenet), Slovakia (SMU) and Switzerland (METAS). Two transfer standards – electromagnetic flowmeters Krohne – were circulated among the participants over a period of approximately one year. This report summarizes the results obtained.

2. Participants and a time schedule

The meters were calibrated in twelve European laboratories as listed in Tab.2.1 below. Each laboratory had approximately two weeks for doing the measurements and for sending the meters to the following laboratory. Due to problems with customs documents the meters were delayed in Norway for two months. The meters were calibrated at the beginning, at the end and four times during the travelling period at the pilot laboratory to check their stability. During the measurements in Latvia some technical problems at their test rig occurred and therefore the data from LNMC are not included in this report. LNMC withdrew the participation in the comparison.

Country	Laboratory	Address of the place of calibration	e-mail telephone Fax	Date of calibration	Responsible person
Czech Republic (PILOT LAB)	CMI (CZ)	CMI Depatment of flow and heat Okruzni 31, 63800 Brno, Czech Republic	jgersl@cmi.cz llojek@cmi.cz Tel. +420 545 555 717 Fax. +420 545 555 183	19.5.-1.6. 2008	Jan Gersl Libor Lojek
Switzerland	METAS (CH)	METAS Laboratory Flow and Volume Lindenweg 50, CH-3003 Bern-Wabern Switzerland	hugo.bissig@metas.ch Tel. +41 31 32 34 915	2.6.-15.6. 2008	Hugo Bissig
Norway	Justervesenet (NO)	Justervesenet Fetveien 99 2007 Kjeller Norway	gks@justervesenet.no	16.6.-24.8. 2008	Gunn Kristin Svendsen
Czech Republic	CMI (CZ)			25.8.-7.9. 2008	Jan Gersl

Latvia	LNMC	LNMC Ltd Valdemara str. 157 Riga, LV-1005 Latvia	romans.zaharovs@lnmc.lv Tel. +371 67339213 Fax. +371 67362805	8.9.-21.9. 2008	Romans Zaharovs
Czech Republic	CMI(CZ)			22.9.-7.10. 2008	Jan Gersl
Republic of Macedonia	BoM (MK)	Bureau of metrology bul. Jane Sandanski 109a 1000 Skopje R.Macedonia	a.sarevska@yahoo.com Tel. +389 2 2403 676 Fax. +389 2 444 677	8.10.-19.10. 2008	Anastazija Sarevska
Greece	EIM (GR)	EIM Industrial Area of Thessaloniki Block 45, GR 57 022, Sindos Thessaloniki, Greece	zoe@eim.gr Tel. +30 2310 56 99 62 Fax. +30 2310 56 99 96	20.10.-2.11. 2008	Zoe Metaxiotou
Hungary	MKEH (HU)	Hungarian Trade Licensing Office Section of Flow Measurement Nemetvolgyi ut 37. H-1124 Budapest Hungary	czibulkacs@mkeh.hu Tel. (+36-1) 4585 853 Fax. (+36-1) 458 5927	3.11.-16.11. 2008	Csaba Czibulka
Slovakia	SMU (SK)	SMU Karloveska 63 842 55 Bratislava Slovakia	benkova@smu.gov.sk Tel. +421 2 602 94 202 Fax. +421 2 602 94 332	17.11.-1.12. 2008	Miroslava Benková
Czech Republic	CMI (CZ)			2.12.-8.12. 2008	Jan Gersl
Austria	BEV (AT)	BEV Arltgasse 35, A-1160 Vienna, Austria	petra.milota@bev.gv.at Tel. +43 1 21110-6524 Fax. +43 1 21110-6000	9.12.-19.12. 2008	Petra Milota
France	CETIAT (FR)	CETIAT Domaine Scientifique de la Doua 54 avenue Niels Bohr 69100 Villeurbanne France	christopher.david@cetiat.fr Tel. +33 (0)4 72 44 59 45 Fax. +33 (0)4 72 44 49 49	12.1.-25.1. 2009	Christopher David

Lithuania	VMT/LEI (LT)	Lithuanian Energy Institute Breslaujos str. 3, LT-44403 Kaunas, Lithuania	zygmanta@mail.lei.lt testlab@mail.lei.lt Tel. +370 (37) 401 861 Fax. +370 (37) 351 271	26.1.-8.2. 2009	Gediminas Zygmantas
Czech Republic	CMI(CZ)			9.2.-1.4. 2009	Jan Gersl
Bosnia and Herzegovina	Institute of Metrology of Bosnia and Herzegovina (BA)	Institute of Metrology of Bosnia and Herzegovina Dolina 6 71000 Sarajevo Bosnia and Herzegovina	zijad.dzemic@met.gov.ba Tel. +387 33 275 642 Fax. +387 33 714 711	2.4.-17.4. 2009	Zijad Dzemic
Czech Republic (PILOT LAB)	CMI (CZ)	CMI Depatment of flow and heat Okruzni 31, 63800 Brno, Czech Republic	jgersl@cmi.cz llojek@cmi.cz Tel. +420 545 555 289 Fax. +420 545 555 183	18.4.-30.6. 2009	Jan Gersl Libor Lojek

Tab.2.1 Participants and the time schedule

3. Transfer standards

Two electromagnetic flowmeters KROHNE IFM 5080K of the same parameters were used as the transfer standards. The meters belong to BEV, Arltgasse 35, Wien, Austria and were borrowed by CMI for the purpose of the interlaboratory comparison. The identical meters were used for a comparison project EUROMET No. 669 organized by BEV in years 2002 – 2005. The meters were manufactured by:

KROHNE Altometer
Kerkeplaat 12
3313 LC Dordrecht
The Netherlands

The meter with serial number A01 13857 is denoted as No.857 and the meter with serial number A01 13858 is denoted by No.858 in the text. The inside nominal diameter of the meters is DN 25 (27.5 mm). They are equipped with fixed inlet and outlet straight pipe sections (Fig.3.1). The dimensions of pipes and the meter are shown in Fig.3.2. The output pulse rate is 1 kHz at a flow of 10 m^3/h, the active pulse output was used. Both meters were provided with a power supply stabilizer (see Fig.3.1). Flanges of the type DN 25 DIN 2527 PN 16 were used.
During transports the meters were packed in wooden boxes depicted in Fig.3.3.
Some of the specifications of the meters are summarized in Tab.3.1.

Serial no.	A01 13857	A01 13858
Pulse output	active (amplitude 15 V)	active (amplitude 15 V)
Output pulse rate	1kHz for 10 m^3/h	1kHz for 10 m^3/h
Time constant	ONLY I (switched off for pulse output)	ONLY I (switched off for pulse output)
Cut - off	OFF	OFF
GK	3.742	3.819
Power supply	(200 – 260)V AC/ 50 Hz	(200 – 260)V AC/ 50 Hz

Tab.3.1 Parameters and settings of the meters

Fig.3.1 – The electromagnetic flowmeter KROHNE

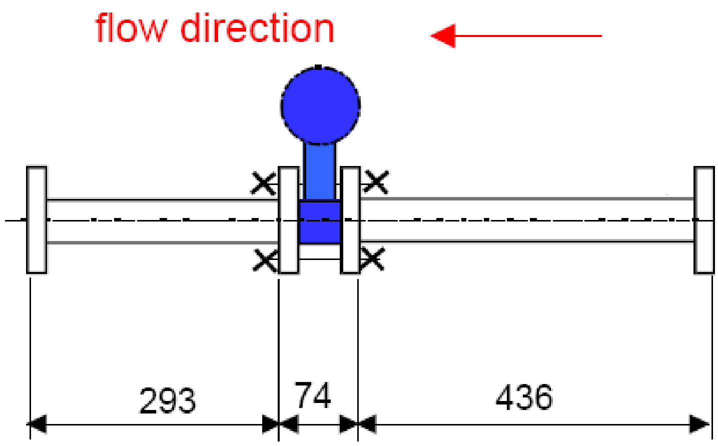


Fig.3.2 - Dimensions of the meters in milimeters

Fig.3.3 – The wooden boxes for the transfer standards

4. Test procedure

4.1 Method

The participating laboratories used their usual calibration procedure.

4.2 Reference conditions

- The calibration medium: water with el. conductivity ≥ 200 μS/cm
- Water temperature: (20 ± 5)°C , as near to 20°C as possible
- Water pressure downstream of the meter: (2 ± 1) bar
- Ambient temperature range: 15 °C to 25 °C
- Ambient relative humidity range: 45 % to 75 %
- Ambient atmospheric pressure range: 86 kPa to 106 kPa (0.86 bar to 1.06 bar)

If a laboratory does not meet the requirement for the water conductivity the water which they have was used and the actual value of conductivity was included in the results report.

4.3 Instructions for measurement

- Both flowmeters were examined separately under the same conditions.
- Both flowmeters were examined for the following 5 values of reference flow *Q*: (1.0 ; 2.5; 5.0; 7.5; 10.0) m^3/h.
- The etalon value of flow has to be in an interval ± 3% of the reference value for each single measurement.
- The test in one flow should be repeated at least 10 times.
- The flowmeter has to be installed in the test rig such that possible disturbances of the flow velocity field in the meter due to imperfect smoothness of the connection of pipes are minimized.
- Before the first measurement of a series is performed the power supply stabiliser and the signal convertor of the transfer standards should be powered at least for 30 minutes to allow for stabilisation.

- Before starting the first measurement, the transfer standard should be filled with water for at least 1 minute.
- The pulse output of the meters will be used.
- The inlet and outlet pipes and the power supply are an integral part of the travel standard and should not be disconnected at any time. Also the parameters of signal convertors should not be changed.
- The power stabiliser connected to the transfer standard should be as far away as possible from the signal convertor and the test rig pulse counter to avoid possible electromagnetic disturbance.

5. Overview of participants' facilities and measurement methods

Czech Republic – CMI

Facility description

The test rig of Czech metrology institute (Fig.5.1) was fabricated by a Czech company ENBRA. The facility enables to use the gravimetric methods with flying or standing start/stop. As the main standards two balances Mettler-Toledo KCC 300 and KES 3000 with electromagnetic force compensation are used. Flow and the water pressure can be adjusted by a pump frequency and by a system of pipes and valves behind the test section. The main technical parameters of the test rig are summarized in Tab.5.1.

Fig.5.1 The water flow test rig of CMI

Range of flows:	(0,05 - 150) m^3/h
Range of diameters:	DN 15 - DN 150
Maximum pressure:	2,5 MPa
Medium:	Cold potable water
Water temperature:	20 ± 5 °C
Minimum test volume:	50 dm^3
Maximum test volume:	3000 dm^3
Methods of measurement:	Gravimetric, flying start/stop
	Gravimetric, standing start/stop
Expanded uncertainty:	0,07 % - 0,10 %

Tab.5.1 The main technical parameters of the test rig of CMI.

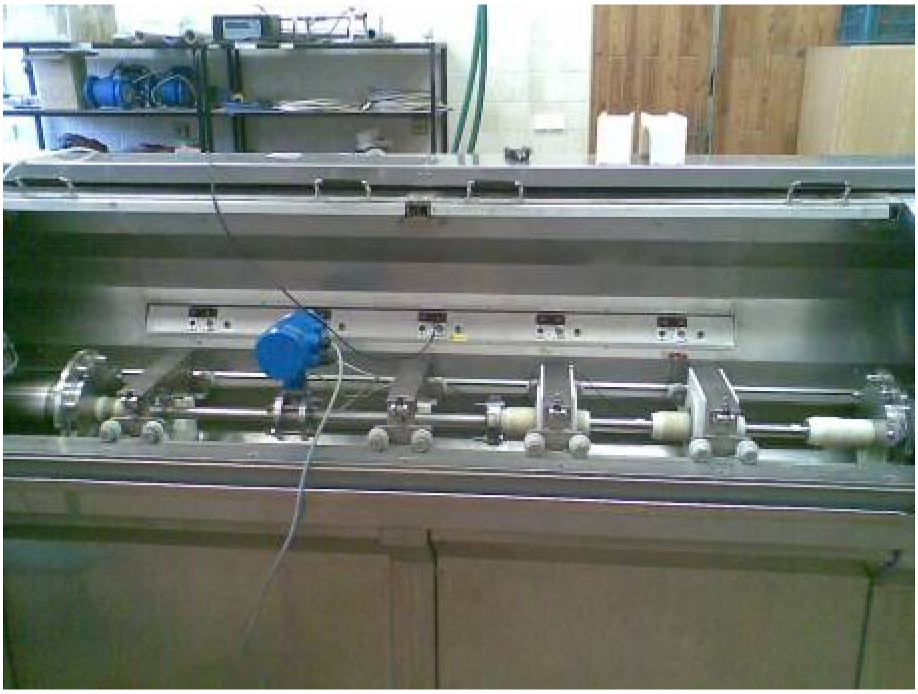


Fig.5.2 Installation of the meter

Test procedure
The meter was installed into the test rig as illustrated by Fig.5.2. The inlet straight pipe in front of the pipe fixed to the meter was 88.6 cm long. The outlet straight pipe installed behind the pipe fixed to the meter was 20.2 cm long. No flow straightener was used. The electronics was switched on at least one hour before measurement. The water in the test rig was cooled down to a temperature of approximately 18°C. The cooling took more than three hours depending on the initial temperature. During this time the meter was kept filled with water. After that air was removed from the test rig and the measurements started. The measurements were done from the lowest flow to the highest one, each flow ten repetitions. The gravimetric method with flying start/stop was used.

Switzerland – METAS

Facility description
The basic principle of the test facility is based upon two tanks of 700 litres, where different pressures are generated. The pressure difference between the two tanks induces the flow from the high pressure tank to the low pressure tank. The overpressure is realised by means of the internal compressed air network which has to be at least at 10 bar in order to generate the maximum flow. The high pressure tank we have roughly 9 bar, while in the low pressure tank we have only 4 bar.
At the gravimetric flying start-stop procedure the water circuit is opened as the water passed through the DUT is first conducted to the drain. The switch over of the passed water onto the balance is regulated by a mechanical diverter.
The overpressure and the temperature in the tanks as well as the water recirculation between the two tanks are controlled by the software.

Test procedure
The measurements are done at the test facility with adjustable water temperature. The calibration is done by means of the gravimetric flying start-stop procedure. The determined volume flow is then compared to the amount of pulses generated by the DUT multiplied by the pulse weight.

Norway – Justervesenet

Facility description

Water is circulated from a 9000 dm^3 sump tank through a closed loop with a pump. The loop is comprised of the transfer standard, a three way diverter valve and a weighing tank. The diverter valve controls the water flow, either looped back to the sump tank or collected within the weighing tank. The diverter is a closed type based on two ball valves mounted on each outlet branch of the symmetric T-pipe.

Test procedure

The transfer standards were mounted one by one into the pipeline with 1 meter DN25 straight inlet pipe 0.5 meter straight outlet pipe. No flow straighteners were used. The test was performed using the gravimetric method with flying start and stop. Water is flowing continuously while the diverter is used to switch the flow from the sump tank into the weighing tank for a timed period. The mass of fluid in the measured time interval is measured and converted to volume through known water density. This volume is then compared to the volume indicated by the transfer standard. Indicated volume of the transfer standard is achieved by counting the number of pulses during the same timed period and using the transfer standards quoted output pulse rate. The balance is checked with weights for every repetition.

Flow range:	(0.36 - 90) m^3/h
Temperature range:	(10 – 90) °C
Flow medium:	Water
Range of diameters:	DN 10 - 150
Balances:	Mettler Toledo KE 5000, sensitivity 10 g
Reference meters:	Micro Motion CMF300
Methods of measurement:	Gravimetric weighing with flying start/stop
	Gravimetric weighing with standing start/stop
	Master meter (Micro Motion CMF300)

Tab.5.2 Specifications of JV flow test loop

Fig.5.3 T-pipe section of the test flow rig at JV

Republic of Macedonia - BoM

Facility description

The reference standard (OT1500 Piston Prover) used belong to BOM with serial number 05418 manufactured by Trigas FI GmbH. The traceability is to PTB through Trigas FI GmbH.
The OT1500 Calibrator uses a piston within a smooth bore tube to act as a moving barrier between the pressurizing gas and the displaced test fluid. It generates a continuous train of electrical pulses by use of a linear encoder/translator attached to the piston. Each pulse represents an extremely small but very precise volume of fluid.
The OT1500 consists of a precision honed measure flow tube, a flow piston and shaft, a photoelectric sensor (encoder), associated valves, supply tank, and a counter to count and display the data.
Air pressure is introduced to the upstream side of the piston to provide fluid power for the calibration. Downstream of the piston, the system is flooded and fully bled with the fluid used to calibrate the flowmeter. The run valve operates to permit the calibration run and the flow is controlled by operation of the throttling valves. As the piston moves down the precision honed flow tube dispensing fluid in precise manner through the flowmeter under test, it also moves the photoelectric sensor past the etched glass rule. The encoder produces an electrical pulse each time an etched line interrupts the light beam impinging on it. The frequency of the continuous pulse train produced by the OT1500 during a calibration is proportional to piston velocity and thus to the flow of fluid dispensed from the tube. The total pulse count is directly proportional to the volume of fluid displaced by the piston.
The piston is returned to the upstream position for another run by venting the air from the upstream position, air pressure is removed and vented from the surge tank. This method of piston positioning does not pass the fluid through the flowmeter during the return function.
The pulses are collected by a counter which collects the pulses from the OT1500 and the UUT (flowmeter) at the same time. (method of double chronometry). Double Chronometry is a technique for use with positive displacement calibrators. It minimizes uncertainty by insuring that during data acquisition , whole (undivided) pulses are counted and timed for both the flowmeter under test and the linear encoder used in the calibrator. This technique eliminates the possibility of including unknown fractions of a pulse in the calibration time interval, thus, avoiding an uncertainty that is potentially large, especially at low flows where the pulse count is small for both flowmeter and linear encoder.
The testing section length is equal to 100 cm. After installation of the flowmeter we check the leakage in the testing section. For this purpose we run the piston in downstream position with the operating handle in RUN position.
If there is no leakage in the testing section we should vent the residual air in the system.

Test procedure

After proper mechanical installation of the Unit Under Test (UUT) there is no leakage, no air bubbles in the system we continue with the electrical installation of the UUT. Detection of the pulse output is provide by Fluke scope meter and then it is connected to counter 1. Active wire to red connection and passive wire to the black connection from the counter 1. The yellow-green wire is the ground wire and it is connected to the special grounding provided to the laboratory.

1. Before the start of the calibration we should prepare the counters for counting (means pressing the buttons by the following order STOP,RESET and START)
    - Move the operating handle in the RETURN position
    - When the piston reaches the upstream position (full cylinder) wait for the counters to stop counting
    - Prepare the counters for counting (means pressing the buttons by the following order STOP,RESET and START)
    - Move the operating handle in the NEUTRAL position
    - Wait for the counters to stop counting and then press the buttons STOP and RESET
    - Move the operating handle in the RUN position
    - Arrange flow by three valves for min flow , middle flow and max flow during the first run. (current value of the flow is followed by the third line from the counter)

- For constant flow the value in the third display should be constant.

2. After flow is stable, activate the counter by pressing the button START
   - After short time interval (estimated by the staff) stop the counters by pressing STOP
   - Move the operating handle in the NEUTRAL position
   - Fill the calibration protocol with the values displayed by the counter 1 (total pulses N1 from the UUT) and counter 2 (total pulses N2 from the piston prover) and RUN time (time interval t).
3. Repeat steps 1 and 2 for each measurement point at least 10 times in identical conditions.
4. If the standard deviation between measurement results is greater than 0.05% reject the value with max deviation from the mean of the measurement results and repeat the measurements until you reach a standard deviation lower than 0.05%.

During calibration, the temperatures of calibration liquid and measuring devices did not deviate by more than 1 K from the temperature of the calibration room.
Measurements are to be carried out, if possible, in a short interval of time to guarantee identical conditions.

Fig.5.4 The test rig of BoM

Greece - EIM

Facility description
The water flow test facility, manufactured and installed in our laboratory in the year 2007 by the Finish company VEMIT Kalibro Oy, was used for the calibration of the transfer standards of this inter-comparison. The test facility operates according to the gravimetric principle with diverter in a flying start stop (FSS) and a standing start stop (SSS) mode. In the framework of this comparison only the FSS mode was used. The test facility is equipped with three Mettler Toledo balances as well as three reference meters. More details about the technical specifications of the system are given in Tab.5.3.

