EURAMET project No. 1439

Comparison of standards for liquid flow up to 28.5 t/h

***Final** Report*

Pilot

TUBITAK UME, Turkey

May 2019

Contents

1 Introduction

The aim of this comparison is to compare the results of the calibration of mass flowmeters obtained by different NMIs water flow laboratories that participated in this exercise. A DN 40 ABB coriolis mass flowmeter was used as a transfer standard in the flow range from 3 t /h to 28.5 t/h.

2 Participants

The participants and proposed planning are shown in Table 1. Each laboratory will have 1 month to perform the measurements (including receiving and preparation for transport).

Table 1. Participants and proposed time schedule

Country	NMI	Shipping address	Contact	date
Turkey (PILOT)	TUBITAK UME National Metrology Institute of Turkey	**TÜBİTAK UME** Gebze Yerleşkesi Barış Mah. Dr.Zeki Acar Cad. No:1 41470 Gebze / KOCAELİ TURKEY	Başak AKSELLİ basak.akselli@tubitak.gov.tr	April 2018
Moldova	INM, National Institute of Metrology Republic of Moldova	**National Institute of Metrology Republic of Moldova**, Chisinau, MD2064 28, Eugen Coca str.	Grusca Victor debite@metrologie.md Alina Șincarenco relatii.externe@metrologie.md	May 2018
Romania	BRML-INM Romanian Bureau of Legal Metrology- National Institute of Metrology	**BRML-INM** Institutul National de Metrologie şos. Vitan-Bârzeşti, nr. 11, sect. 4, 042122, Bucureşti	Radu POENARU-BORDEA rpoenaru@inm.ro	June 2018
Turkey (PILOT)	TUBITAK UME National Metrology Institute of Turkey	**TÜBİTAK UME** Gebze Yerleşkesi Barış Mah. Dr.Zeki Acar Cad. No:1 41470 Gebze / KOCAELİ TURKEY	Başak AKSELLİ basak.akselli@tubitak.gov.tr	July 2018

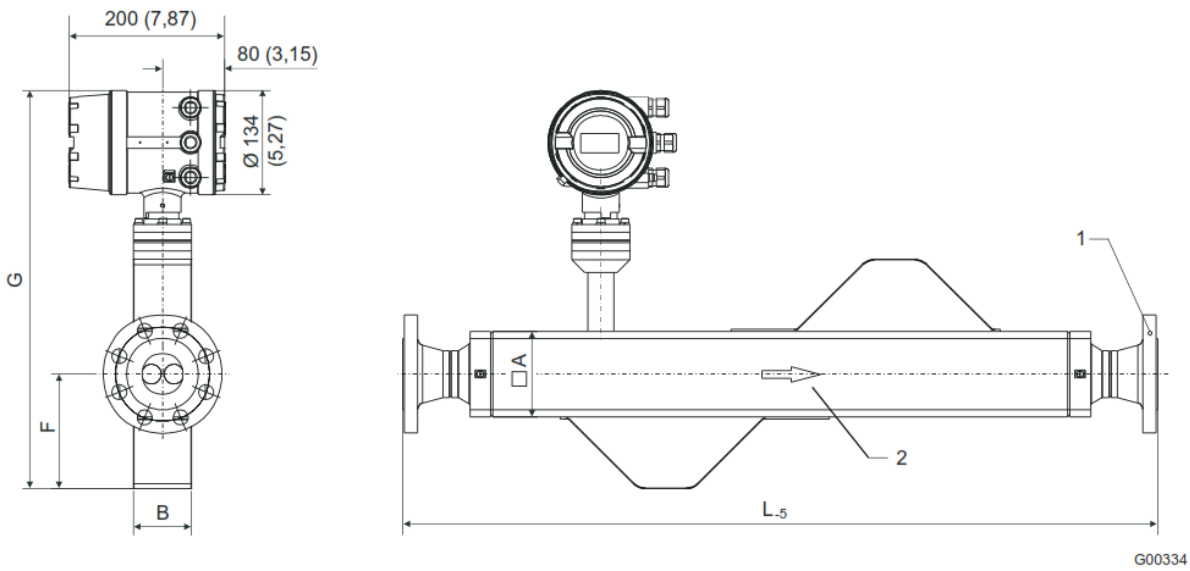
3 The transfer standard

The coriolis mass flowmeter was the instrument to be tested. A description and a picture of the transfer meter are given in Table 2 and in Figure 1 and Figure 2.

Table 2. Technical specification of the transfer meter

Manufacturer: ABB	
Serial number: 000419556/X001	Model: FCM2000 MC23
Model size: DN40	Pulse number: 500 pulse/kg
Process connection: DN50	Pressure class: PN40
Flowrate range: 0-475 kg/min	Weight: approximately 24 kg

Figure 1. The coriolis mass flowmeter



Meter size DN	A	F	B	G	L-5
40	90	129	64	486	940

Figure 2. Dimensions of the coriolis mass flowmeter

Electrical connections of display unit:

- Operating voltage is 220 V

Pulse output connection:

- Pulse counter can connect to the transfer meter as seen on Figure 3.

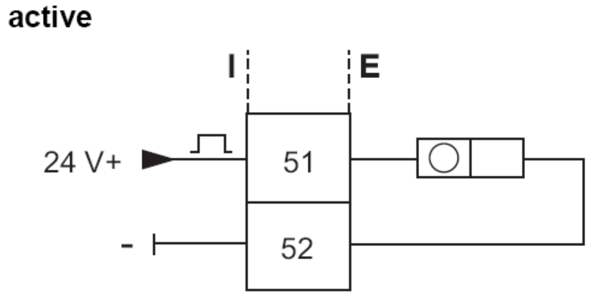


Figure 3. Pulse output connection of the transfer meter

4 The measurement procedure

4.1 Method of measurement

The participating NMI will use their usual calibration protocol. However, the following recommendations are given:

- The transfer standard is tested in the horizontal position.
- The temperature at the transfer standard is measured upstream of the transfer standard.
- The pressure at the transfer standard is measured downstream of the transfer standard.
- It is necessary to use a pulse connection.
  Pulse factor for the meter is 500 pulses/kg
- The flow points should be measured from high to low. Hence, when has to start with the highest flow rate. Furthermore, prior to the calibrations the meter has to run for at least 5 minutes.
- The test in one flow rate should be repeated at least 5 times. The flow rate has to be in the interval ± 3% of the required value.
- For each flow point it is required to have stabilized flow. Depending on the facility this may take up to a few minutes.

4.2 Equipment

Each laboratory described the equipment used in the calibration and the respective traceability.

A summary of used equipment, range of flow rate and traceability can be found in the table 3.

Table 3 – Method of measurement

Country NMI	NMI standard	Flow range of comparison	Traceability
TURKEY TUBITAK UME	Gravimetric Liquid Flow Measurement System	(3 – 28.5) t/h	Independent laboratory
INM, National Institute of Metrology Republic of Moldova	Gravimetric Liquid Flow Measurement System	(3 – 28.5) t/h	Independent laboratory
BRML-INM Romanian Bureau of Legal Metrology-National Institute of Metrology	Gravimetric Liquid Flow Measurement System	(3 – 28.5) t/h	Independent laboratory

5 Measurements results

5.1 Stability of the transfer standard

The stability of the transfer standard was checked before and after the comparison by TUBITAK-UME(Table 4, Figure 4). For calculating of the uncertainty caused by the stability (reproducibility) of the transfer standard (Table 7), 5 measurements was done, because two measurement was not enough.

Table 4- Relative errors (%) of the transfer standard obtained at TUBITAK-UME

Flow rate(t/h)	1st measurement	2nd measurement	3rd measurement	4th measurement	5th measurement
3	-1.215	-1.299	-1.247	-1.137	-1.183
6	-0.658	-0.546	-0.746	-0.681	-0.667
14	-0.384	-0.372	-0.395	-0.378	-0.356
20	-0.431	-0.303	-0.376	-0.333	-0.342
28,5	-0.182	-0.229	-0.151	-0.271	-0.220

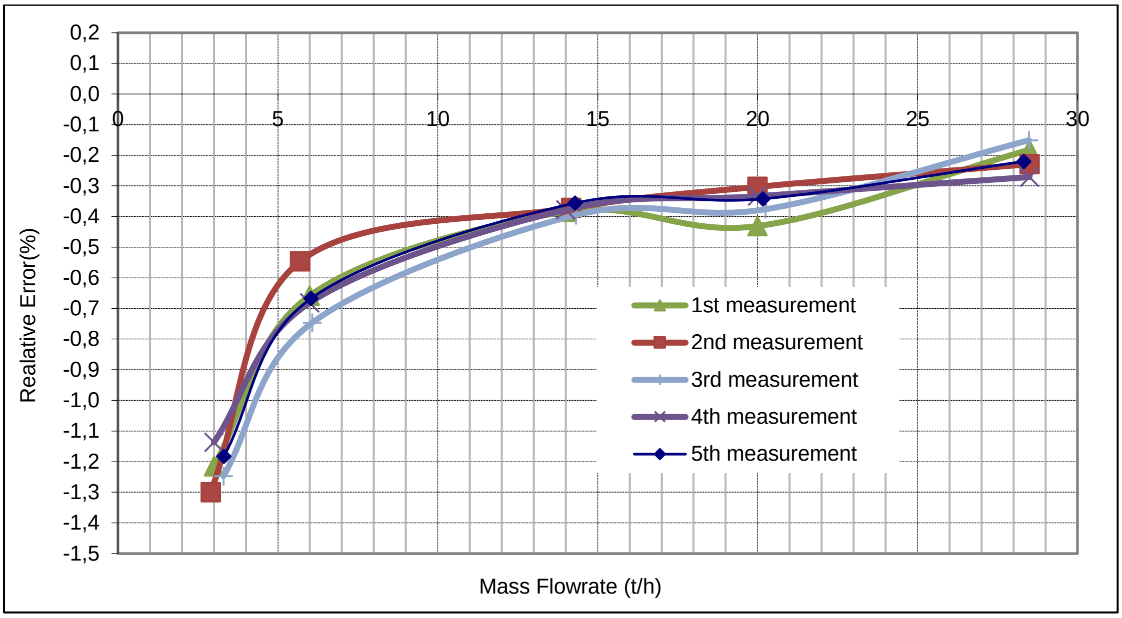


Figure 4. Stability of the transfer standard

5.2 Laboratory results

All data collected from the participating laboratories are summarized in following tables and pictures. Third measurement of TUBITAK-UME was used in the evaluation.