Type :	VEMIT Kalibro D50 / 4 / 30 CH
Flow range :	0.006 …. 30 m^3/h
Temperature range :	Ambient … 70 ^oC

Balances :	Mettler Toledo KCC 150, sensitivity 1g
	Mettler Toledo KC 501, sensitivity 0.1 g
	Mettler Toledo KC 1500, sensitivity 1 g
Reference meters :	KROHNE Optiflux 6000 F (3 pcs)
Thermal stability :	Double piping, thermal insulation, air & water circulation in the test section
Test flowmeter installation :	Hydraulic compression
Operation :	Fully automated

Tab.5.3 Specifications of VEMIT Kalibro water flow test facility

Test Procedure
The transfer standard was attached to the flow facility at the outer left position of the test section, providing in this way the longest possible inlet straight pipe length available for the development of a disturbance-free flow profile. This inlet straight pipe length was approximately 2100 mm long corresponding to a distance over 80D (Fig.5.5).

Fig.5.5 Installation setup

The development of a disturbance-free flow profile is also aided by the use of a flow straightener which is installed just before the entrance to the test section. After installation of the meter the air is removed from the flow line by operation at low pressure and the meter is left filled with water for at least one hour. During that time the power supply stabilizer and signal converter of the transfer standard are powered to allow for stabilization of the electronics.
In the mean time, the flows to be tested, the volumes of water to be measured, the K-factor of the meter and all other experimental parameters are filled in the test protocol used by the software of the system to control and execute the calibration.
After a 1-hour long preconditioning stage the signal of the transfer standard is checked with an oscilloscope for its shape and frequency.
The calibration is launched starting with the highest flow. The calibration cycle is repeated 10 times for TS No 857 and 15 times for TS No 858. All calibration raw data are automatically stored in a database.

Hungary – MKEH

Location of calibration: Tiszateszt Méréstechnikai Kft., H-4440 Tiszavasvári, Kabay J. út 29. (www.tiszateszt.hu)

Facility description

The water medium test rig is capable of providing volume flows from 90 liter/hour to 300 m^3/hour with the gauge pressure ranging from 0.5 to 4 bar. The 300 m^3/h volume flow is provided by four separately controlled water pumps connected in parallel. Static and flying start-stop measuring methods are both available with either one of the four electromagnetic reference flowmeters or the hopper scale. A diverter is used for flying start-stop method with weighing scale standard. The scale contains a 3 m^3 tank, hanging on 3 cell's. The maximum load is 3000 kg, and has 4 separate working ranges with different resolutions:

working range	resolution
(30...150) kg	10 g
(150..600) kg	20 g
(600...1500) kg	50 g
(1500...3000) kg	100 g

Tab.5.4 Parameters of weighing systém of MKEH

The Meter Under Test (MUT) can be fitted horizontally, providing the requested up and downstream pipe length. The reference flowmeters with different nominal diameters are fitted in parallel, vertically. The diverter is the highest point in the system. From there, water falls into the collecting tanks situated under the floor, next to the pumps, or into the scale's tank. Water is emptied from the scale's tank by gravity. The pipes are thermally isolated, except the ones that are used for fitting in the MUT. The pumps have a joint intake manifold fed by both collecting tanks, and they pump the water to a common pipe. The required flow along with the pressure is set by the frequency controlled pumps and the controlling valves placed after the MUT. A sight glass is used to monitor the air bubbles in the system, and there are two manually controlled valves before and after the MUT to eliminate air from the system. Valves that took part in starting and stopping the measurement are controlled automatically by a PLC. The PLC does the signal processing, the pump controlling and communicates with the scale's electronics and a PC. Parametering can be done either from the PC or the PLC's control panel. All correction, linearisation of the reference meters, density etc. are executed only by the PC. The raw and corrected results are collected in a read only database.

There was no flow straightener used during measurements. The length of the inlet pipe was 2,5 meter, the length of the outlet pipe was 1 meter.

Test procedure

The measurements were carried out using the static start-stop method. The required flow was provided by the same and only one pump through the whole range. Its max. flow is 20 m^3/h. The rig has been primed before the actual measurements. (Filled with water and circulating for no less than 10 minutes). The requested flow was set by the displayed flow of the MUT, before each new flow. The required volume for one measurement was chosen so that the minimum 60 seconds measuring time and the minimum of 1000 impulses from the MUT was realised.

Fig.5.6 Test rig of MKEH (Hungary)

The high frequency counter of the PLC has been reset, the scale's tank has been emptied fully, the valve at its bottom has been closed, then the scale was zeroed before every measurements. Pressing the start button opens the valves, starts the pump. The required flow was reached within 2-3 seconds, and kept constant until the end of the measurement.

The valves located after the pumps and after the reference flowmeters are shut at the same time, when the last incoming pulse corresponding to the required volume is counted. Impulse counting did not stop until the end of the measurement. The same amount of time has been taken to wait for the water to drain every drop into the scale's tank at the end of every measurement. The measurement was ended with saving all the measured parameters with pushing of a button. The measured mass was corrected with upthrust, then calculated to volume (reference volume) with a density that has been calculated from the water temperature measured after the MUT. The reference volume flow was calculated from the reference volume and the time measured while the valves were open.

During measurements, the diverter was not used, it always directed the water into the scale's tank.

Slovakia – SMU

Facility description
Establishment of the national standard of flow and of delivered volume of water is constructed taking into consideration the requirements for quality system and requirements for possibility of measuring instruments tests. These tests are based on the different measuring principles with requirement to use different measuring methods (weighing or volumetric with flying or fixed starts with direct reading of impulses or a method of complete impulses). Also measuring instruments with mechanical counter, passive impulse output and active impulse output can be used. The device is composed of the following

parts - source of flow with a system of overflow tank, measuring lines – small and medium measuring lines, flowmeter branches, 3 different weighing systems and controlling system of measurement. The main parameters of equipment are:

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

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

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

Tab.5.5 Installation parameters of SMU

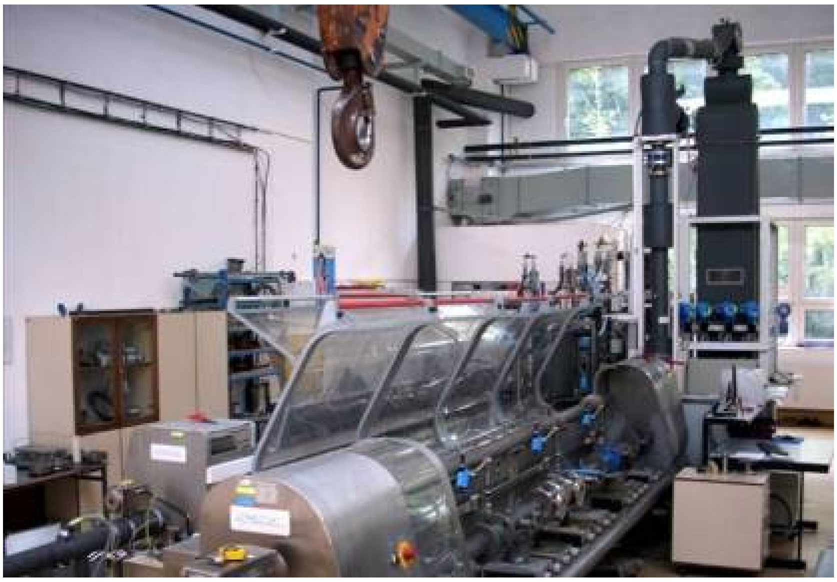


Fig.5.7 View at the national standard of flow and delivered volume of water (SMU, Slovakia)

Austria - BEV

Facility description
The test rig was built in 1998. It allows measurements for cold-, and hot water- as well for heat meters.
Possible diameters of test meters: Up to DN 150. Our test rig allows the control of the flow in the range of 6 l/h up to 180 000 l/h and the temperature from 4 °C to 90 °C. Additionally we can perform

measurements with pressures up to 6 bar, thereby increasing the temperature range up to 120° C. Our facility consists of three storage tanks with a total volume of 7 m³. The pipes from the storage tanks to the test rig are heated by a double shell system to guarantee constant temperature conditions inside the test rig.

The master meter is a magnetic-inductive flowmeter with ceramic coating. Primary measuring standards for the test volume are scales. Furthermore, the influence of the evaporation of the water inside the containers on the weighing instrument is eliminated by determining the absolute humidity before, during and after a measurement. Also the influence of buoyancy in humid air is considered. The calibration procedure for water meters can be carried in different manners. In the "flying mode" the flow will be built up by which the water meters will be calibrated later on; doing so the water is deflected back to the storage tank immediately (closed loop mode). Having reached stationary conditions with regard to constant flow, pressure and temperature the volume flow will be by-passed to the scales selected by means of one of the two diverters. Provided the test volume selected is reached the diverter lets the volume flow return to the storage tanks. In all modes, including the "flying mode", the scales are used as measuring standards. The measuring procedure is controlled by the meter to be tested themselves by triggering a start pulse for the comparison measurement with the master meter. The pulse rate of the master meter is very high which leads to a high resolution of the comparison measurement. Simultaneously, i.e. at each testing point, the measuring deviation of the master meter is determined by the weighing instrument. The whole determination of the measuring deviation of the meter to be tested depends on the calibration of the scales used, the accuracy of the determination of density and buoyancy as well as on the switching procedure which deflects the volume flow for the measuring procedure from "closed loop mode" into the container at the weighing instrument and vice versa.

For the current tests the length of the straight inlet pipe (to the first fixed flange of the flowmeters) was 2.0 m with an DN 150 inlet flange. The oulet length was 1.3 m with an outlet flange of 5.5 cm in diameter. No flow straightener has been used.

Master meter (KROHNE IFC 110)	**Flow range [l/h]**	**Pulse rate**
MID 1	$6 \leq Q < 150$	10^4
MID 2	$150 \leq Q < 1800$	10^3
MID 3	$1800 \leq Q < 17000$	10^2
MID 4	$17000 \leq Q < 180000$	10
Scale	**Maximum load [kg]**	
No 1 Mettler ID 1 Plus/KCC 150	120	
No 2 Mettler ID 1 Plus/KCS 600	600	
No 3 Mettler ID 1 Plus/KE 3000	3000	

Tab.5.6 Some parameters of the test rig of BEV

Test procedure

Each meter has been tested separately ten times in the following order:
Q/V (Q [l/h] and V [l]) = 1000/500, 2500/1000, 5000/2500, 7500/2500 and 10000/2500 in the "flying mode".

Fig.5.8 Installation of the transfer standards at BEV

France – CETIAT

Facility description
CETIAT facility was created in 1980 for industrial purpose and became the French designated institute for water flow measurements in 2002 (LNE – CETIAT). This gravimetric test rig uses a start/stop method to measure the reference water flow. Calibration can be done on delivered mass or mass flow measurements using three Mettler Toledo balances. Delivered volume and volume flows can also be obtained using the same protocol and water density. One of the main advantages of this calibration rig is the possibility to change the temperature of water easily.

Flow	0.008 $m^3.h^{-1}$ to 36 $m^3.h^{-1}$
Fluid	Water
Pipe diameter	DN 1 to DN 100
Pressure range	1 bar to 3 bar
Water temperature	15°C to 90°C
Method of measurement	Gravimetric
Expanded uncertainty	0,05 % to 0,16 %

Tab.5.7 Main technical parameters of CETIAT's test rig (France)

Fig.5.9 Part of the water flow calibration facility of CETIAT (France)

Test Procedure
The meters were installed in the test rig as illustrated below and no flow straightener was used. The temperature regulated water is sent to a constant head tank (10 m above the laboratory) which discharges at constant pressure (~1 bar) through the flowmeter under calibration. During calibration, the liquid flows constantly through the device under test (DUT) and a diverter enables to switch the flow either to the weighing tank or to the storage tank. This switching is synchronised with electrical pulses sent by the DUT (or with a manual switch). A stopwatch and an electronic counter are utilized (started and stopped) simultaneously and results are then used to calculate the flow.

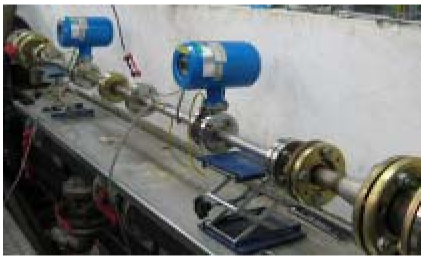


Fig.5.10 Installation of the meters in the CETIAT's test rig (France)

Lithuania – VMT/LEI

Facility description

Parameter	Specifications	
Mass flow (qm)	0.01 - 100 000 kg/h	
Volume flow (qv)	0.01 - 100 000 l/h	
Pipe dimension (DN)	Line №1	max. 100 mm
	Line №2	max. 50 mm

Water temperature - medium			18°C – 25 °C (50°C)- not accredited
Reservoir tank			10 m^3
Scales			1500 kg + 60 kg (Line №1)
			600 kg + 60 kg (Line №2)
Straight pipe length upstream			4.0 m (Line №1)
			1.0 m (Line №2)
Length of working zone			2.0 m (for bought lines)
Calibration principle	Calibration using mass and time (primary)	Flying start-stop with the use of a diverter	YES
		Standing start-stop	YES
	Calibration with a reference meter (secondary)	Flying start-stop with the use of a diverter	YES
		Standing start-stop	YES

Tab.5.8 Technical parameters of flow facility of VMT/LEI

Fig5.11 Water flow laboratory of VMT/LEI (Lithuania)

Fig.5.12 Installation of the meter in VMT/LEI

Bosnia and Herzegovina - IMBH

Facility description

Calibration method: volumetric with standing start/stop.

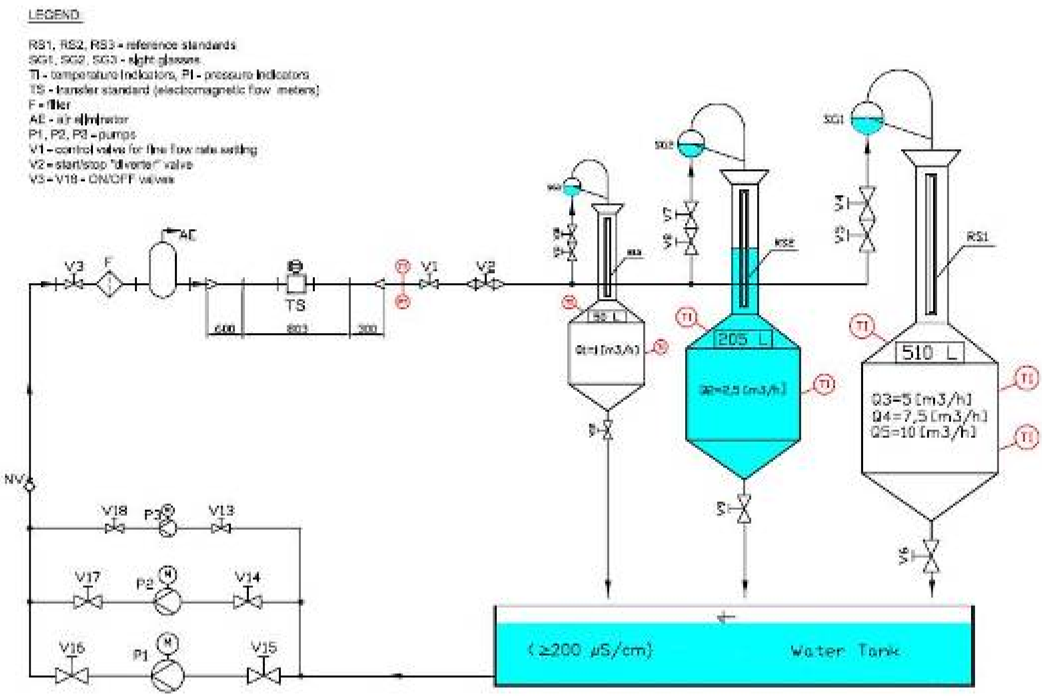


Fig.5.13 Scheme of the test rig of IMBH (Bosnia and Herzegovina)

Fig.5.14 The facility of IMBH.

6. Measurement results

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

6.1 Definitions of the collected quantities

The particular repetitions of measurement for given reference flow and a given meter are labelled by an index α. The values of this index can be α = 1,…, N, where N is the number of repetitions.

Q_E … The mean etalon value of flow, i.e. the mean of $Q_{E\alpha}$

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

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

E … The mean relative error of the meter, i.e. the mean of E_α given as

$$E_\alpha = \frac{V_{T\alpha} - V_{E\alpha}}{V_{E\alpha}}.100\,, \qquad (1)$$

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

N … The number of repetitions

V_E … The mean volume indicated by the etalon, i.e. the mean of $V_{E\alpha}$

T … The mean temperature of the water used for the test

p… The mean pressure downstream of the meter
U_A … The type A uncertainty of *E* for level of confidence 95% (k=2)
U_B … The type B relative uncertainty of the etalon value of flow for level of confidence 95%
U … The combined uncertainty for level of confidence 95%

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

$$u_A^2 = \frac{1}{N(N-1)} \sum_{\alpha=1}^{N} (E_\alpha - E)^2 , \qquad (2)$$

$$U_A = 2u_A , \qquad (3)$$

$$U^2 = U_A^2 + U_B^2 . \qquad (4)$$

6.2 Deviations from the parameters prescribed

Below one can find a list of deviations of the real measurement parameters from the ones prescribed in the instructions:

FR – both meters in series, out of ambient temperature range
NO – water conductivity 69.9 µS/cm, water pressure not measured
CH, GR, SK, BA – out of water pressure range
BA – out of water temperature range
NO, GR, SK, FR, LT – out of ambient humidity range
CH – out of ±3 % tolerance for flow (meter No. 857, 858; 10 m^3/h)
NO – out of ±3 % tolerance for flow (meter No. 857; 1 m^3/h, 5 m^3/h)
SK – out of ±3 % tolerance for flow (meter No. 858; 7.5 m^3/h)

The impact of the deviations from the prescribed range of flows depends on the calibration curve of the transfer standards *E(Q)*. The error shift is then calculated as

$$E(Q_{actual}) - E(Q_{nominal}) . \qquad (5)$$

The quantitative effect of the deviations from the prescribed flow is discussed later in the section 8.2.
The deviations in ambient conditions also does not affect the measurement significantly as well as the water conductivity.
Measurement in series means that the flow profile in both meters will not be the same during the measurement. It does not affect the part of evaluation of the data where both of the meters are treated separately. It could have some influence on interpretation of correlations between the data from the two meters.
If the water pressure influence is based only on the elasticity of the pipe of the meter then the error change caused by pressure change in percent will be given by

$$-\frac{\Delta p . r}{d . E_{young}} .100 \qquad (6)$$

where Δp is the pressure change, *r* is the pipe radius, *d* is the wall thickness and E_{young} is the Young's modulus of the wall. The inner wall of the pipe in the measurement area of the flowmeter used for the comparison is made from a ZrO_2 ceramics with Young's modulus between 100 and 200 GPa. For a

pressure change of 6 bar this gives an error change of order of 10^{-5} %. Therefore any pressure corrections are not necessary for the data of the comparison since the pressure differences between labs are not greater then 6 bar.
Similarly if the influence of the water temperature can be reduced to the change of the pipe size of the meter then the error shift as a function of the temperature shift is given as $-\alpha\Delta T.100$, where the value of α is approximately 10^{-5} °C^{-1}. For a temperature change of 10°C it corresponds to 0.01 %. Even if this is not of a great significance it is worth looking to the influence of temperature change more closely. The temperature dependence of the error curve of the transfer standards was measured at CMI and at BEV and the results are summarised in section 8.1.

6.3 Stability measurements at CMI

A calibration curve of both meters was obtained at CMI six times during one year of the circulation of the meters. The results of the measurements are summarized in Tab.6.1 and in Fig.6.1 and Fig.6.2.