Table 5- Relative errors (%) of the transfer standard obtained at laboratories

Flow rate (t/h) \ NMI	TURKEY	MOLDOVA	ROMANIA
3	-1.247	-1.306	-1.287
6	-0.746	-0.747	-0.749
14	-0.395	-0.418	-0.349
20	-0.376	-0.364	-0.327
28.5	-0.151	-0.223	-0.180

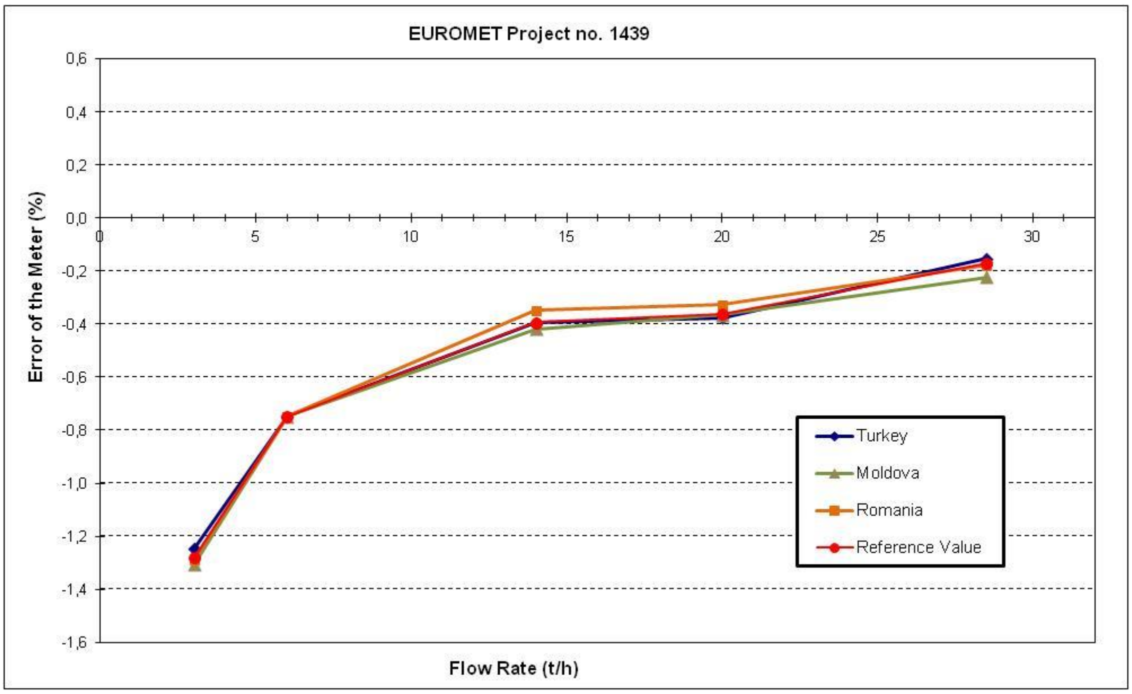


Figure 5. Relative errors of the participating laboratories

5.3 Laboratory uncertainty

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

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

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

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

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

Combined uncertainty is calculated according to the following formulas:

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

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

$$U = k \cdot u_c . \tag{5}$$

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

Uncertainty values of the participating laboratories are stated in following table 6.

Table 6- Expanded uncertainties (%) of measurements reported by laboratories

Flow rate (t/h) \ NMI	TURKEY	MOLDOVA	ROMANIA
3	0.080	0.067	0.12
6	0.070	0.064	0.12
14	0.070	0.093	0.12
20	0.050	0.094	0.12
28.5	0.050	0.140	0.13

5.4 Uncertainty of the corrections and stability of the transfer standard

The standard uncertainties (not expanded) of the error in different laboratories u_{x1}, u_{x2},.....u_{xn} (equation (6)) included the stability of the meter. These uncertainties were calculated by

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

where $U(x_i)$ is the expanded uncertainty (*k*=2) determined by laboratory *i* and presented in results of laboratory *i*

u_{st} is estimated expanded uncertainty caused by the stability (reproducibility) of the transfer standard.

The transfer standard was tested five times in the pilot laboratory (based on the time schedule) and from these results u_{st} was determined. A maximum difference for each flowrate was found during the experiments (E_{exp}) and given table 7.

$$u_{st} = \sqrt{\left(\frac{E_{exp}}{2\sqrt{3}}\right)^2} \qquad (7)$$

Table 7- *The stability (reproducibility) of the transfer standard*

Flow rate (t/h)	E_{exp}	u_{st}
3.0	0.162	0.047
6.0	0.200	0.058
14.0	0.039	0.011

20.0	0.128	0.037
28.5	0.120	0.035

Corrected uncertainty values of each laboratory are stated in annex B. This values were used in the evaluation.