Meter No. 857							
date	Q	m^3/h	1	2.5	5	7.5	10
21.5.2008	E	%	-0.077	-0.130	-0.090	-0.048	-0.040
1.9.2008	E	%	-0.086	-0.179	-0.136	-0.095	-0.079
5.12.2008	E	%	-0.100	-0.152	-0.107	-0.078	-0.063
15.5.2009	E	%	-0.074	-0.161	-0.122	-0.086	-0.068
19.6.2009	E	%	-0.065	-0.122	-0.067	-0.026	-0.010
23.6.2009	E	%	-0.040	-0.115	-0.069	-0.028	-0.013

Meter No. 858							
date	Q	m^3/h	1	2.5	5	7.5	10
22.5.2008	E	%	-0.068	-0.186	-0.164	-0.127	-0.116
29.8.2008	E	%	-0.042	-0.153	-0.121	-0.091	-0.083
3.12.2008	E	%	-0.076	-0.170	-0.152	-0.120	-0.105
14.5.2009	E	%	-0.082	-0.204	-0.183	-0.150	-0.136
4.6.2009	E	%	-0.085	-0.211	-0.179	-0.152	-0.135
22.6.2009	E	%	-0.092	-0.214	-0.199	-0.159	-0.148

Tab.6.1 Errors of the meters obtained at various times at CMI. Expanded uncertainty is always 0.07 %.

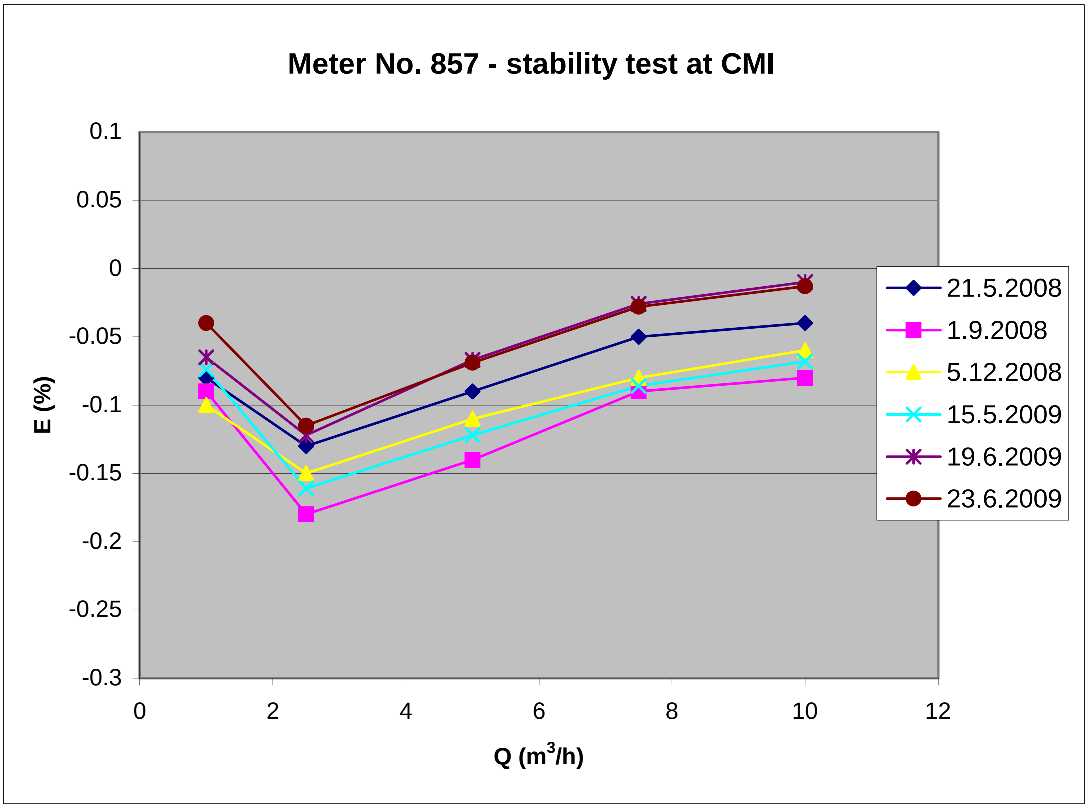


Fig.6.1 Calibration curves – meter No.857, various times

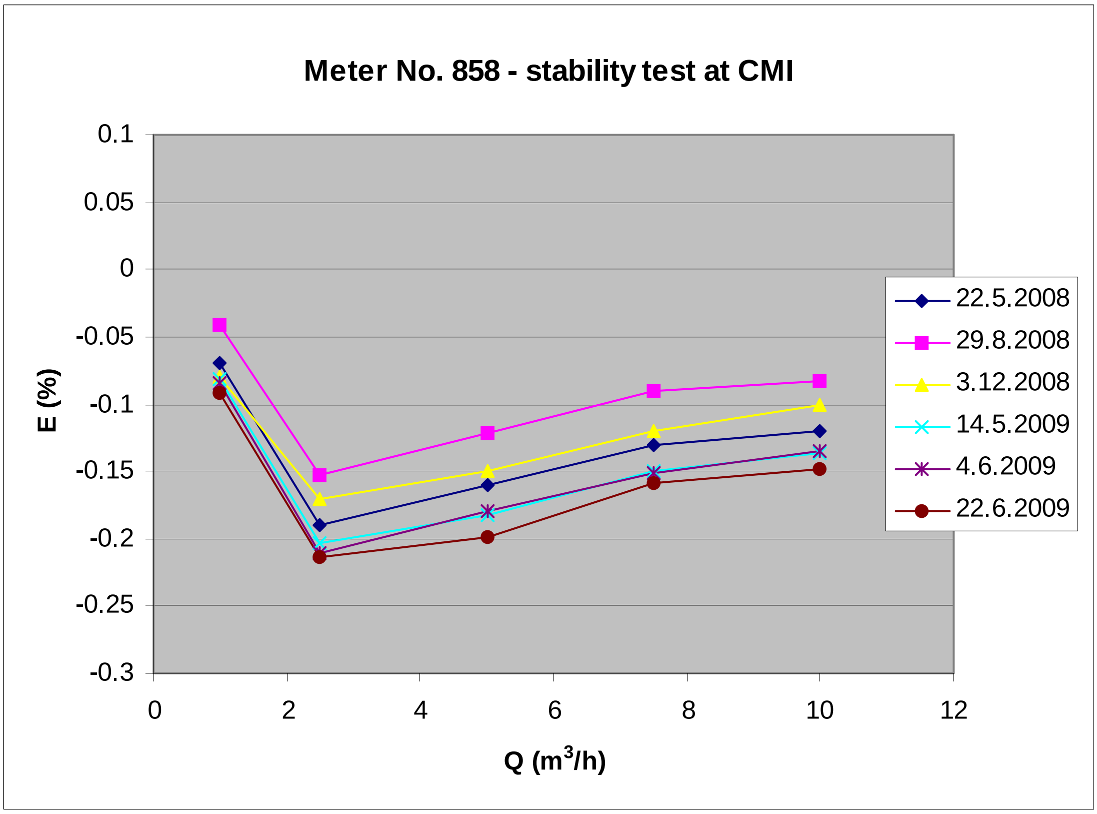


Fig.6.2 Calibration curves – meter No.858, various times

7. Evaluation

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

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

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

$$y = \frac{\frac{x_1}{u_{x1}^2} + \frac{x_2}{u_{x2}^2} + \dots\dots\dots \frac{x_n}{u_{xn}^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots\dots\dots \frac{1}{u_{xn}^2}} \,, \tag{7}$$

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

$$u_{xi} = \sqrt{\left(\frac{U(x_i)}{2}\right)^2 + u_{st}{}^2} \,, \tag{8}$$

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

$$u_{st} = \frac{(E_{\max} - E_{\min})}{2\sqrt{3}} \,. \tag{9}$$

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

$$\frac{1}{u_y^2} = \frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots\dots\dots \frac{1}{u_{xn}^2} \,. \tag{10}$$

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

$$U(y) = 2.u_y \,. \tag{11}$$

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

$$\chi^2_{obs} = \frac{(x_1 - y)^2}{u^2_{x1}} + \frac{(x_2 - y)^2}{u^2_{x2}} + ... + \frac{(x_n - y)^2}{u^2_{xn}} . \qquad (12)$$

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

$$\Pr\{ \chi^2_\nu > \chi^2_{obs} \} < 0.05. \qquad (13)$$

The function CHIDIST(χ^2_{obs}; ν) in MS Excel will be used. The consistency check fails if CHIDIST(χ^2_{obs}; ν) < 0.05. If the consistency check does not fail then *y* will be accepted as *the comparison reference value* x_{ref} and *U(y)* will be accepted as the expanded uncertainty of the comparison reference value $U(x_{ref})$.
If the consistency check fails there are several methods how to proceed. One of the methods (method I) is determining the so called *best largest consistent subset* [2]. In this approach one is looking for a subset of laboratories satisfying the following properties: a) the results of the subset are *consistent* according to the chi-square test, b) the subset is the *largest* one from all the subsets satisfying the point a), c) in case when there are more then one subsets satisfying a) and b) the *best* subset with the smallest value of χ^2_{obs} is chosen.
The second possibility (method II) is to exclude the laboratory whose exclusion leads to the smallest new value of χ^2_{obs} (i.e. the value calculated without the laboratory excluded - with the values of *y* and its uncertainty obtained from the reduced set of laboratories). This step is repeated until the subset satisfying the consistency check is obtained.
The third possibility (method III) is to exclude the laboratory with the highest value of $(x_i - y)^2/u_{xi}^2$. Recalculate the value of *y*, the uncertainty u_y and the chi-squared value χ^2_{obs} without the values of the excluded laboratory and try the consistency check again. This procedure is repeated until the consistency check passes. These three methods do not give the same result in general.
Cox [1] also suggests a method (method IV) which is not based on reduction of the number of laboratories entering the evaluation. This method is referred to as procedure B in [1]. According to this procedure a median is chosen to represent the reference value. An error and a standard uncertainty declared by a given laboratory is used to generate a sample of *M* values satisfying the normal distribution with the error as the mean value and the same standard uncertainty. This sample represents hypothetical measurement values of the given laboratory in case of *M* repetitions of the measurement. This sample is obtained for each of the laboratories. Let us denote *r* the index which marks a particular value from the sample, i.e. $r=1,\ldots, M$. Then the median is calculated for each value of *r* from the corresponding set of *n* errors (*n* is the number of laboratories). Thus a set of *M* values of median is obtained. Then the reference value is obtained as the mean of the medians and its standard uncertainty is given as the standard uncertainty of the set of the medians. Furthermore a method for evaluating the coverage interval with a level of confidence 95 % and a method for evaluating the degrees of equivalence with its uncertainties are presented by Cox [1].

The uncertainty contribution u_{st} due to the instability of the meters and installation effects was evaluated from the data in Tab.6.1. No correlation indicating a significant influence of the test rig of CMI to the scatter of the data was found (see analysis in the section 7.3). The resulting values of u_{st} are summarized in Tab.7.1 below. The values obtained here are comparable to the values (0.015 – 0.03) % obtained by professor Adunka for a standard deviation contribution due to an installation effects during the inter-laboratory comparison Euromet No.669 where the same meters were used [3].

	Meter No.857					Meter No.858				
Q (m^3/h)	1	2.5	5	7.5	10	1	2.5	5	7.5	10
u_{st} (%)	0.017	0.018	0.020	0.020	0.020	0.015	0.018	0.022	0.020	0.019

Tab.7.1 Contribution to an uncertainty due to the meter stability

In the Tab.7.2 the errors E of all the participants can be found together with their declared expanded combined uncertainties $U(E)$ (see also Appendix A) and the uncertainty raised by the meter stability and installation effects contribution $U(E)_{st}$. The uncertainty $U(E)_{st}$ is defined as $U(E)_{st} = 2.u_{xi}$, where u_{xi} is given by the formula (8) and x_i is the error E for i-th laboratory for the flow and the meter under consideration.
The weighted mean y_{all} and its uncertainty $u(y_{all})$ was calculated based on the data from all of the laboratories. The data fail to satisfy the chi-squared consistency check for almost all of the flows since the probability $Pr(\chi^2(\nu)>\chi^2_{obs,all})$ is smaller then 5 % in most cases.
The best largest consistent subset (blcs) was determined for both meters and for each of the flows. The laboratories which had to be excluded from the set are listed in Tab.7.2 line "blcs without". The value y_{blcs} with the uncertainty $u(y_{blcs})$ is considered to be the *comparison reference value*.
The method II leads to the same result as the blcs-method (method I). The method III differs only in one point – for the meter No.858 and 5 m^3/h Lithuania is excluded instead of Macedonia. The value of weighted mean then changes to –0.128 % from the original –0.142 %. The results of method IV ($y_{procedureB}$, $u(y_{procedureB})$) are also included in the table just for completeness and for comparison.
The results of Tab.7.2 are represented also graphically in Appendix C and also in Fig.7.1 and Fig.7.2.

		Meter No.857					Meter No.858				
	Q (m^3/h)	1	2.5	5	7.5	10	1	2.5	5	7.5	10
Czechia	**E (%)**	**-0.077**	**-0.130**	**-0.090**	**-0.048**	**-0.047**	**-0.068**	**-0.186**	**-0.164**	**-0.127**	**-0.094**
	U(E) (%)	0.070	0.070	0.070	0.070	0.075	0.067	0.070	0.070	0.070	0.075
	$U(E)_{st}$ (%)	0.078	0.079	0.081	0.080	0.085	0.073	0.078	0.083	0.080	0.084
Switzerland	**E (%)**	**-0.02**	**-0.09**	**-0.03**	**0.01**	**0.03**	**0.08**	**-0.08**	**-0.07**	**-0.05**	**-0.05**
	U(E) (%)	0.050	0.051	0.051	0.051	0.051	0.052	0.051	0.051	0.051	0.051
	$U(E)_{st}$ (%)	0.061	0.063	0.065	0.065	0.065	0.060	0.062	0.068	0.064	0.063
Norway	**E (%)**	**-0.183**	**-0.186**	**-0.125**	**-0.057**	**0.014**	**-0.058**	**-0.200**	**-0.159**	**-0.100**	**-0.055**
	U(E) (%)	0.015	0.009	0.008	0.010	0.009	0.029	0.009	0.008	0.009	0.010
	$U(E)_{st}$ (%)	0.038	0.038	0.041	0.041	0.041	0.041	0.037	0.046	0.040	0.039
Macedonia	**E (%)**	**-0.140**	**-0.163**	**-0.058**	**-0.063**	**-0.075**	**-0.062**	**-0.107**	**-0.054**	**-0.072**	**-0.077**
	U(E) (%)	0.050	0.049	0.052	0.053	0.053	0.052	0.050	0.050	0.053	0.052
	$U(E)_{st}$ (%)	0.061	0.061	0.066	0.066	0.066	0.060	0.061	0.067	0.066	0.064
Greece	**E (%)**	**-0.06**	**-0.12**	**-0.10**	**-0.06**	**-0.06**	**0.00**	**-0.10**	**-0.11**	**-0.08**	**-0.08**
	U(E) (%)	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	$U(E)_{st}$ (%)	0.071	0.072	0.074	0.074	0.074	0.069	0.071	0.077	0.073	0.072
Hungary	**E (%)**	**0.000**	**-0.056**	**-0.041**	**0.001**	**0.022**	**0.050**	**-0.136**	**-0.102**	**-0.020**	**-0.015**
	U(E) (%)	0.072	0.071	0.070	0.071	0.070	0.071	0.071	0.071	0.070	0.070
	$U(E)_{st}$ (%)	0.080	0.080	0.081	0.081	0.081	0.077	0.079	0.084	0.080	0.079
Slovakia	**E (%)**	**-0.032**	**-0.116**	**-0.139**	**-0.105**	**-0.134**	**-0.036**	**-0.112**	**-0.138**	**-0.114**	**-0.158**
	U(E) (%)	0.124	0.152	0.185	0.139	0.117	0.120	0.150	0.186	0.142	0.117
	$U(E)_{st}$ (%)	0.129	0.156	0.189	0.145	0.124	0.123	0.154	0.191	0.147	0.123
Austria	**E (%)**	**-0.018**	**-0.071**	**-0.067**	**-0.016**	**0.004**	**0.054**	**-0.098**	**-0.139**	**-0.102**	**-0.098**
	U(E) (%)	0.054	0.052	0.052	0.052	0.052	0.053	0.051	0.052	0.052	0.052
	$U(E)_{st}$ (%)	0.064	0.064	0.066	0.065	0.065	0.060	0.062	0.069	0.065	0.064
France	**E (%)**	**-0.071**	**-0.132**	**-0.085**	**-0.040**	**-0.018**	**-0.010**	**-0.173**	**-0.169**	**-0.097**	**-0.076**
	U(E) (%)	0.103	0.101	0.101	0.101	0.101	0.106	0.101	0.101	0.100	0.100
	$U(E)_{st}$ (%)	0.109	0.108	0.109	0.109	0.109	0.110	0.107	0.111	0.107	0.107
Lithuania	**E (%)**	**-0.117**	**-0.171**	**-0.161**	**-0.147**	**-0.159**	**-0.050**	**-0.213**	**-0.251**	**-0.241**	**-0.253**
	U(E) (%)	0.088	0.084	0.084	0.082	0.082	0.085	0.086	0.087	0.086	0.085
	$U(E)_{st}$ (%)	0.095	0.092	0.093	0.091	0.091	0.090	0.093	0.098	0.095	0.093
Bosnia	**E (%)**	**-0.07**	**-0.16**	**-0.18**	**-0.10**	**-0.05**	**-0.05**	**-0.14**	**-0.15**	**-0.13**	**-0.11**
	U(E) (%)	0.028	0.030	0.022	0.023	0.033	0.026	0.030	0.019	0.024	0.026
	$U(E)_{st}$ (%)	0.045	0.048	0.046	0.046	0.052	0.039	0.046	0.049	0.046	0.046
y_{all} (%)		-0.093	-0.140	-0.106	-0.056	-0.026	-0.021	-0.147	-0.134	-0.100	-0.084
$u(y_{all})$ (%)		0.010	0.010	0.010	0.010	0.010	0.009	0.010	0.011	0.010	0.010
$\chi^2_{obs,all}$		45.19	19.67	24.96	15.96	24.85	30.93	22.59	18.49	18.49	22.73
$Pr(\chi^2(\nu)>\chi^2_{obs,all})$ (%)		0.00	3.25	0.54	10.09	0.56	0.06	1.24	4.72	4.73	1.18
blcs without		NO	NO	BA		LT	CH, A	NO	MK	LT	LT
y_{blcs} (%) (=CRV=x_{ref})		**-0.062**	**-0.124**	**-0.089**	**-0.056**	**-0.019**	**-0.041**	**-0.127**	**-0.142**	**-0.094**	**-0.076**
$u(y_{blcs})$ (%)		0.011	0.011	0.011	0.010	0.010	0.010	0.011	0.011	0.010	0.010
$\chi^2_{obs,blcs}$		14.65	11.83	11.99	15.96	15.88	9.36	10.98	12.25	9.20	8.88
$Pr(\chi^2(\nu)>\chi^2_{obs,blcs})$ (%)		10.10	22.28	21.39	10.09	6.94	31.31	27.69	19.94	41.91	44.82
$y_{procedureB}$ (%)		-0.066	-0.131	-0.093	-0.054	-0.035	-0.025	-0.137	-0.137	-0.097	-0.085
$u(y_{procedureB})$ (%)		0.018	0.019	0.019	0.016	0.019	0.019	0.018	0.017	0.016	0.016

Tab.7.2 Summary of the data, comparison reference value and chi-squared test. For definitions of the quantities in the table see the paragraph above the table.