Note:
The value of flow stability from (7) was determined from the measurements at pilot laboratory during the whole period of comparison.

6 Evaluation

The reference value was determined in each flow rate separately. The method of determination of the reference value in each flow rate was correspond to the procedure A presented by M.G.Cox [1]. Only results from independent laboratories was taken into account for the determination of the EURAMET reference value (ECRV) and of the uncertainty of the EURAMET reference value. Then the results from dependent laboratories was compared with the EURAMET reference value and with the uncertainty of the EURAMET reference value.

The determination of the ECRV based on the independent laboratories will include a consistency check according to [1].

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

The reference value *y* will be calculated as weighted mean error (WME):

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

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

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

The standard uncertainty of the reference value u_y is given by

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

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

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

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

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

The degrees of freedom ν was assigned

$$\nu = n - 1 \qquad (12)$$

where *n* is a number of evaluated laboratories.

The consistency check was failing if

$$Pr\{\chi^2_{\nu} > \chi^2_{obs}\} < 0{,}05 \qquad (13)$$

(The function *CHIINV(0,05;* ν*)* in MS Excel was used. The consistency check was failing if *CHIINV(0,05;* ν*)*< χ^2_{obs})

If the consistency check does not fail then *y* was accepted as the EURAMET comparison reference value x_{ref} and *U(y)* was accepted as the expanded uncertainty of the EURAMET comparison reference value $U(x_{ref})$.

If the consistency check fails then the laboratory with the highest value of $\frac{(x_i - y)^2}{u^2_{xi}}$ was excluded for the next round of evaluation and the new reference value *y* (WME), the new standard uncertainty of the reference value u_y and the chi-squared value χ^2_{obs} was calculated again without the values of excluded laboratory. The consistency check was calculated again, too. This procedure was repeated ones till the consistency check has passed.