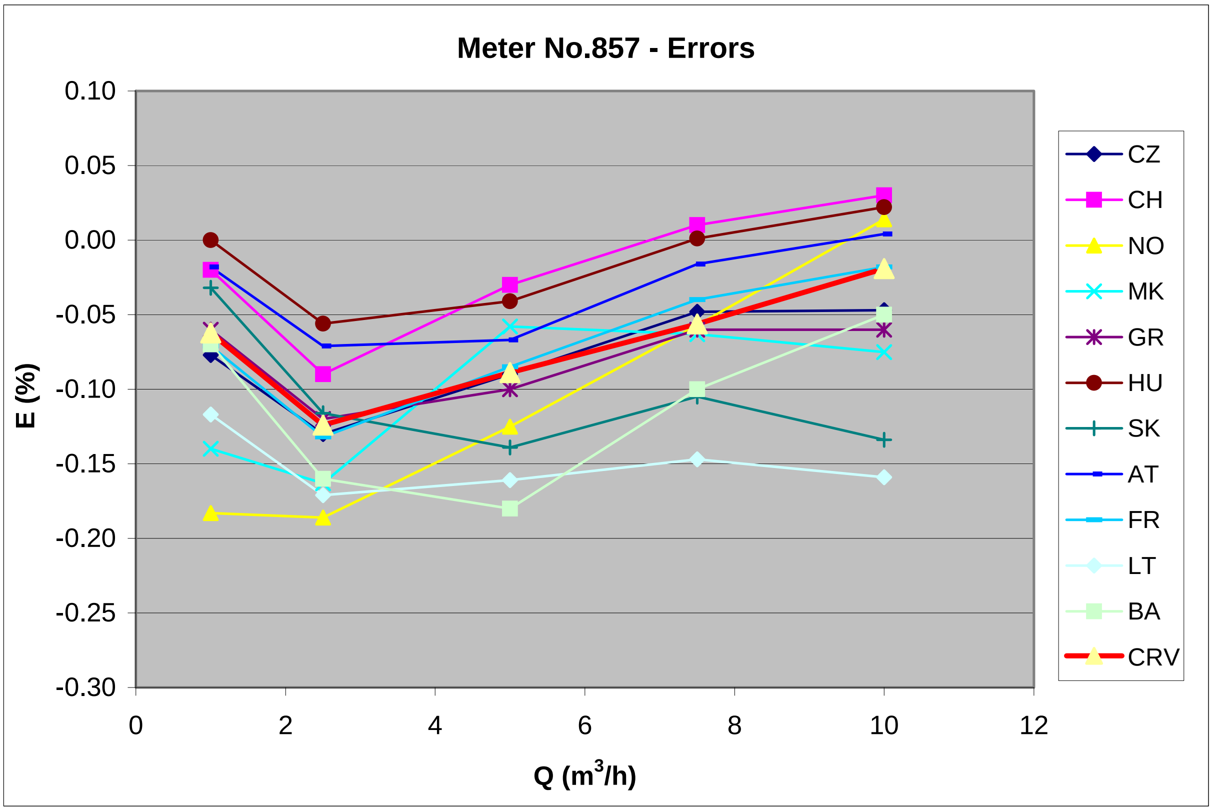


Fig.7.1 Calibration curves for various laboratories – meter No.857

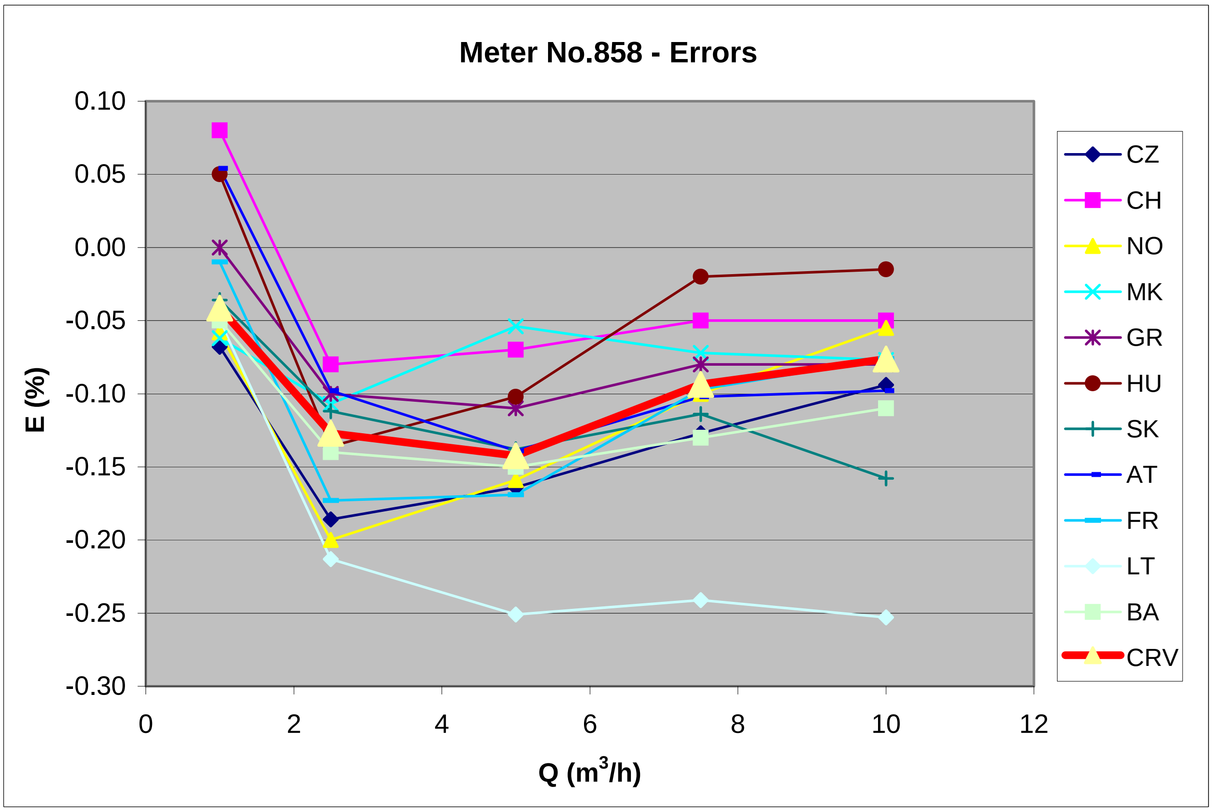


Fig.7.2 Calibration curves for various laboratories – meter No.858

7.2 The determination of the differences “Lab to CRV”, “Lab to Lab” and degrees of equivalence

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

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

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

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

$$D_i = \left| \frac{d_i}{2u(d_i)} \right| , \tag{16}$$

$$D_{ij} = \left| \frac{d_{ij}}{2u(d_{ij})} \right| , \tag{17}$$

where

$$u(d_i)^2 = u_{xi}{}^2 - u(x_{ref})^2 , \tag{18}$$

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

$$u(d_i)^2 = u_{xi}{}^2 + u(x_{ref})^2 \tag{19}$$

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

$$u(d_{ij})^2 = u_{xi}^2 + u_{xj}^2 \,. \tag{20}$$

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

		Meter No.857					Meter No.858				
	Q (m³/h)	1	2.5	5	7.5	10	1	2.5	5	7.5	10
Czechia	D_1	0.20	0.08	0.02	0.11	0.34	0.38	0.78	0.27	0.43	0.22
Switzerland	D_2	0.75	0.58	0.97	1.08	0.80	1.93	0.81	1.13	0.71	0.44
Norway	D_3	2.76	1.40	1.06	0.02	0.94	0.47	1.70	0.42	0.18	0.64
Macedonia	D_4	1.37	0.68	0.50	0.11	0.89	0.37	0.35	1.25	0.34	0.01
Greece	D_5	0.03	0.06	0.16	0.05	0.58	0.63	0.40	0.44	0.19	0.05
Hungary	D_6	0.81	0.89	0.62	0.73	0.53	1.24	0.12	0.50	0.95	0.80
Slovakia	D_7	0.24	0.05	0.27	0.34	0.94	0.04	0.10	0.02	0.14	0.67
Austria	D_8	0.73	0.89	0.35	0.65	0.37	1.49	0.50	0.05	0.14	0.36
France	D_9	0.08	0.08	0.04	0.15	0.01	0.29	0.44	0.25	0.03	0.00
Lithuania	D_{10}	0.60	0.53	0.80	1.02	1.50	0.10	0.95	1.14	1.52	1.86
Bosnia	D_{11}	0.20	0.86	1.80	1.06	0.66	0.26	0.32	0.18	0.88	0.82

Tab.7.3 Summary of “lab to CRV” standardized equivalence degrees.

The “lab to CRV” standardized equivalence degrees D_i are summarized in Tab.7.3. The tables with “lab to lab” standardized equivalence degrees D_{ij} are in Appendix B.

7.3 Correlations and Youden plots

A Youden plot [4] is a graphical means how to display correlations between data from the two transfer standards. If the errors of both meters are shifted to the same direction by the same amount when measured in a new laboratory then the most likely cause of the shift is a deviation in performance of the new test rig as compared to the previous one. Therefore the correlation in the data from the two meters expresses how much the deviations between various test rigs play a role in the scatter of the data as compared to the role of instability of the meter or installation effects.
A Youden plot is a graph of points where each point represents one laboratory whereas the x-coordinate of the i - th point is given by a difference ($E_i(1)$-$E_{mean}(1)$) and the y-coordinate of the i – th point is given by a difference ($E_i(2)$-$E_{mean}(2)$) where $E_i(1)$ and $E_i(2)$ are errors of a meter 1 and a meter 2 respectively as obtained in the i – th laboratory and $E_{mean}(1)$, $E_{mean}(2)$ are arithmetic means of the errors obtain in various laboratories for the meter 1 and the meter 2.
Quantities which are not correlated correspond to points distributed symmetrically inside a circle. Positive correlation would lead to a deformation of the circle to an ellipse which is longer along the $x = y$ line. We can define quantities N_i and P_i according to the Fig.7.3 (see also [3]). In terms of coordinates the quantities can be expressed as follows:

$$N_i^2 = \frac{1}{2}[(x_i - x_0) - (y_i - y_0)]^2 \quad \text{and} \quad P_i^2 = \frac{1}{2}[(x_i - x_0) + (y_i - y_0)]^2 . \qquad (21)$$

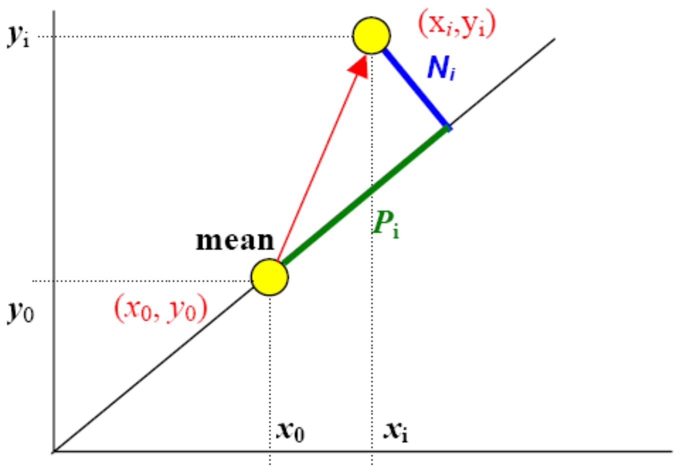


Fig.7.3 Definition of N_i and P_i

Then we can define

$$u_r^2 = \frac{1}{n-1}\sum_i N_i^2 = \frac{1}{2}(u_1^2 + u_2^2 - 2u_{1,2}) \quad \text{and} \quad u_s^2 = \frac{1}{n-1}\sum_i P_i^2 = \frac{1}{2}(u_1^2 + u_2^2 + 2u_{1,2}) . \qquad (22)$$

where

$$u_1^2 = \frac{1}{n-1}\sum_i (x_i - x_0)^2 , \quad u_2^2 = \frac{1}{n-1}\sum_i (y_i - y_0)^2 \quad \text{and} \quad u_{1,2} = \frac{1}{n-1}\sum_i (x_i - x_0)(y_i - y_0) . \qquad (23)$$

The quantities u_1 and u_2 are just the standard deviations of the data from the particular meter and $u_{1,2}$ is a covariance of the data from both meters. The quantity u_r connected to the scatter of the Youden plot points in $x = -y$ direction then represents a "random" variance of the data not including the "systematic" effects which have the same influence on both of the meters. On the other hand the quantity u_s connected to a scatter of the points in $x = y$ direction includes also the systematic effects caused by a deviation of the test rig. Other quantities separating the test rig deviation from a meter instability or installation effects can be defined using the correlation coefficient

$$r_{1,2} = \frac{u_{1,2}}{u_1 u_2} . \tag{24}$$

For the meter 1 they read [3]

$$u_{1,PE}^2 = r_{1,2} u_1^2 \quad \text{and} \quad u_{1,Z}^2 = (1 - r_{1,2}) u_1^2 \tag{25}$$

and analogously for the meter 2. The quantity $u^2_{1,PE}$ represents the part of the standard deviation connected to the influence of the test rig deviations and the quantity $u^2_{1,Z}$ represents the part corresponding to the meter instability and installation effects (the installation effects are considered to be random and different for both meters in general). To compare these quantities with the ones defined above suppose that the values of u_1 and u_2 are approximately the same. For this case we obtain

$$u_{1,PE}^2 \approx u_{1,2} \quad \text{and} \quad u_{1,Z}^2 \approx u_r^2 . \tag{26}$$

The values of the quantities defined above for the data in Tab.7.2 obtained from the comparison measurements are summarized in Tab.7.4.

Q	m^3/h	1	2.5	5	7.5	10
$u_{1,2}$	$\%^2$	0.002	0.001	0.002	0.002	0.003
$r_{1,2}$		0.755	0.589	0.689	0.835	0.874
$u_{857,PE}$	%	0.049	0.032	0.040	0.043	0.058
$u_{857,Z}$	%	0.028	0.027	0.027	0.019	0.022
$u_{858,PE}$	%	0.046	0.035	0.044	0.051	0.059
$u_{858,Z}$	%	0.026	0.029	0.030	0.023	0.022
u_r	%	0.027	0.028	0.029	0.022	0.022
u_s	%	0.072	0.055	0.067	0.070	0.086

Tab.7.4 Various quantities expressing the role of test rig in error shifts

The Youden plots are contained in Appendix D. From the plots as well as from the table Tab.7.4 we see that the scatter of the errors is caused by the test rigs dominantly. The correlation coefficient $r_{1,2}$ is much larger then zero, $u_s > u_r$ and $u_{x,PE} > u_{x,Z}$. In the plots contained in the Appendix D circles of radius $2u_r$ are drawn to visualize the systematic deviations graphically. In the case of normal distribution of the data and absence of systematic deviations, approximately 95 % of the points would lie within the circle. The points lying outside indicate the presence of a systematic deviation.
It also is useful to compare the standard uncertainty of the meters due to long time instability and installation effects u_{st} as obtained by the repeated measurements in the pilot laboratory (Tab.7.1) and the values of u_r, $u_{857,Z}$ or $u_{858,Z}$ as calculated in the Tab.7.4. We see that the values are quite similar.

In the Appendix E there are also Youden plots for measurements obtained at various times at CMI in order to determine the long time stability of the meters. The corresponding quantities are summarized in Tab.7.5 below. The quantities u_r and u_s are not calculated according to (22) in this case. Since the uniform distribution was used to calculate the uncertainty u_{st} , a similar procedure was applied also to obtain the uncertainties u_r and u_s. Namely:

$$u_r = \frac{1}{2\sqrt{3}}(\max(N_i) - \min(N_i)) \quad \text{and} \quad u_s = \frac{1}{2\sqrt{3}}(\max(P_i) - \min(P_i)). \qquad (27)$$

The circles in the plots contained in Appendix E would contain 95 % of the points in case of absence of systematic deviations again. The radius of the circles is determined as $0.95\sqrt{3}u_r$.

Q (m^3/h)	1	2.5	5	7.5	10
$u_{1,2}$ (%^{2})	-0.00019	-0.00036	-0.00046	-0.00038	-0.00039
$r_{1,2}$	-0.560	-0.707	-0.728	-0.632	-0.723
u_r (%)	0.020	0.026	0.030	0.028	0.027
u_s (%)	0.010	0.010	0.010	0.012	0.010

Tab.7.5 Correlations of the two meters during the stability measurements

From the Tab.7.5 and also from the Youden plots we see that there is no positive correlation between the data. Actually the data are rather anticorrelated. Therefore we can conclude that the influence of the test rig on the scatter of the data is unimportant since the deviations due to the test rig would cause a positive correlation. It means that the scatter of the data is caused by the long time instability of the meters plus installation effects.

7.4 References

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

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

[3] Adunka F., *Intercomparison of two electromagnetic meters*, Euromet project No.669 – report, 2005

[4] Youden W. J., *Graphical Diagnosis of Interlaboratory Test Results*, Industrial Quality Control, 1959, Vol. XV, No. 11, 133 – 137

8. Discussion of some deviations from prescribed conditions

8.1 Temperature tests of the transfer standards

Some laboratories (Bosnia and Herzegovina) were outside the prescribed range of water temperature. We therefore decided to perform additional tests of the transfer standards which should verify the assumption that the water temperature shift does not change the error of the transfer standards significantly. The measurements presented here were performed in May 2010 at CMI at a new test rig (different from the one participating in the comparison). The measurements were performed also in BEV with slightly higher error shifts. The transfer standard no. 857 was used for the measurements and the results are summarised in the graphs Fig.8.1 and Fig.8.2.

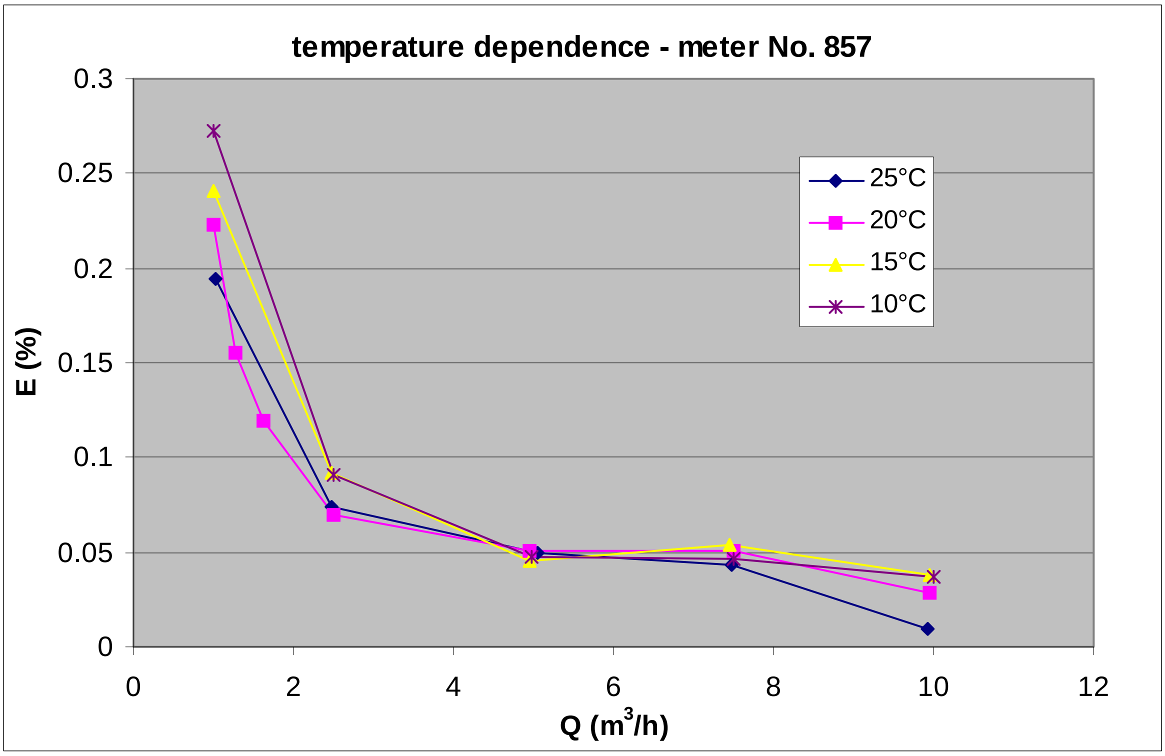


Fig.8.1 Error as a function of flow for various temperatures - the transfer standard No.857.