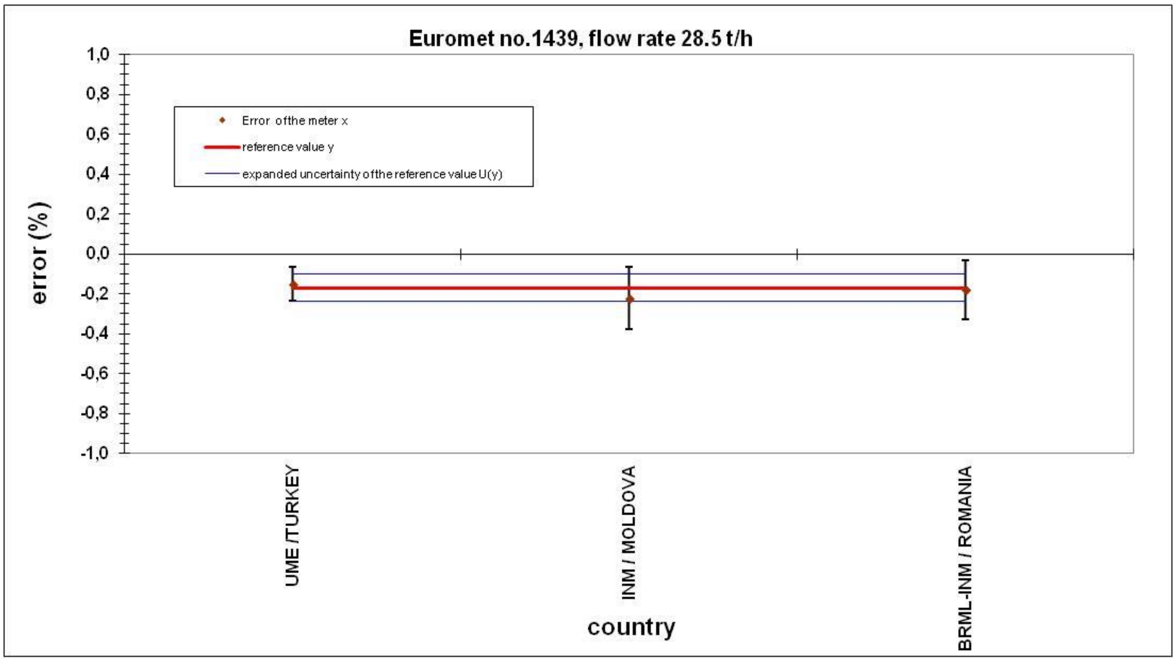


Figure 6. Flowrate evaluation at 28.5 t/h

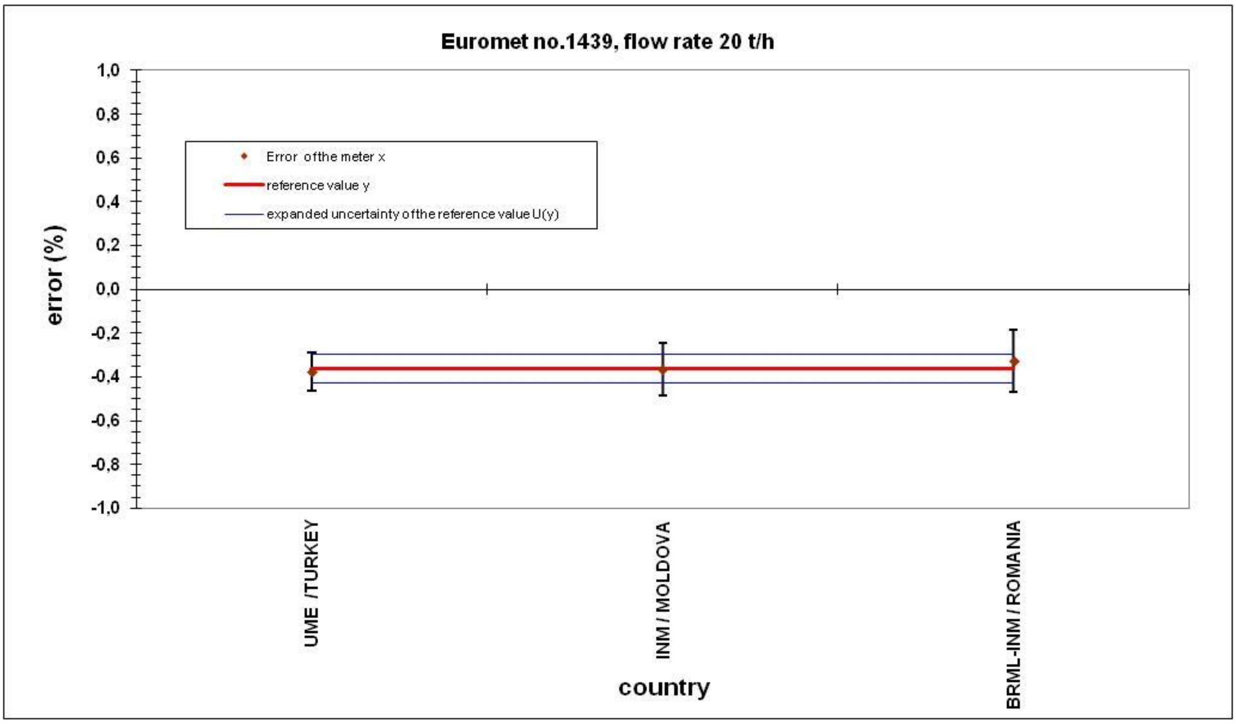


Figure 7. Flowrate evaluation at 20 t/h

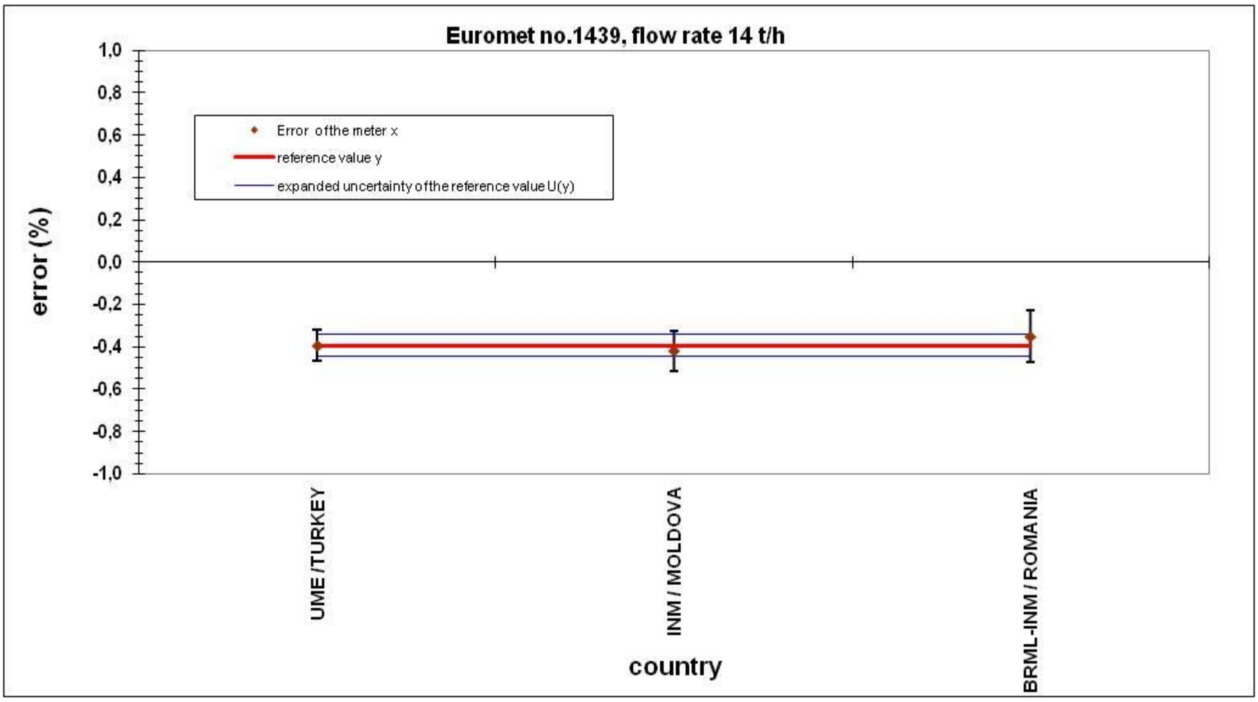


Figure 8. Flowrate evaluation at 14 t/h

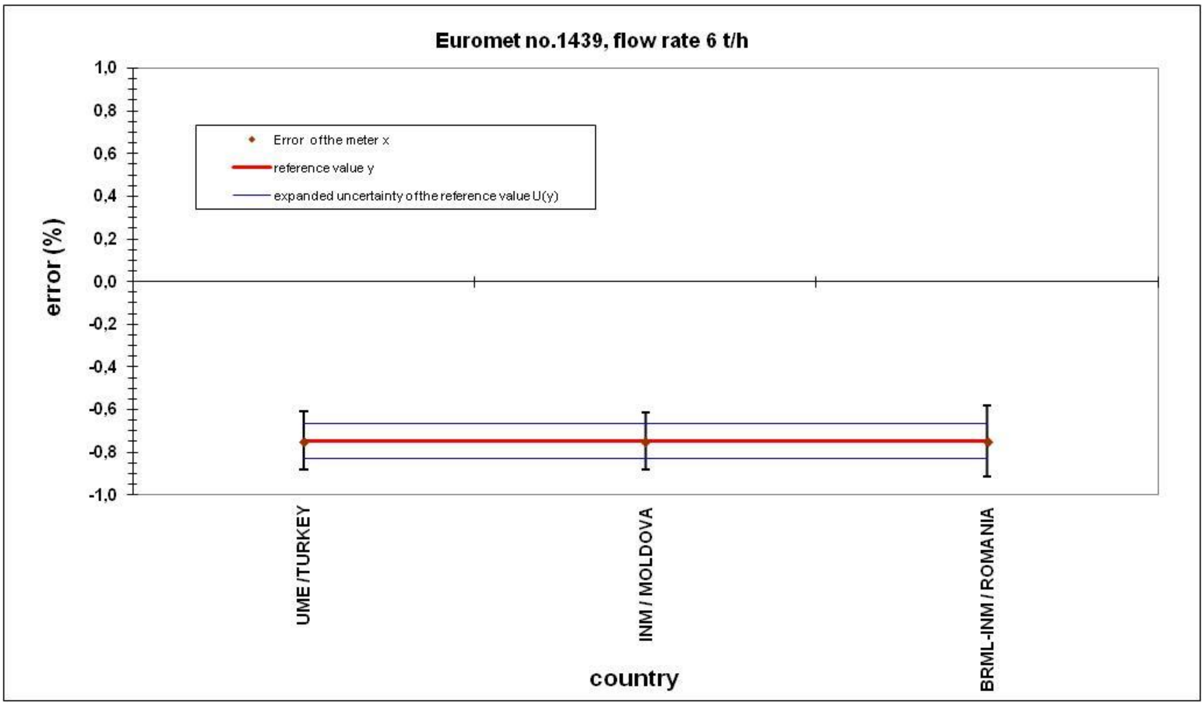


Figure 9. Flowrate evaluation at 6 t/h

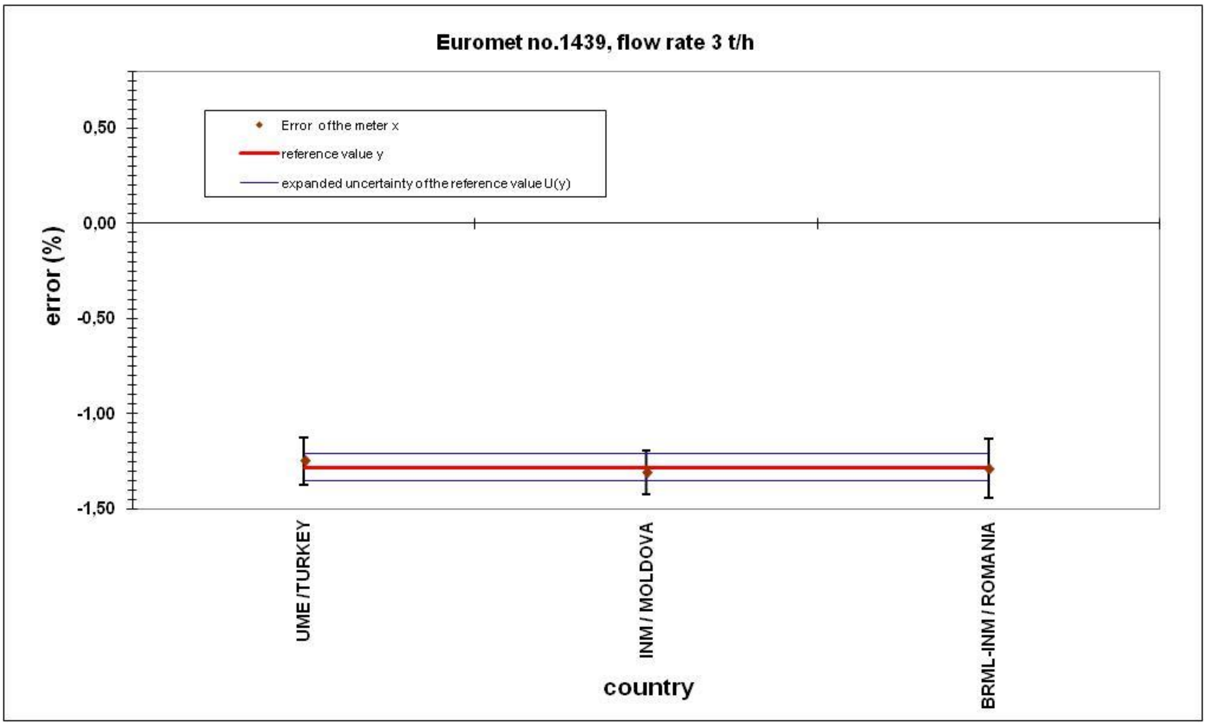


Figure 10. Flowrate evaluation at 3 t/h

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

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

$$di = x_i - x_{ref} \qquad (14)$$

$$dij = x_i - x_j \qquad (15)$$

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

$$Ei = \left|\frac{di}{U(di)}\right| \qquad (16)$$

and $$Eij = \left|\frac{dij}{U(dij)}\right|$$ respectively. (17)

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

- the results of a laboratory was *equivalent (**passed**) if Ei or Eij ≤ 1.*
- the laboratory was determined as *not equivalent (**failed**) if Ei or Eij >1.2*.

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

The calculation of the *DoE* needs the information about the uncertainty of the differences *di* and *dij* (equations (14) and (15)). To make statements about this, it is necessary to consider first the general problem of the difference of two values x_1 and x_2. If we look to the pure propagation of (standard) uncertainty we find:

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

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

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

6.3 Differences to the ECRV

a) *Independent laboratories with contribution to the ECRV*

The covariance between the result of a laboratory (with contribution to the ECRV) and the ECRV is the variance of the ECRV itself. [1)]

$$\Rightarrow u(di) = \sqrt{u_{xi}^2 + u_{xref}^2 - 2.u_{xref}^2} = \sqrt{u_{xi}^2 - u_{xref}^2} \qquad (19)$$

b) *Independent laboratories without contribution to the ECRV*

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

$$\Rightarrow u(di) = \sqrt{u_{xi}^2 + u_{xref}^2} \qquad (20)$$

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

In this case we have covariance between the laboratory and the ECRV because the laboratory is linked to the ECRV via the source of traceability. Although we have no detailed information about it, we can determine a conservative estimation of an upper limit of this covariance. The upper limit is determined for the theoretical case if we have no additional stochastic influence in the traceability of the lab from its source (which is the lab contributing to the ECRV). Then the results of the lab considered here would be strongly correlated with the results of the laboratory contributing to the ECRV (correlation coefficient = 1) and there would be the same covariance to the ECRV as in case A1. In any case of additional uncertainty caused stochastically the correlation and consequently the covariance is smaller.

$$=> u(di) = \sqrt{u_{xi}^2 + u_{xref}^2 - 2u_{xref}^2} = \sqrt{u_{xi}^2 - u_{xref}^2} \quad (21)$$

The χ_{obs}^2 value was determined and the outlier was removed from the ECRV determined. The results are in following Table 8.