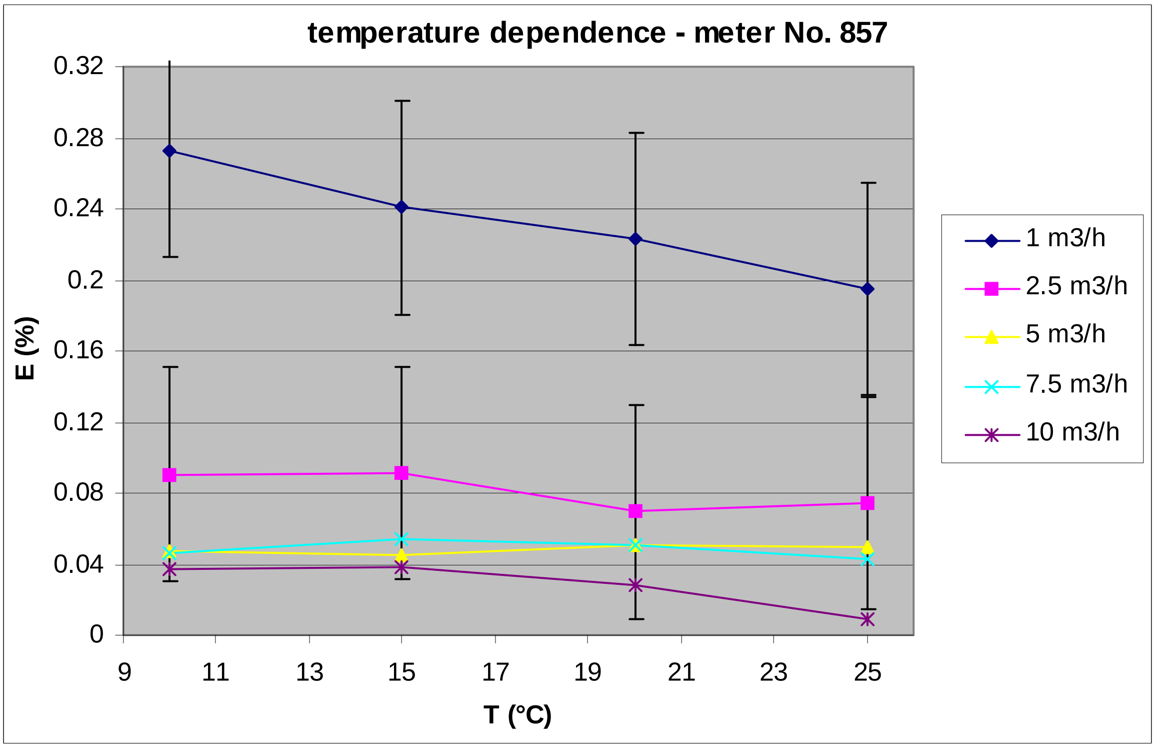


Fig.8.2 Error as a function of temperature for various flows- the transfer standard No.857. The vertical lines express the expanded uncertainty of the measurement.

From the graph Fig.8.1 we can see the shifts of the calibration curves due to temperature changes. The calibration curves themselves differ from the curves obtained during the comparison. The reasons are two – different installation conditions of the meter in the new test rig and a shift of the calibration curve of the transfer standard since the last comparison measurement. However, we need the information about error shifts due to temperature only so the absolute value of the error is not important in this case.
From the graph Fig.8.2 we can see that for the flows ≥ 2.5 m^3/h the error differences in the temperature range (10 – 20)°C are below 0.05 % and for the flows ≥ 5 m^3/h temperature effects are below 0.02 % which is in accordance with the theoretically predicted shift.
Since the largest deviations of the result of Bosnia and Herzegovina from the reference value (leading to the lab-CRV equivalence degrees larger then one) occur for the meter no. 857 and flows 5 m^3/h and 7.5 m^3/h where the temperature shift of error is very small we can conclude that the reason of the deviation is not the influence of the water temperature to the transfer standard performance. On the other hand the temperature of water was the lowest for these two cases (11.5 °C and 12.0°C) and it is possible that the deviation is caused by some temperature effect in the test rig of Bosnia and Herzegovina which was not corrected or included in the uncertainty calculation.
The measurement of error shift due to a temperature change performed at BEV showed slightly higher values of the shift. However, the values remained below 0.03 % for the temperature change of 10°C.

8.2 Flow deviation and its influence on error shift

For the determination of a shift of the error of the transfer standard due to a shift of the flow the calibration curve *E(Q)* of the transfer standard is needed. We can consider the errors obtained as the comparison reference values as the best estimates of the errors of the transfer standards in the prescribed flows. The complete calibration curve can then be estimated by some fit of the data measured.
For Q > 2.5 m^3/h the fit obtained just by linear interpolation of the points seems to be quite a good estimate. If we look to the laboratories where the flows were shifted by more then 3% from the prescribed (nominal) value we obtain the maximal shift $E(Q_{actual}) - E(Q_{nominal})$ of - 0.008 % for Switzerland, meter No. 857, Q = 10 m^3/h. This value is negligible with respect to the usual expanded uncertainty above 0.05 %.
For Q < 2.5 m^3/h the slope of the calibration curve can be larger and at the same time the linear interpolation probably does not fit well to the real curve. We can see this on the Fig.8.3 below.

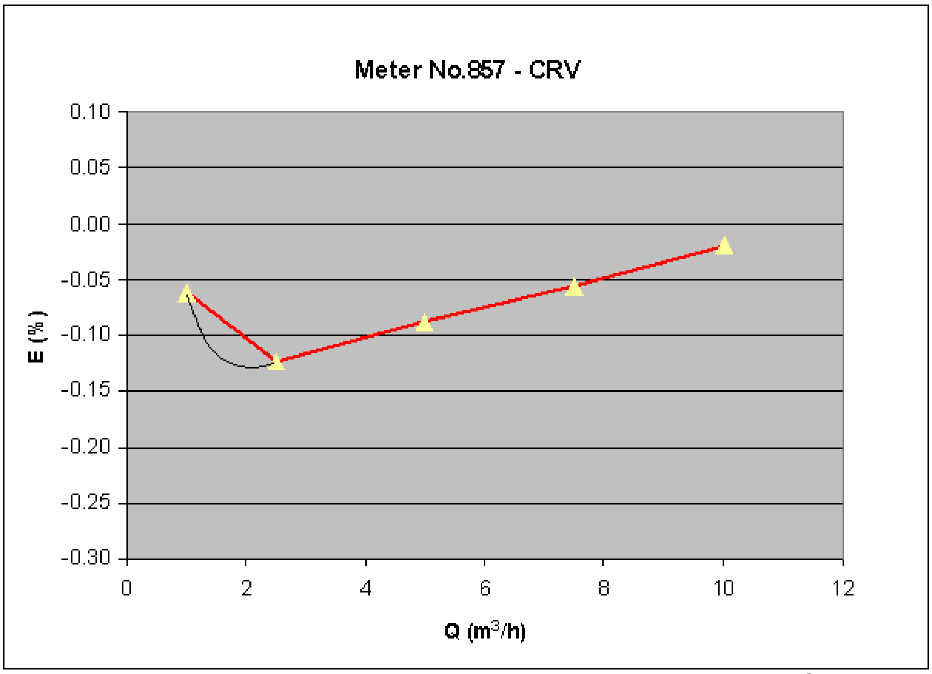


Fig.8.3 Possible fit of the CRV curve in the range (1 – 2.5) m^3/h.

For a good fit we would need more measurement data in the range (1 – 2.5) m^3/h. Since Norway measured the error of the meter No. 857 for Q = 1.274 m^3/h the error could be lower by several hundredths of percent as compared to the error for Q = 1 m^3/h just by this flow shift. Therefore we can say that the error measured by Norway is not included in the largest consistent subset of errors for Q = 1 m^3/h because the flow used in Norway was too far from the flow prescribed.

9. Conclusions

The results of measurement of eleven European water flow laboratories were evaluated by standard methods following the works of Cox. One laboratory withdrew from the comparison. The weighted mean of errors of the best largest consistent subset of laboratories was used as the reference value for each flow. The consistency of the results in the sense of chi-square test was satisfactory – in general only one laboratory of the total number of eleven had to be excluded to obtain the consistent set. Two laboratories were excluded for one flow and for one of the transfer standards. Only 16 % of the "lab to CRV" (CRV = comparison reference value) standardized degree of equivalence values were out of the satisfactory range (larger than one).

From the general recommendations for particular laboratories which follow from the comparison results we can mention the following. Norway should check their uncertainty calculation. Lithuania should check the measurement procedure or installation conditions. Bosnia should check the temperature corrections in the error calculation or how the temperature effects are included in the uncertainty calculation.

No labs from the CCM.FF-K1 (2006) comparison participated in this regional comparison. Therefore it is not presently possible to quantify the degree of equivalence of the labs in this comparison with labs outside the region.

Appendix A – Tables with full measurement results.

Czech Republic

Meter No. 857	start	end
Ambient temperature	21°C	23°C
Ambient humidity	50 %	56 %
Atmospheric pressure	97.6 kPa	98.6 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.0111	1.0107	1.0115	-0.077	10	167.9	18.1	1.17	0.026	0.065	0.0700
2.5	2.5038	2.5016	2.5063	-0.130	10	418.0	19.4	1.77	0.005	0.070	0.0702
5	4.996	4.980	5.007	-0.090	10	834.8	20.7	1.10	0.003	0.070	0.0701
7.5	7.507	7.487	7.524	-0.048	10	1252	22.4	2.18	0.004	0.070	0.0701
10	10.038	10.031	10.050	-0.047	10	1002	19.0	2.02	0.002	0.075	0.0750

Meter No. 858	start	end
Ambient temperature	22°C	23°C
Ambient humidity	46 %	53 %
Atmospheric pressure	98.1 kPa	98.8 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.0112	1.0106	1.0117	-0.068	10	167.9	18.1	1.17	0.017	0.065	0.0672
2.5	2.5007	2.4964	2.5041	-0.186	10	418.0	19.4	1.77	0.003	0.070	0.0701
5	5.000	4.997	5.004	-0.164	10	834.8	20.7	1.10	0.004	0.070	0.0701
7.5	7.524	7.500	7.534	-0.127	10	1252	22.3	2.17	0.002	0.070	0.0700
10	10.040	10.034	10.049	-0.094	10	1002	20.7	2.03	0.002	0.075	0.0750

Switzerland

Meter No. 857	start	end
Ambient temperature	19 °C	21 °C
Ambient humidity	47 %	50 %
Atmospheric pressure	94.5 kPa	95.1 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.009	1.008	1.009	-0.02	10	49	20.6	7.0	0.0063	0.05	0.0504
2.5	2.501	2.487	2.539	-0.09	10	64	20.8	6.8	0.0072	0.05	0.0505
5	5.013	4.955	5.123	-0.03	10	74	20.6	6.5	0.0095	0.05	0.0509
7.5	7.486	7.376	7.571	0.01	10	82	20.7	6.1	0.0073	0.05	0.0505
10	9.442	9.385	9.477	0.03	10	69	20.8	6.1	0.0121	0.05	0.0514

Meter No. 858	start	end
Ambient temperature	19 °C	21 °C
Ambient humidity	47 %	50 %
Atmospheric pressure	94.5 kPa	95.1 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.010	1.007	1.015	0.08	10	49	20.4	7.0	0.0134	0.05	0.0518
2.5	2.514	2.495	2.533	-0.08	10	63	20.3	6.8	0.0105	0.05	0.0511
5	5.001	4.923	5.057	-0.07	10	64	20.3	6.5	0.0087	0.05	0.0507
7.5	7.452	7.381	7.488	-0.05	10	74	20.5	6.1	0.0104	0.05	0.0511
10	9.456	9.405	9.489	-0.05	10	69	20.5	6.1	0.0068	0.05	0.0505

Norway

Meter No. 857	start	end
Ambient temperature	20.5 °C	20.1 °C
Ambient humidity	32.2 %	32.7 %
Atmospheric pressure	99.74 kPa	99.85 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.274	1.27	1.28	-0.183	12	779.43	20.98		0.0145	0.0040	0.015
2.5	2.500	2.50	2.50	-0.186	12	757.31	20.74		0.0079	0.0042	0.009
5	5.268	5.25	5.29	-0.125	12	744.86	20.57		0.0064	0.0049	0.008
7.5	7.496	7.49	7.50	-0.057	12	741.85	20.41		0.0089	0.0050	0.010
10	9.990	9.99	9.99	0.014	11	738.59	18.40		0.0074	0.0042	0.009

Meter No. 858	start	end
Ambient temperature	21.2 °C	20.5 °C
Ambient humidity	44.0 %	39.1 %
Atmospheric pressure	99.13 kPa	98.84 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.000	1.00	1.00	-0.058	12	762.78	20.55		0.0284	0.0044	0.029
2.5	2.500	2.50	2.50	-0.200	12	745.94	19.98		0.0067	0.0053	0.009
5	5.040	5.03	5.06	-0.159	12	742.60	19.50		0.0061	0.0043	0.008
7.5	7.495	7.49	7.50	-0.100	12	742.05	19.19		0.0073	0.0050	0.009
10	9.990	9.99	9.99	-0.055	11	738.53	18.96		0.0088	0.0042	0.010

Macedonia

Meter No. 857	start	end
Ambient temperature	21 °C	22 °C
Ambient humidity	56 %	50 %
Atmospheric pressure	987.6 hPa	984.6 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.9989	0.9948	1.005	-0.140	10	21.877	24.5	2.5	0.013	0.049	0.050
2.5	2.504	2.496	2.518	-0.163	10	25.533	24.5	2.5	0.006	0.049	0.049
5	5.010	4.984	5.065	-0.058	10	31.519	24.5	2.5	0.015	0.049	0.052
7.5	7.491	7.473	7.503	-0.063	10	22.228	24.5	2.5	0.012	0.051	0.053
10	10.070	10.025	10.112	-0.075	10	22.710	24.5	2.5	0.009	0.052	0.053

Meter No. 858	start	end
Ambient temperature	22 °C	23 °C
Ambient humidity	51 %	48 %
Atmospheric pressure	983.4 hPa	992.2 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.9992	0.9935	1.008	-0.062	10	10.193	24.5	2.5	0.016	0.049	0.052
2.5	2.504	2.496	2.511	-0.107	10	23.407	24.5	2.5	0.008	0.049	0.050
5	5.016	4.999	5.050	-0.054	10	26.818	24.5	2.5	0.009	0.049	0.050
7.5	7.519	7.473	7.563	-0.072	10	21.362	24.5	2.5	0.016	0.051	0.053
10	10.013	9.997	10.039	-0.077	10	22.791	24.5	2.5	0.003	0.052	0.052

Greece

Meter No. 857	start	end
Ambient temperature	23 °C	23 °C
Ambient humidity	43 %	43 %
Atmospheric pressure	1020 hPa	1020 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.99628	0.9946	0.9999	-0.06	10	501.8158	21.6	4.1	0.00669	0.06200	0.062
2.5	2.4997	2.492	2.505	-0.12	10	502.3721	21.4	2.9	0.00392	0.06200	0.062
5	5.0078	4.992	5.019	-0.10	10	501.7784	21.3	4.2	0.00414	0.06200	0.062
7.5	7.5039	7.486	7.526	-0.06	10	602.2367	21.2	4.1	0.00257	0.06200	0.062
10	10.003	9.987	10.036	-0.06	10	703.2864	21.2	3.9	0.00333	0.06200	0.062

Meter No. 858	start	end
Ambient temperature	23 °C	23 °C
Ambient humidity	46 %	46 %
Atmospheric pressure	1018 hPa	1018 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.996713	0.9943	1	0.00	15	501.8312	21.1	4.1	0.00342	0.06200	0.062
2.5	2.503267	2.49	2.516	-0.10	15	502.123	21.0	2.9	0.00321	0.06200	0.062
5	5.019267	4.998	5.038	-0.11	15	501.8917	20.9	4.2	0.00280	0.06200	0.062
7.5	7.500533	7.489	7.511	-0.08	15	602.7947	20.8	4.1	0.00239	0.06200	0.062
10	10.00367	9.983	10.032	-0.08	15	719.401	20.9	3.9	0.00244	0.06200	0.062

Hungary

Meter No. 857	start	end
Ambient temperature	22.5 °C	22.4 °C
Ambient humidity	51%	48%
Atmospheric pressure	1012 mbar	1011 mbar

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.01	1.00	1.01	0.000	10	50	19.7	2.5	0.015	0.070	0.072
2.5	2.50	2.49	2.52	-0.056	10	100	19.6	2.6	0.011	0.070	0.071
5	5.06	5.06	5.06	-0.041	10	201	19.5	2.5	0.008	0.070	0.070
7.5	7.58	7.55	7.72	0.001	10	202	19.5	2.6	0.010	0.070	0.071
10	9.87	9.83	9.94	0.022	10	302	19.4	2.6	0.007	0.070	0.070

Meter No. 858	start	end
Ambient temperature	22.3 °C	22.5 °C
Ambient humidity	53%	52%
Atmospheric pressure	1015 mbar	1015 mbar

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.01	1.01	1.02	0.050	10	50	20.0	2.5	0.013	0.070	0.071
2.5	2.53	2.52	2.54	-0.136	10	100	19.9	2.6	0.011	0.070	0.071
5	5.06	5.06	5.06	-0.102	10	201	19.8	2.5	0.012	0.070	0.071
7.5	7.57	7.55	7.71	-0.020	10	201	19.8	2.6	0.007	0.070	0.070
10	9.85	9.85	9.85	-0.015	10	301	19.8	2.6	0.008	0.070	0.070

Slovakia

Meter No. 857	start	end
Ambient temperature	22.3 °C	22.3 °C
Ambient humidity	33 %	33 %
Atmospheric pressure	98.2 kPa	98.2 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.001	0.994	1.006	-0.032	10	50.0874	20.59	4.32	0.076	0.098	0.124
2.5	2.537	2.481	2.548	-0.116	10	100.3297	20.79	4.30	0.116	0.098	0.152
5	5.004	5.000	5.029	-0.139	10	201.5126	20.89	4.23	0.116	0.144	0.185
7.5	7.504	7.498	7.522	-0.105	10	301.7587	21.01	4.10	0.076	0.116	0.139
10	9.994	9.981	10.020	-0.134	10	32.1175	21.05	3.95	0.018	0.116	0.117

Meter No. 858	start	end
Ambient temperature	20.5 °C	20.5 °C
Ambient humidity	27 %	27 %
Atmospheric pressure	96.8 kPa	96.7 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.999	0.995	1.003	-0.036	10	50.0540	20.43	4.31	0.070	0.098	0.120
2.5	2.539	2.458	2.551	-0.112	10	100.2219	20.74	4.30	0.114	0.098	0.150
5	5.004	4.992	5.024	-0.138	10	201.6402	20.97	4.22	0.118	0.144	0.186
7.5	7.556	7.364	8.128	-0.114	10	302.0629	21.00	4.04	0.082	0.116	0.142
10	10.003	9.984	10.015	-0.158	10	302.3195	21.21	4.00	0.016	0.116	0.117

Austria

Meter No. 857	start	end
Ambient temperature	21.0 °C	22.5 °C
Ambient humidity	55 %	55 %
Atmospheric pressure	986.0 hPa	989.4 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1.0	1.000	0.989	0.996	-0.018	10	500	17.920	1.577	0.019	0.051	0.054
2.5	2.491	2.475	2.503	-0.071	10	1000	17.900	1.597	0.007	0.051	0.052
5.0	4.980	4.942	5.004	-0.067	10	2500	17.890	1.605	0.007	0.052	0.052
7.5	7.482	7.408	7.527	-0.016	10	2500	17.900	1.602	0.004	0.052	0.052
10.0	9.973	9.860	10.025	0.004	10	2500	17.900	1.580	0.003	0.052	0.052

Meter No. 858	start	end
Ambient temperature	22.5 °C	23.0 °C
Ambient humidity	55 %	55 %
Atmospheric pressure	989.4 hPa	992.2 hPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1.0	1.000	0.988	0.996	0.054	10	500	17.930	1.586	0.013	0.051	0.053
2.5	2.492	2.478	2.502	-0.098	10	1000	17.910	1.588	0.003	0.051	0.051
5.0	4.989	4.954	5.019	-0.139	10	2500	17.930	1.577	0.003	0.052	0.052
7.5	7.481	7.413	7.512	-0.102	10	2500	17.900	1.608	0.005	0.052	0.052
10.0	9.971	9.871	10.025	-0.098	10	2500	17.900	1.583	0.004	0.052	0.052

France

Meter No. 857	start	end
Ambient temperature	26.5 °C	26.5 °C
Ambient humidity	23.0 %	30.5 %
Atmospheric pressure	97.1 kPa	96.6 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.997	0.994	1.003	-0.071	10	57.8	20.25	1.014	0.0237	0.1000	0.1028
2.5	2.495	2.477	2.507	-0.132	10	69.7	20.02	1.014	0.0164	0.1000	0.1013
5	4.984	4.965	5.019	-0.085	10	100.9	20.02	1.013	0.0147	0.1000	0.1011
7.5	7.495	7.478	7.513	-0.040	10	137.9	20.00	1.012	0.0131	0.1000	0.1009
10	9.982	9.952	10.015	-0.018	10	177.2	20.06	1.011	0.0150	0.1000	0.1011

Meter No. 858	start	end
Ambient temperature	22.1 °C	23.0 °C
Ambient humidity	28 %	31 %
Atmospheric pressure	97.9 kPa	98.2 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.999	0.993	1.010	-0.010	10	57.8	20.05	1.015	0.0356	0.1000	0.1062
2.5	2.495	2.487	2.505	-0.173	10	59.0	20.22	1.014	0.0133	0.1000	0.1009
5	4.993	4.974	5.020	-0.169	10	60.2	20.05	1.014	0.0136	0.1000	0.1009
7.5	7.488	7.464	7.523	-0.097	10	61.4	19.99	1.013	0.0091	0.1000	0.1004
10	9.993	9.968	10.015	-0.076	10	62.6	19.99	1.011	0.0065	0.1000	0.1002

Lithuania

Meter No. 857	start	end
Ambient temperature	19.8 °C	21.3 °C
Ambient humidity	36.6 %	34.4 %
Atmospheric pressure	98.6 kPa	98.8 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.00	1.00	1.01	-0.117	10	50	20.33	1.55	0.029	0.083	0.088
2.5	2.51	2.51	2.52	-0.171	10	151	20.31	1.55	0.006	0.084	0.084
5	5.03	5.03	5.04	-0.161	10	301	20.38	1.56	0.006	0.084	0.084
7.5	7.54	7.53	7.54	-0.147	10	402	20.47	1.57	0.006	0.082	0.082
10	10.01	10.00	10.03	-0.159	10	502	20.42	1.60	0.004	0.082	0.082

Meter No. 858	start	end
Ambient temperature	19.1 °C	21.2 °C
Ambient humidity	33.4 %	33.6 %
Atmospheric pressure	98.9 kPa	98.6 kPa

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	1.00	1.00	1.01	-0.050	10	50	20.44	1.63	0.018	0.083	0.085
2.5	2.50	2.50	2.51	-0.213	10	151	20.40	1.58	0.018	0.084	0.086
5	5.08	5.07	5.08	-0.251	10	301	20.40	1.62	0.024	0.084	0.087
7.5	7.53	7.53	7.54	-0.241	10	402	20.39	1.59	0.026	0.082	0.086
10	9.98	9.97	9.99	-0.253	10	502	20.33	1.52	0.022	0.082	0.085

Bosnia and Herzegovina

Meter No. 857	start	end
Ambient temperature		
Ambient humidity		
Atmospheric pressure		

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.989	0.986	1.009	-0.07	10	50.14	15.3	1.4	0.0193	0.0203	0.028
2.5	2.507	2.470	2.547	-0.16	10	206.00	13.0	1.4	0.0095	0.0285	0.030
5	5.001	4.972	5.020	-0.18	10	512.33	11.5	1.4	0.0122	0.0181	0.022
7.5	7.507	7.478	7.528	-0.10	10	512.28	12.0	1.4	0.0109	0.0206	0.023
10	9.978	9.949	10.01	-0.05	10	512.27	12.8	1.4	0.0232	0.0238	0.033

Meter No. 858	start	end
Ambient temperature		
Ambient humidity		
Atmospheric pressure		

Q [m³/h]	Q_E [m³/h]	Q_{Emin} [m³/h]	Q_{Emax} [m³/h]	E [%]	N	V_E [dm³]	T [°C]	p [bar]	U_A [%]	U_B [%]	U [%]
1	0.999	0.998	1.005	-0.05	10	50.07	17.01	4.60	0.0164	0.0203	0.026
2.5	2.499	2.488	2.515	-0.14	10	205.97	14.37	2.38	0.0090	0.0285	0.030
5	5.021	4.986	5.056	-0.15	10	512.23	14.67	1.75	0.0066	0.0182	0.019
7.5	7.505	7.472	7.571	-0.13	10	512.55	13.30	1.60	0.0122	0.0207	0.024
10	9.999	9.971	10.02	-0.11	10	512.39	15.19	1.25	0.0098	0.0238	0.026

Appendix B – Lab to lab standardized degrees of equivalence (D_{ij}).

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.58							Meter No. 857			
NO	D_{3i}	1.22	2.28						1 m^3/h			
MK	D_{4i}	0.64	1.39	0.60								
GR	D_{5i}	0.16	0.43	1.53	0.86							
HU	D_{6i}	0.69	0.20	2.07	1.39	0.56						
SK	D_{7i}	0.30	0.08	1.13	0.76	0.19	0.21					
AT	D_{8i}	0.58	0.02	2.22	1.38	0.44	0.18	0.10				
FR	D_{9i}	0.04	0.41	0.97	0.55	0.08	0.53	0.23	0.42			
LT	D_{10i}	0.33	0.86	0.65	0.20	0.48	0.95	0.53	0.87	0.32		
BA	D_{12i}	0.08	0.66	1.94	0.93	0.12	0.77	0.28	0.67	0.01	0.45	

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.40							Meter No. 857			
NO	D_{3i}	0.64	1.30						2.5 m^3/h			
MK	D_{4i}	0.33	0.83	0.32								
GR	D_{5i}	0.09	0.31	0.81	0.45							
HU	D_{6i}	0.66	0.33	1.47	1.06	0.59						
SK	D_{7i}	0.08	0.15	0.43	0.28	0.02	0.34					
AT	D_{8i}	0.58	0.21	1.55	1.04	0.51	0.15	0.27				
FR	D_{9i}	0.01	0.34	0.47	0.25	0.09	0.57	0.08	0.49			
LT	D_{10i}	0.34	0.73	0.15	0.07	0.44	0.94	0.30	0.89	0.28		
BA	D_{12i}	0.32	0.89	0.43	0.04	0.46	1.12	0.27	1.12	0.24	0.11	

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.58							Meter No. 857			
NO	D_{3i}	0.39	1.24						5 m^3/h			
MK	D_{4i}	0.31	0.30	0.87								
GR	D_{5i}	0.09	0.71	0.30	0.43							
HU	D_{6i}	0.43	0.11	0.93	0.16	0.54						
SK	D_{7i}	0.24	0.54	0.07	0.40	0.19	0.48					
AT	D_{8i}	0.22	0.40	0.75	0.10	0.33	0.25	0.36				
FR	D_{9i}	0.04	0.44	0.34	0.21	0.11	0.33	0.25	0.14			
LT	D_{10i}	0.58	1.16	0.35	0.91	0.51	0.98	0.10	0.83	0.53		
BA	D_{12i}	0.97	1.89	0.90	1.53	0.92	1.50	0.21	1.42	0.81	0.18	

Meter No. 857, 7.5 m³/h

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.56										
NO	D_{3i}	0.10	0.88									
MK	D_{4i}	0.14	0.79	0.08								
GR	D_{5i}	0.11	0.71	0.04	0.03							
HU	D_{6i}	0.43	0.09	0.64	0.61	0.56						
SK	D_{7i}	0.34	0.73	0.32	0.26	0.28	0.64					
AT	D_{8i}	0.31	0.28	0.53	0.51	0.45	0.16	0.56				
FR	D_{9i}	0.06	0.40	0.15	0.18	0.15	0.30	0.36	0.19			
LT	D_{10i}	0.81	1.41	0.90	0.75	0.74	1.21	0.25	1.17	0.76		
BA	D_{12i}	0.56	1.39	0.70	0.46	0.46	1.08	0.03	1.05	0.51	0.46	

Meter No. 857, 10 m³/h

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.72										
NO	D_{3i}	0.65	0.21									
MK	D_{4i}	0.26	1.13	1.14								
GR	D_{5i}	0.12	0.92	0.88	0.15							
HU	D_{6i}	0.59	0.08	0.09	0.93	0.75						
SK	D_{7i}	0.58	1.18	1.14	0.42	0.51	1.06					
AT	D_{8i}	0.48	0.28	0.13	0.85	0.65	0.17	0.99				
FR	D_{9i}	0.21	0.38	0.28	0.45	0.32	0.30	0.71	0.17			
LT	D_{10i}	0.90	1.69	1.73	0.75	0.84	1.49	0.16	1.45	0.99		
BA	D_{12i}	0.03	0.97	0.97	0.30	0.11	0.75	0.63	0.65	0.27	1.04	

Meter No. 858, 1 m³/h

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	1.57										
NO	D_{3i}	0.12	1.91									
MK	D_{4i}	0.06	1.68	0.06								
GR	D_{5i}	0.68	0.88	0.73	0.68							
HU	D_{6i}	1.11	0.31	1.24	1.15	0.49						
SK	D_{7i}	0.22	0.85	0.17	0.19	0.25	0.59					
AT	D_{8i}	1.29	0.31	1.53	1.37	0.59	0.04	0.65				
FR	D_{9i}	0.44	0.72	0.41	0.42	0.08	0.45	0.16	0.51			
LT	D_{10i}	0.16	1.21	0.08	0.11	0.44	0.85	0.09	0.96	0.28		
BA	D_{12i}	0.22	1.82	0.14	0.17	0.63	1.16	0.11	1.44	0.34	0.00	

		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	1.06							**Meter No. 858**			
NO	D_{3i}	0.16	1.66						**2.5 m^3/h**			
MK	D_{4i}	0.79	0.31	1.30								
GR	D_{5i}	0.81	0.21	1.25	0.07							
HU	D_{6i}	0.45	0.56	0.73	0.29	0.34						
SK	D_{7i}	0.43	0.19	0.56	0.03	0.07	0.14					
AT	D_{8i}	0.88	0.20	1.42	0.10	0.02	0.38	0.08				
FR	D_{9i}	0.10	0.75	0.24	0.54	0.57	0.28	0.33	0.61			
LT	D_{10i}	0.22	1.19	0.13	0.95	0.96	0.63	0.56	1.03	0.28		
BA	D_{12i}	0.50	0.77	1.02	0.43	0.47	0.04	0.17	0.54	0.28	0.70	

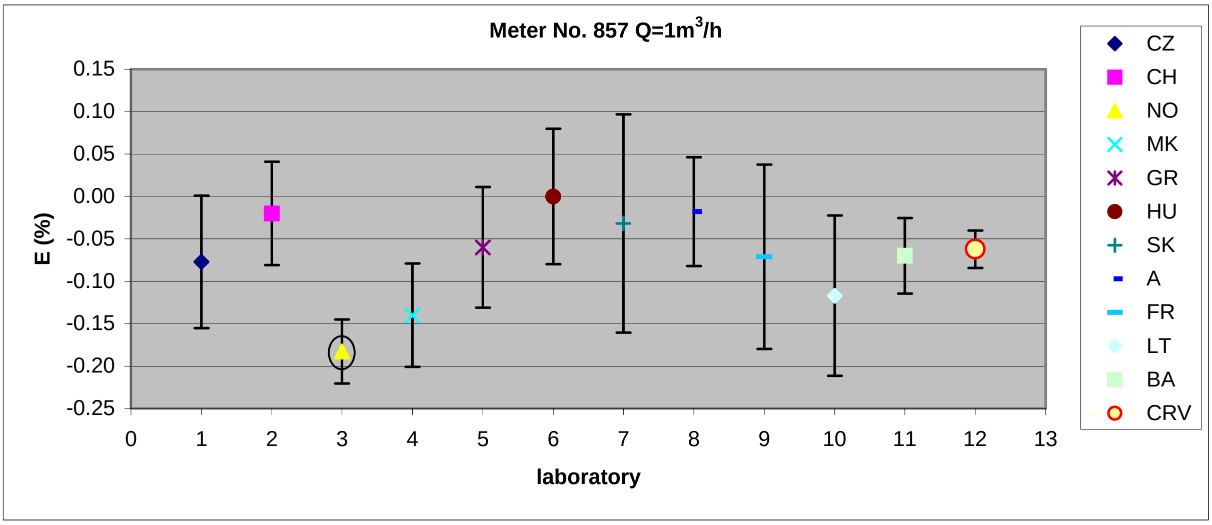
		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.88							**Meter No. 858**			
NO	D_{3i}	0.05	1.09						**5 m^3/h**			
MK	D_{4i}	1.03	0.17	1.29								
GR	D_{5i}	0.48	0.39	0.55	0.55							
HU	D_{6i}	0.52	0.30	0.60	0.45	0.07						
SK	D_{7i}	0.12	0.33	0.11	0.41	0.14	0.17					
AT	D_{8i}	0.23	0.71	0.24	0.88	0.28	0.34	0.00				
FR	D_{9i}	0.04	0.76	0.08	0.89	0.44	0.48	0.14	0.23			
LT	D_{10i}	0.68	1.52	0.85	1.66	1.13	1.16	0.53	0.94	0.56		
BA	D_{12i}	0.15	0.96	0.13	1.16	0.44	0.49	0.06	0.13	0.16	0.92	

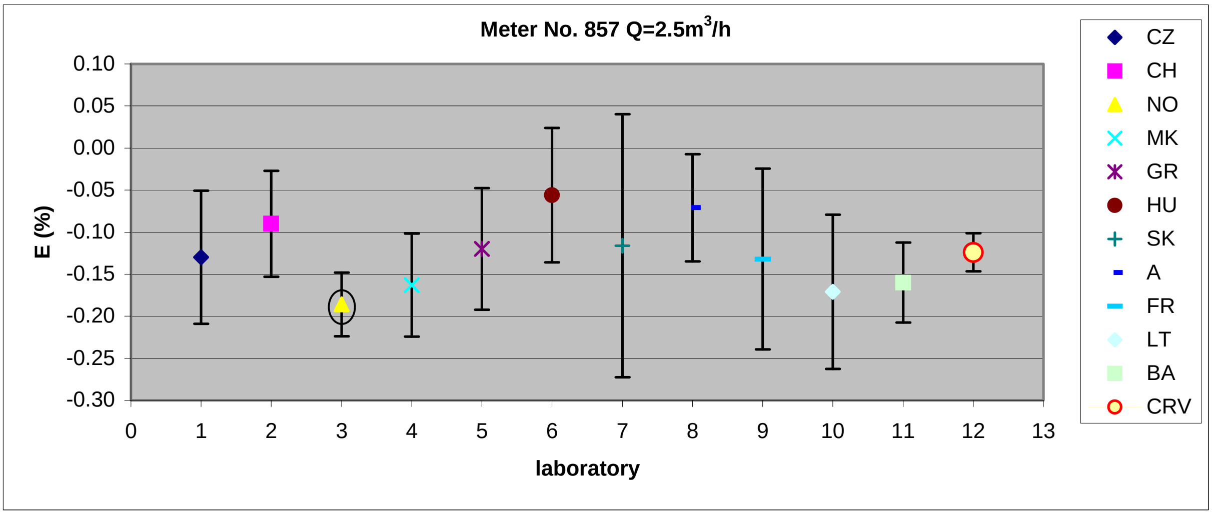
		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	0.75							**Meter No. 858**			
NO	D_{3i}	0.30	0.66						**7.5 m^3/h**			
MK	D_{4i}	0.53	0.24	0.36								
GR	D_{5i}	0.43	0.31	0.24	0.08							
HU	D_{6i}	0.94	0.29	0.89	0.50	0.55						
SK	D_{7i}	0.08	0.40	0.09	0.26	0.21	0.56					
AT	D_{8i}	0.24	0.57	0.03	0.32	0.22	0.79	0.07				
FR	D_{9i}	0.22	0.38	0.03	0.20	0.13	0.57	0.09	0.04			
LT	D_{10i}	0.92	1.67	1.37	1.47	1.34	1.78	0.73	1.21	1.01		
BA	D_{12i}	0.03	1.01	0.49	0.72	0.58	1.19	0.10	0.35	0.28	1.06	

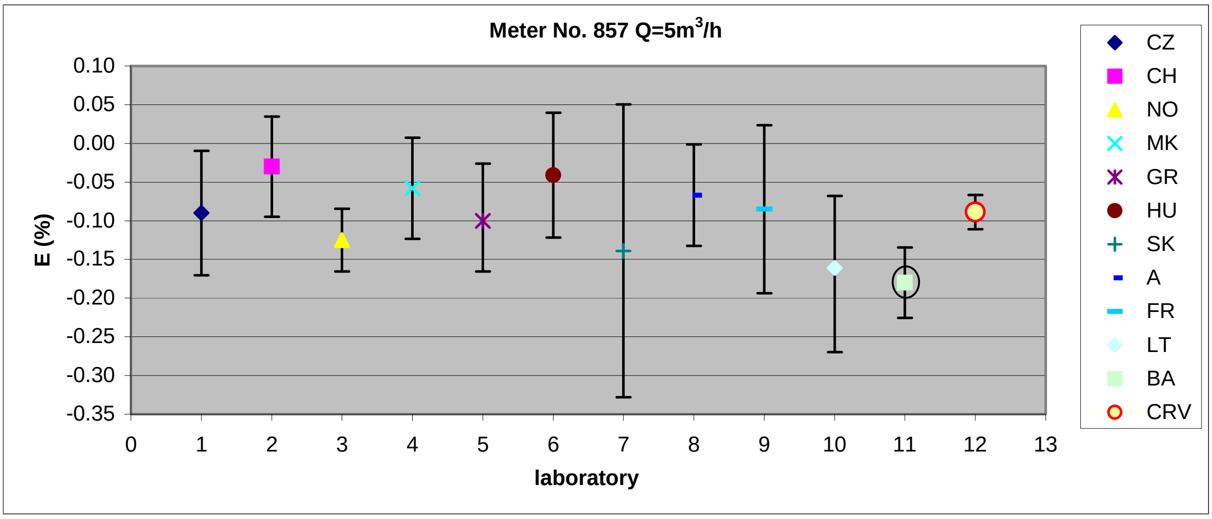
Meter No. 858
10 m³/h

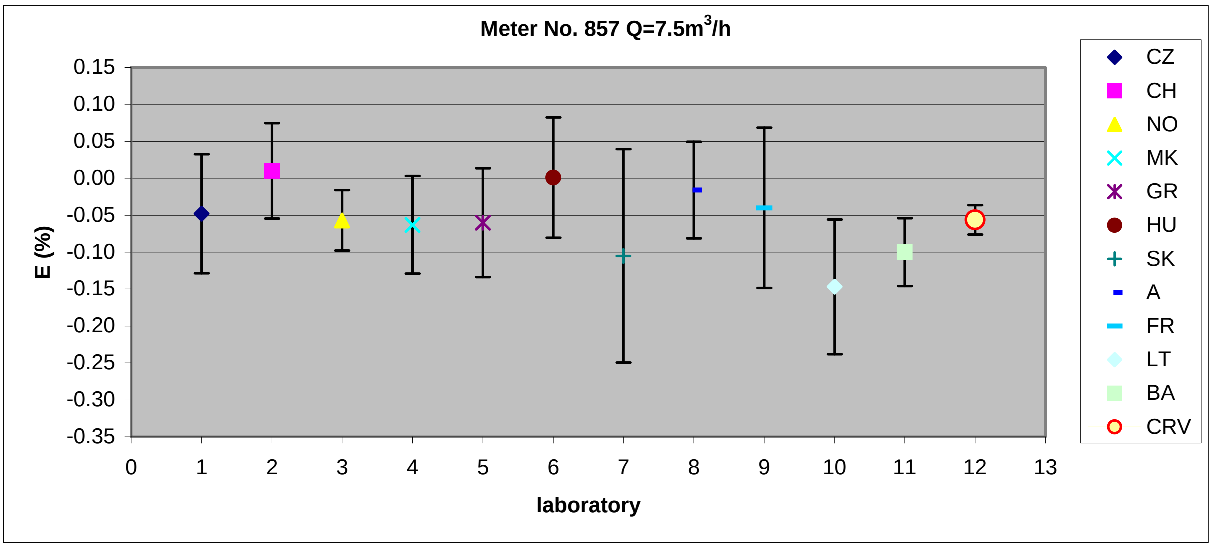
		CZ	CH	NO	MK	GR	HU	SK	AT	FR	LT	BA
CZ	D_{1i}											
CH	D_{2i}	**0.42**										
NO	D_{3i}	**0.42**	**0.07**									
MK	D_{4i}	**0.16**	**0.30**	**0.29**								
GR	D_{5i}	**0.13**	**0.31**	**0.30**	**0.03**							
HU	D_{6i}	**0.68**	**0.34**	**0.45**	**0.61**	**0.60**						
SK	D_{7i}	**0.43**	**0.78**	**0.80**	**0.58**	**0.55**	**0.98**					
AT	D_{8i}	**0.04**	**0.53**	**0.57**	**0.23**	**0.19**	**0.81**	**0.43**				
FR	D_{9i}	**0.13**	**0.21**	**0.18**	**0.01**	**0.03**	**0.46**	**0.50**	**0.18**			
LT	D_{10i}	**1.27**	**1.81**	**1.97**	**1.56**	**1.47**	**1.95**	**0.62**	**1.37**	**1.25**		
BA	D_{12i}	**0.17**	**0.77**	**0.92**	**0.42**	**0.35**	**1.04**	**0.37**	**0.15**	**0.29**	**1.38**	