Table 8- EURAMET reference value (ECRV)

Q (t/h)	3	6	14	20	28.5
ECRV (%)	-1.280	-0.747	-0.393	-0.363	-0.170
U (x_{ref}) (%)	0.074	0.082	0.053	0.064	0.067
χ_{obs}^2	0.4963	0.0006	0.7879	0.3450	0.6598

7 Summary

The degree of equivalence to ECRV is a measure for the equivalence of the results of any laboratory with the ECRV or with any other laboratory, respectively. $E_i \leq 1$ means that *i*-th laboratory is in good agreement with ECRV and E_{ij}>1.2 means that *i*-th and *j*-th laboratory are in good agreement. For values of *DoE* in the range $1 < E_i$ *or* $E_{ij} \leq 1.2$ the "warning level" is defined. In this case some actions to check are recommended to the laboratory.

Table 9- Degree of Equivalence to ECRV

Flow rate(t/h) \ NMI	TURKEY	MOLDOVA	ROMANIA
28.5	0.35	-0.37	-0.06
20	-0.22	-0.01	0.28
14	-0.03	-0.31	0.40
6	0.01	0.00	-0.01
3	0.34	-0.29	-0.05

8 References

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

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

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

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

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

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

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

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

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

9 Conclusions

From the analysis of Table 9 it can be verified that all of the Laboratories have consistent result in all of the measurements.