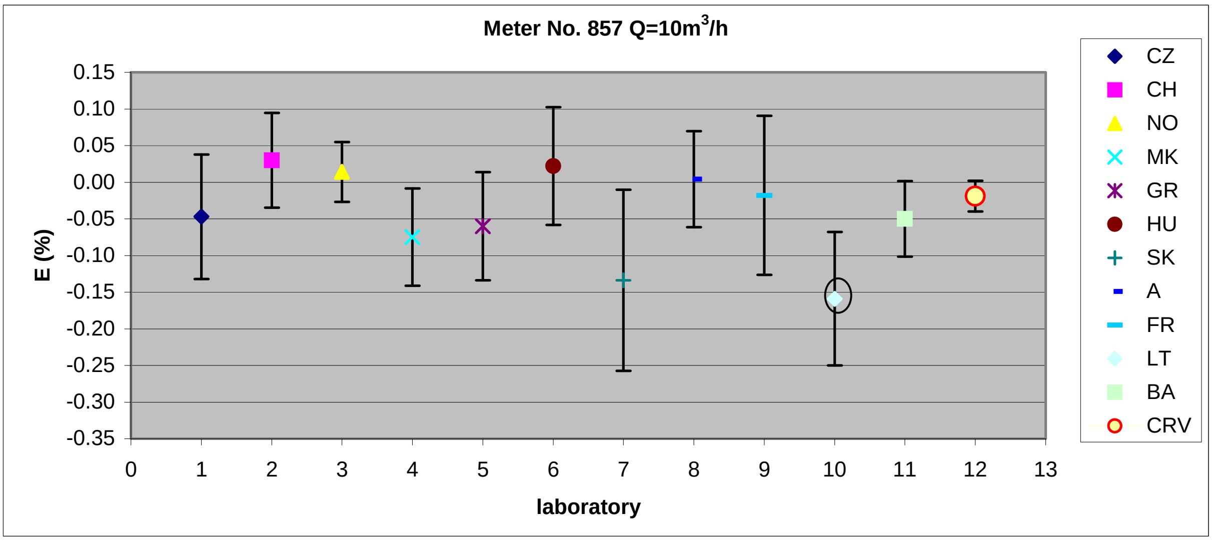
Appendix C – Graphical representation of errors *E* and uncertainties $U(E)_{st}$. Circled data points indicate those found discrepant by the chi-squared test and removed from CRV calculation.

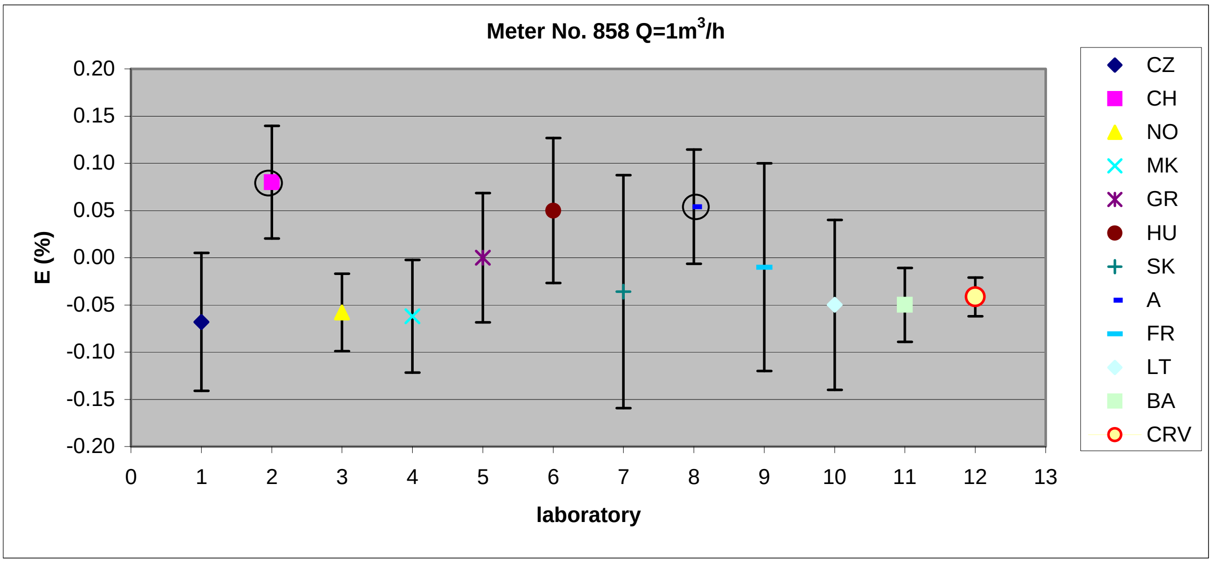


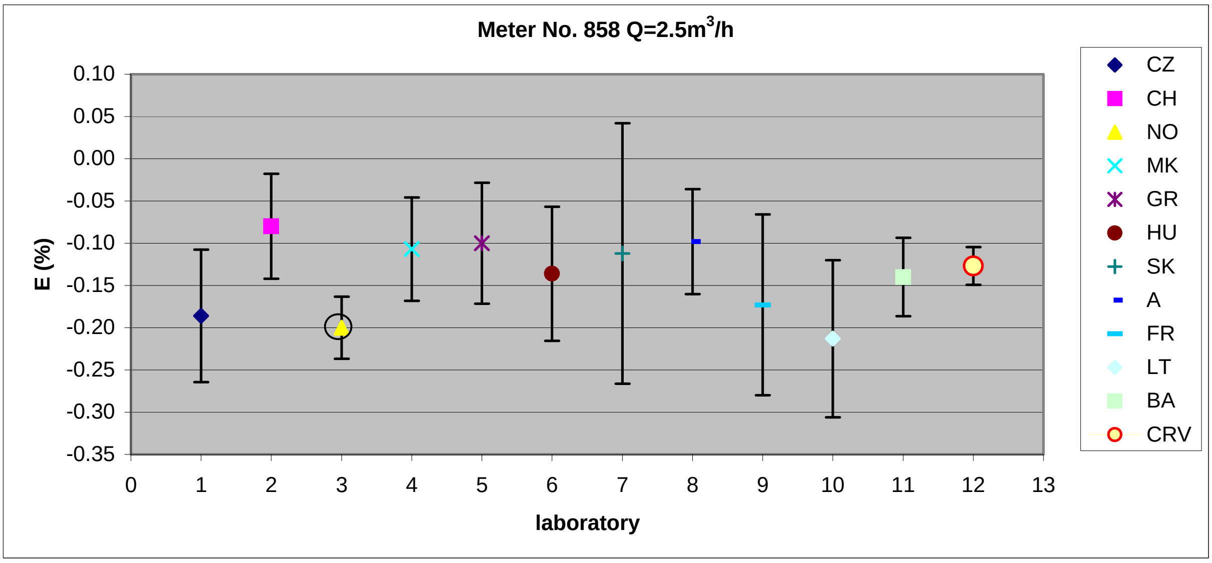


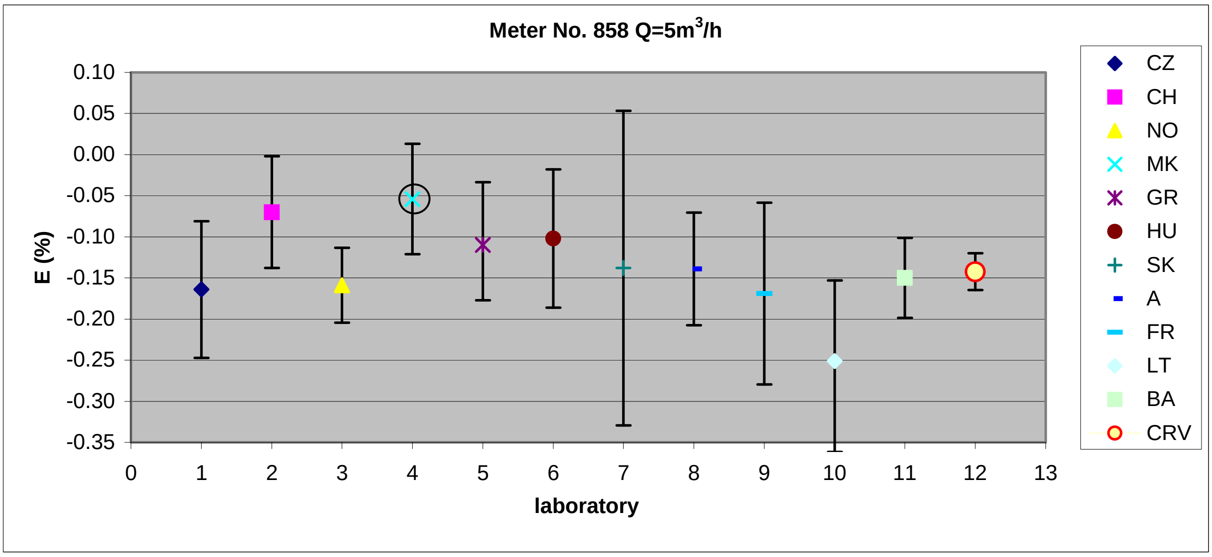

Meter No. 857 Q=5m³/h
E (%)
laboratory
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

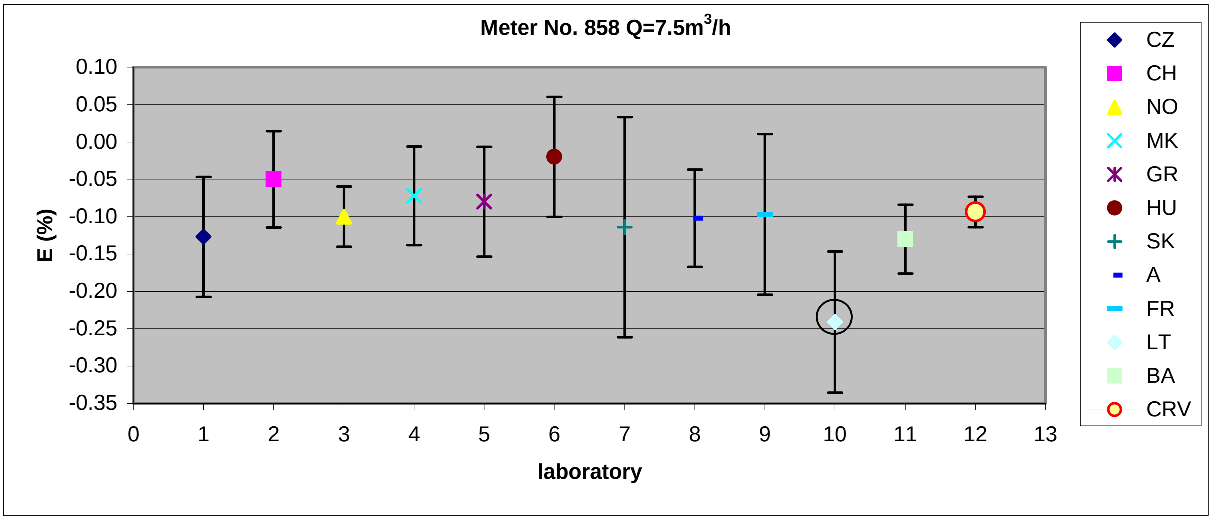

Meter No. 857 Q=7.5m³/h
E (%)
laboratory
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

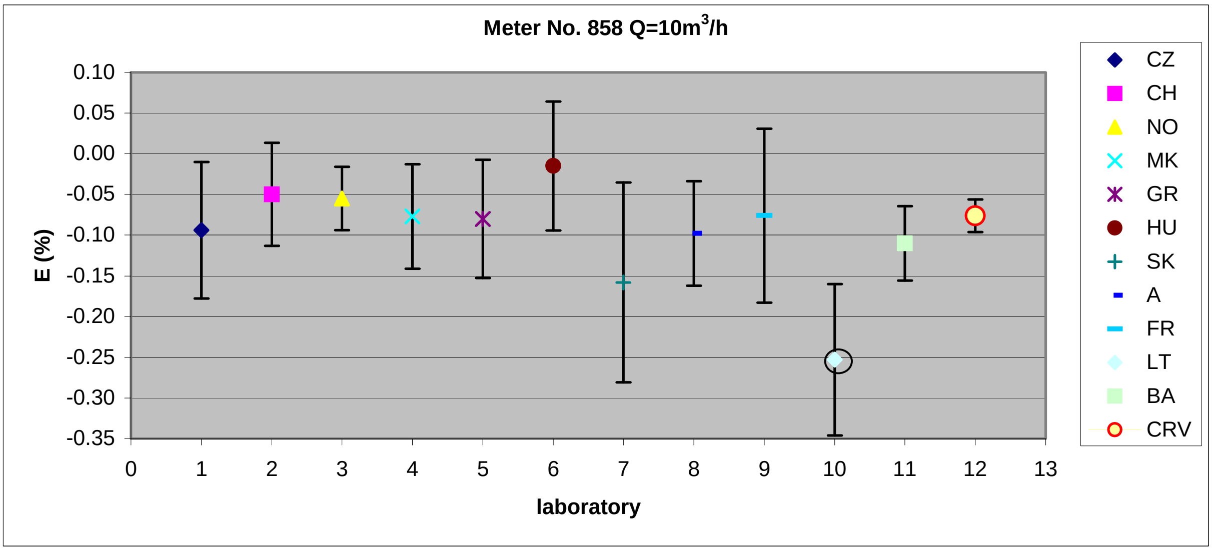

Meter No. 857 Q=10m³/h
E (%)
laboratory
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV


Meter No. 858 Q=1m3/h
E (%)
laboratory
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

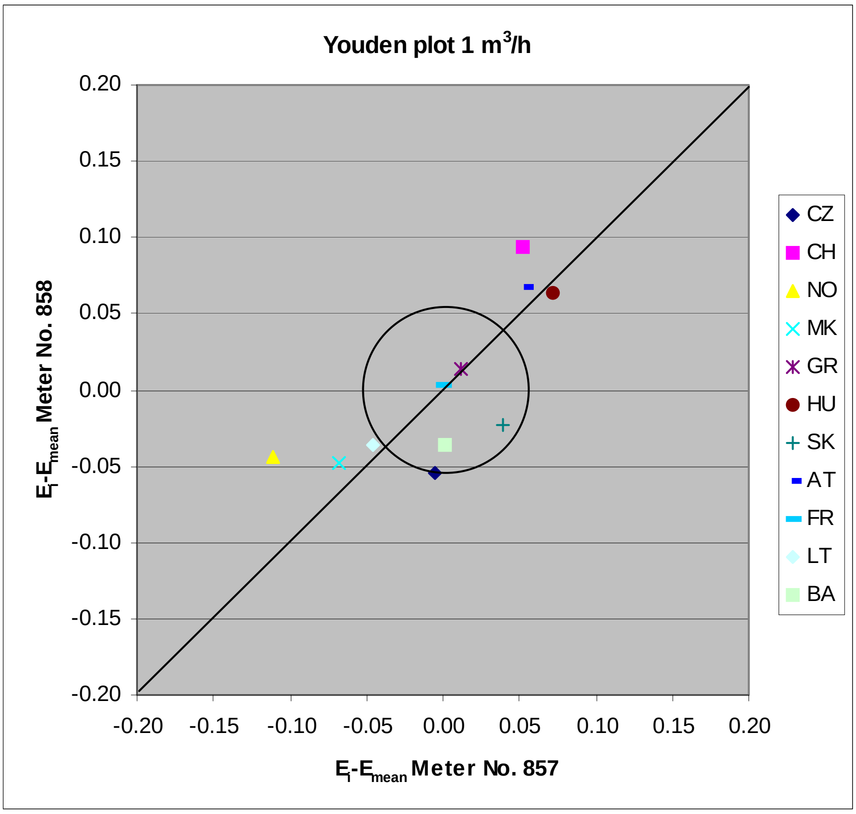

Meter No. 858 Q=2.5m3/h
E (%)
laboratory
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
0
1
2
3
4
5
6
7
8
9
10
11
12
13
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

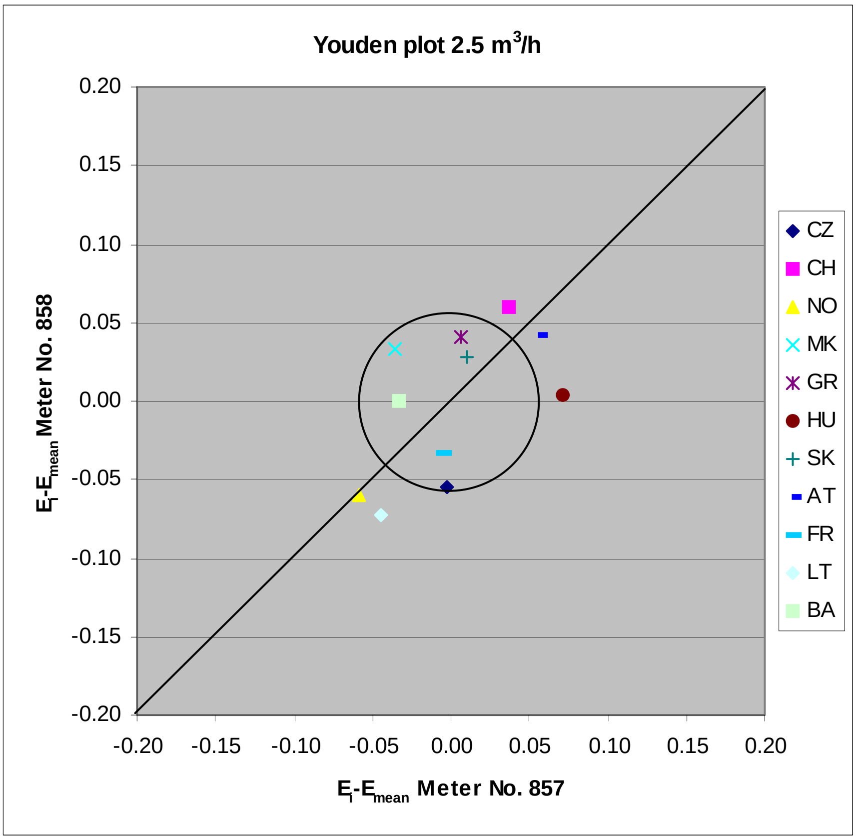

Meter No. 858 Q=5m3/h
E (%)
laboratory
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
0
1
2
3
4
5
6
7
8
9
10
11
12
13
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

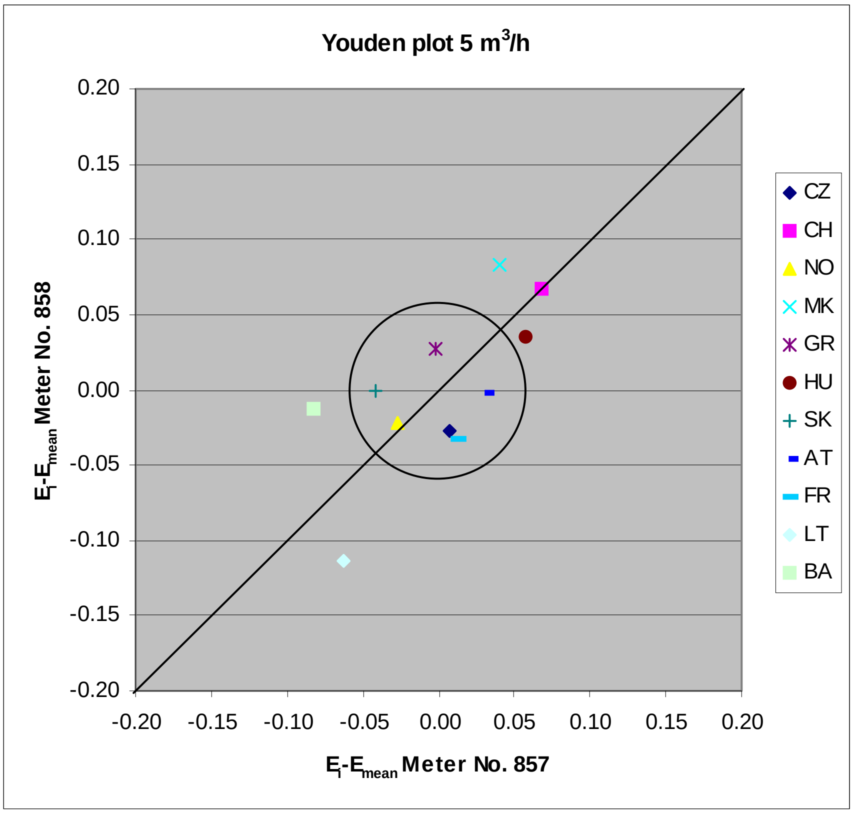

Meter No. 858 Q=7.5m3/h
E (%)
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
0
1
2
3
4
5
6
7
8
9
10
11
12
13
laboratory
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

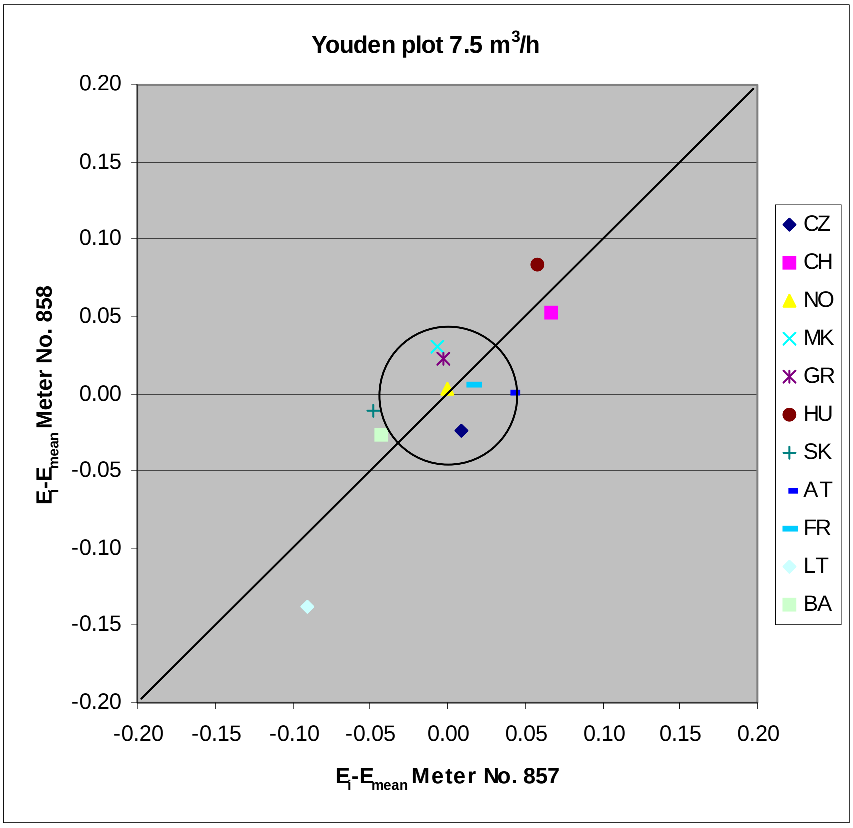

Meter No. 858 Q=10m3/h
E (%)
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
0
1
2
3
4
5
6
7
8
9
10
11
12
13
laboratory
CZ
CH
NO
MK
GR
HU
SK
A
FR
LT
BA
CRV

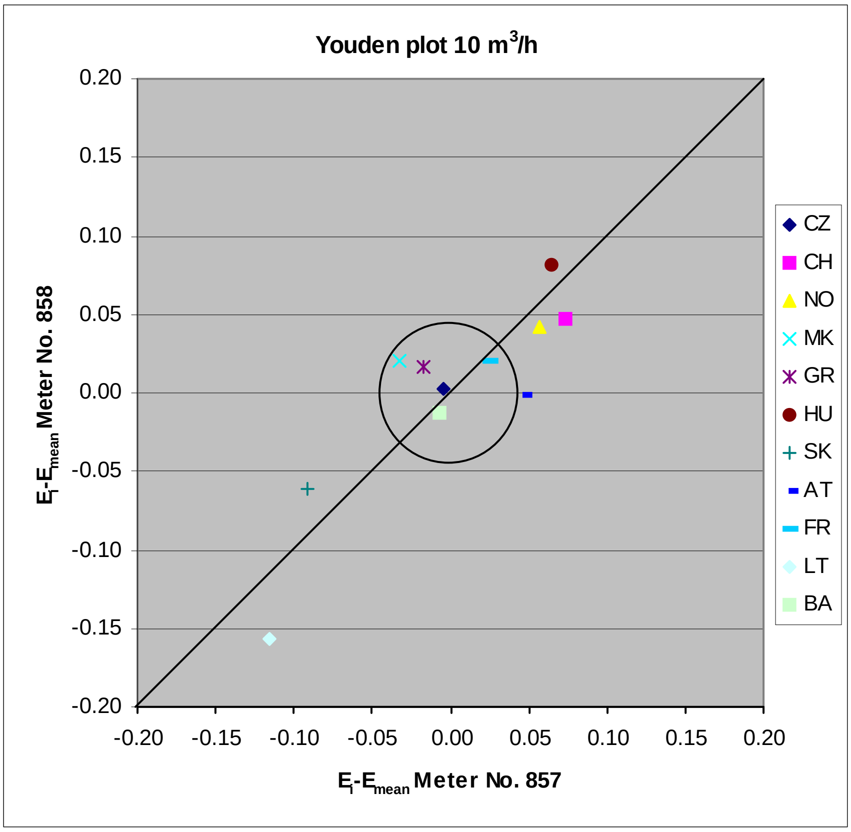
Appendix D – Youden plots for the comparison measurements



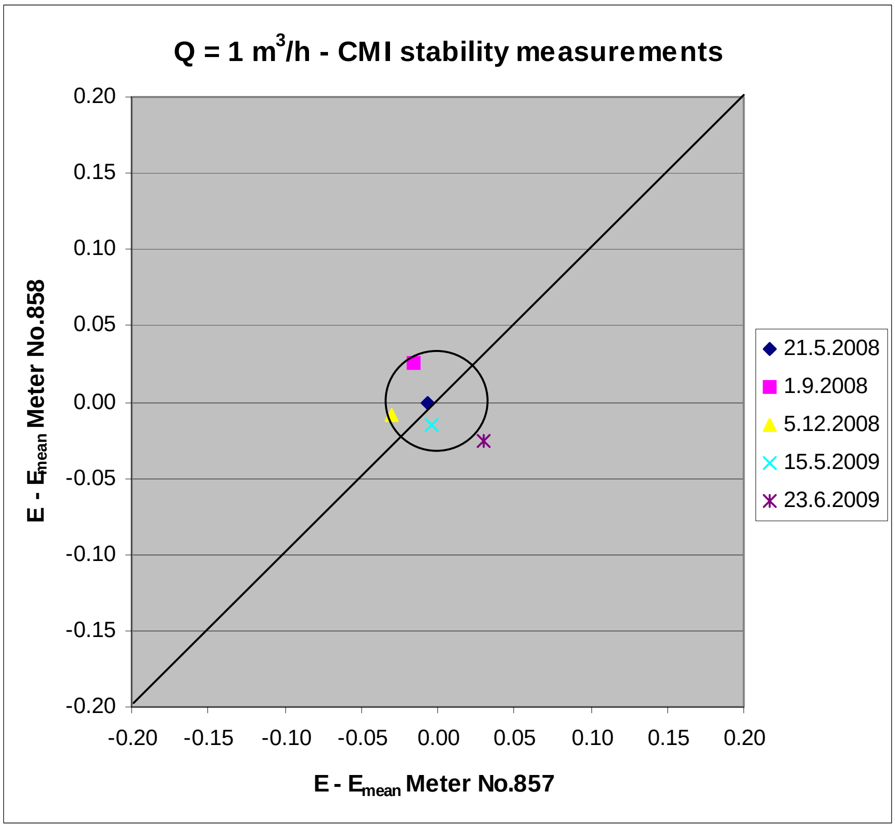


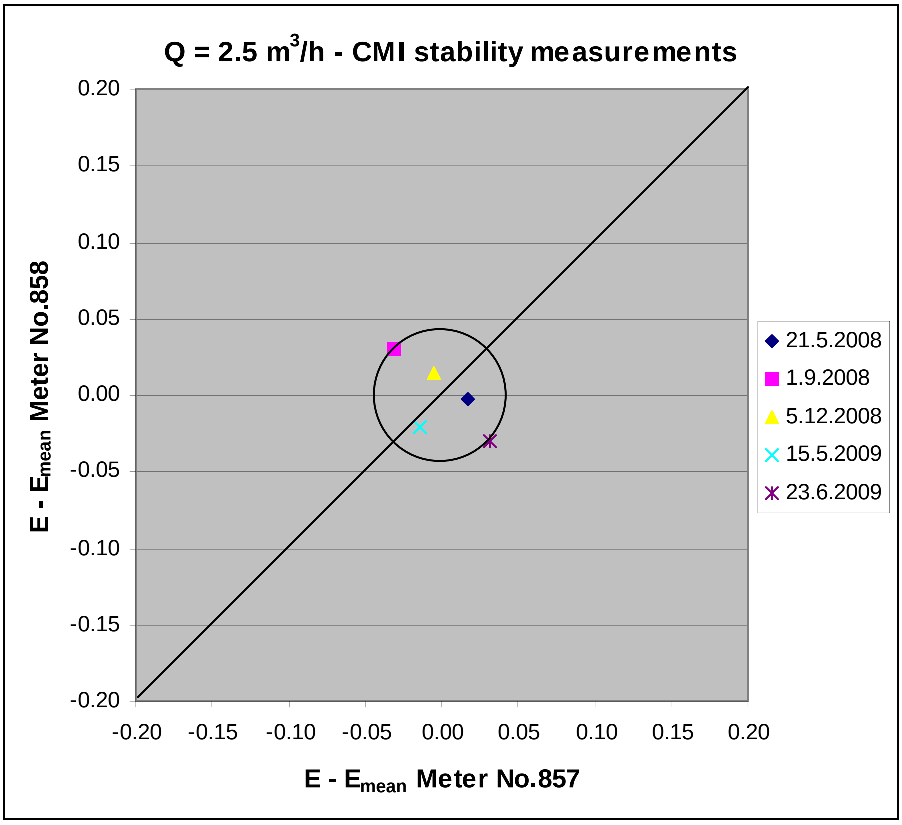

Youden plot 5 m3/h
E_i-E_mean Meter No. 858
E_i-E_mean Meter No. 857
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
CZ
CH
NO
MK
GR
HU
SK
AT
FR
LT
BA

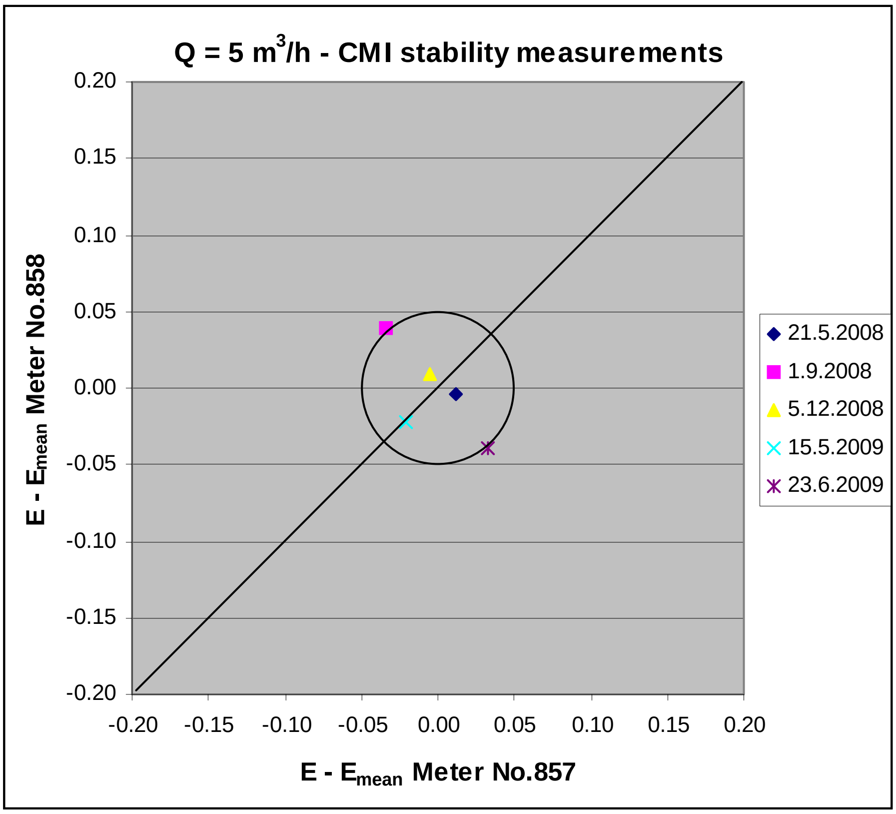

Youden plot 7.5 m3/h
E_i-E_mean Meter No. 858
E_i-E_mean Meter No. 857
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
CZ
CH
NO
MK
GR
HU
SK
AT
FR
LT
BA

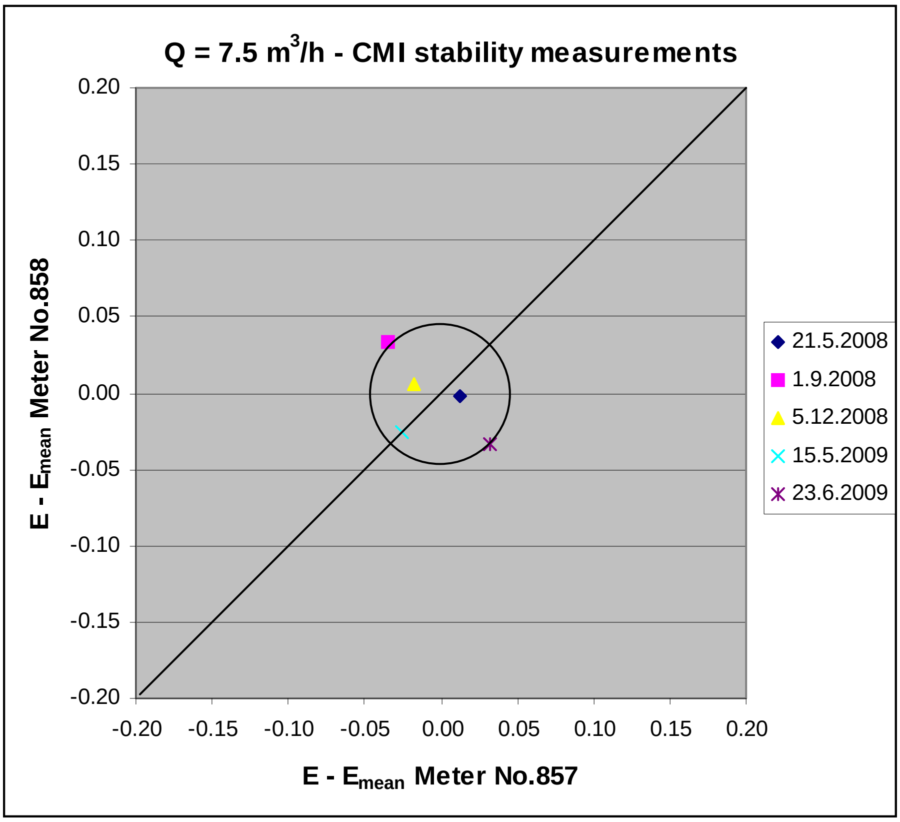

Youden plot 10 m3/h
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Ei-Emean Meter No. 858
-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
Ei-Emean Meter No. 857
CZ
CH
NO
MK
GR
HU
SK
AT
FR
LT
BA

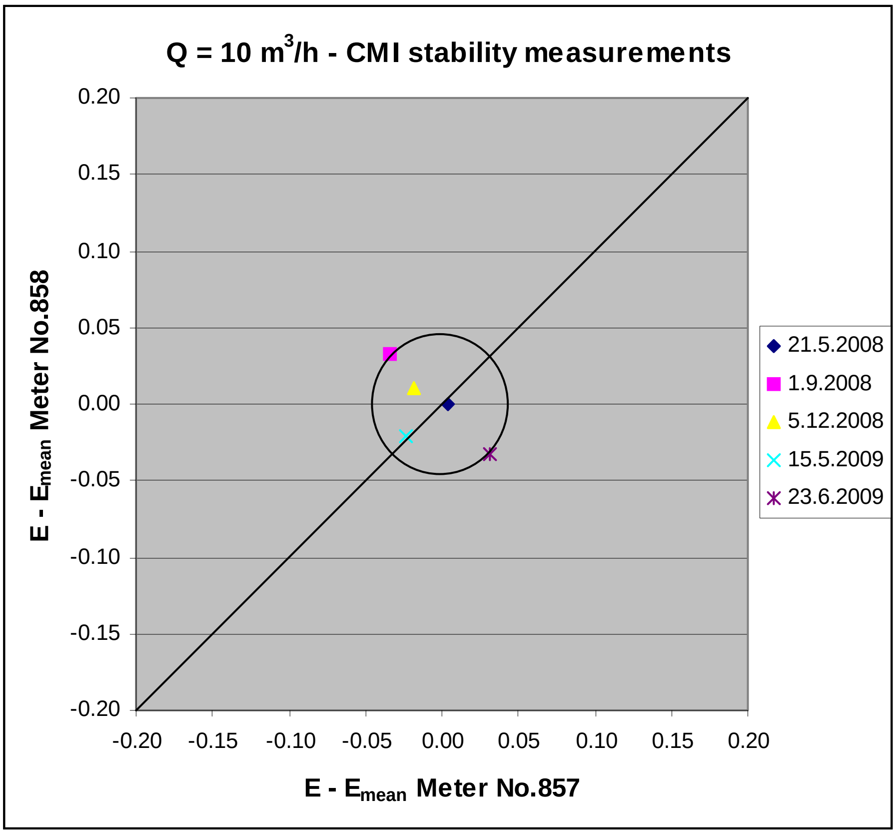
Appendix E – Youden plots for the stability measurements






Q = 5 m3/h - CMI stability measurements
E - Emean Meter No.858
E - Emean Meter No.857
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
21.5.2008
1.9.2008
5.12.2008
15.5.2009
23.6.2009


Q = 7.5 m3/h - CMI stability measurements
E - Emean Meter No.858
E - Emean Meter No.857
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
21.5.2008
1.9.2008
5.12.2008
15.5.2009
23.6.2009


Q = 10 m3/h - CMI stability measurements
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
E - Emean Meter No.858
-0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20
E - Emean Meter No.857
21.5.2008
1.9.2008
5.12.2008
15.5.2009
23.6.2009