Related CMC tables of the participants are as follows:

TUBITAK-UME, Turkey

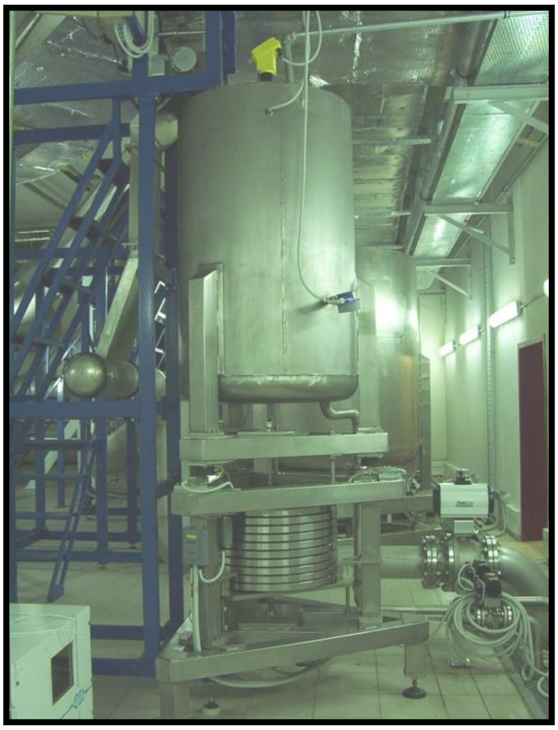
Quantity	Instrument of Artifact	Instrument Type or Method	Minimum Value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of confidence	Is the expanded uncertainty a relative one?	Comments	NMI service identifier
Volume water flow rate	Liquid flow rate (volume)	Visual, pulse or electrical outputs (rotameter, magnetic, ultrasonic, rotary type flowmeters)	0.030	103	m^3/h	Fluid	Water	0.20	%	2	95%	Yes	Approve d on 15 October 2013	TR6
						Temperature	19.5 C to 20.5							
						Pressure	Absolute 0.1 MPa							

Appendix A – NMI reports

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

TUBITAK-UME

Range of flow rate:	(1-100) m^3/h
Uncertainty (k=2):	0,06%



The method in which the mass of liquid collected is deduced from tare and gross weighing made respectively before and after the liquid has been diverted for a measured time interval into the weighing tank.
At least five measurements are carried out for each of series of flow-rate measurement and analysis of random uncertainties are carried out.
The mean mass flow-rate during the filling time is obtained by dividing the real mass m of the liquid collected by the filling time t:

$$q_v = \frac{\Delta m}{\rho \times t} = \frac{m_1 - m_0}{\rho \times t} \times \frac{1 - \frac{\rho_a}{\rho_p}}{1 - \frac{\rho_a}{\rho}}$$

BRML-INM
Romanian Bureau of Legal Metrology-National Institute of Metrology

The installation for calibration / metrological verification of cold water meters and hot water meters - DN 15 ... DN 50 is composed of:

ACFN calibrated at the Mass Laboratory from INMB with traceability to SI;

Digital thermometer with Platinum Thermo resistance, calibrated at the INMB Temperature Laboratory with SI Traceability;

Manometer with elastic element, accuracy class 0,6, calibrated at Pressures Laboratory from INMB, traceable to SI;

Calibration protocol

The measurements were performed on a gravimetric recirculation plant. The transfer standard was mounted in the measuring line in a horizontal position. Upstream of the transfer standard flowmeter a DN 50 section was mounted in which a 45 degree pocket was installed for the introduction of a calibrated Pt 500 sensor, to measure the upstream temperature, and downstream of the flow meter it was mounted a DN 50 section in which a manometer (0- 6) bar – relative pressure, with a resolution of 0.05 bar, calibrated in advance. The conventional flow rate was determined as the ratio between the conventional volume of the installation and the time measured with a stopwatch. The indicated flow rate was determined as the

Characteristic information \ picture of the primary standard used by measurements	Working procedure
Electromagnetic flowmeters MAGFLO, DN 15, Q = (10 ... 3000) dm^3 / h and DN 50, Q = (3 000 ... 28 500) dm^3 / h; Working pressure max. 6 bar; Max temperature in the flow rig: 70 °C; Measured volume (1 ... 275) dm^3; Relative expanded uncertainty of measured volume: (0.14 ... 0.24) %. The flowmeters and the installation are calibrated by the Flow-Volume Laboratory from INMB.	ratio between the indicated mass (mass pulse number multiplied by impulse value) and the mean density during the measurement indicated by the Coriolis flowmeter multiplied with the time measured with the stopwatch. At each flow the measurements were made 3 or 4 times, as shown in the table. The average error for each flow was calculated. Type B uncertainty is determined by compiling the relevant uncertainty sources from the standard installation. **Description of the installation** The working fluid passing through the transfer standard is collected in a 300-liter vessel placed on an ACFN with a maximum mass of 300 kg and d = 2 g. The test flow is controlled by Danfoss electromagnetic flowmeters, by means of a battery of valves and a pump controlled by a frequency converter. A quantity of water is circulated through the transfer standard. The conventional volume is calculated by the installation software taking into account the mass collected on the scale, the water temperature, also taking into account the correction coefficient of the buoyancy.

INM, National Institute of Metrology Republic of Moldova

Type of instalation	MR-T-S 1020/2550
Made by	ENBRA, a.s
Serial number	Nº022013.076
Year of construction	2013, February
The number of test lines	2

Technical characteristics:

Flow range, m³/h	0.01 - 35
Pipe diameter, mm	15 - 50
The temperature of water,°C	10°C - 60°C
The uncertainty of installation in transmission of the unit of volume by comparison method	0.2%
The uncertainty of installation in transmission of the unit of volume by gravimetric method	0.05%
Tank capacity	For cold water – 1000 l For hot water – 1000 l

Components:

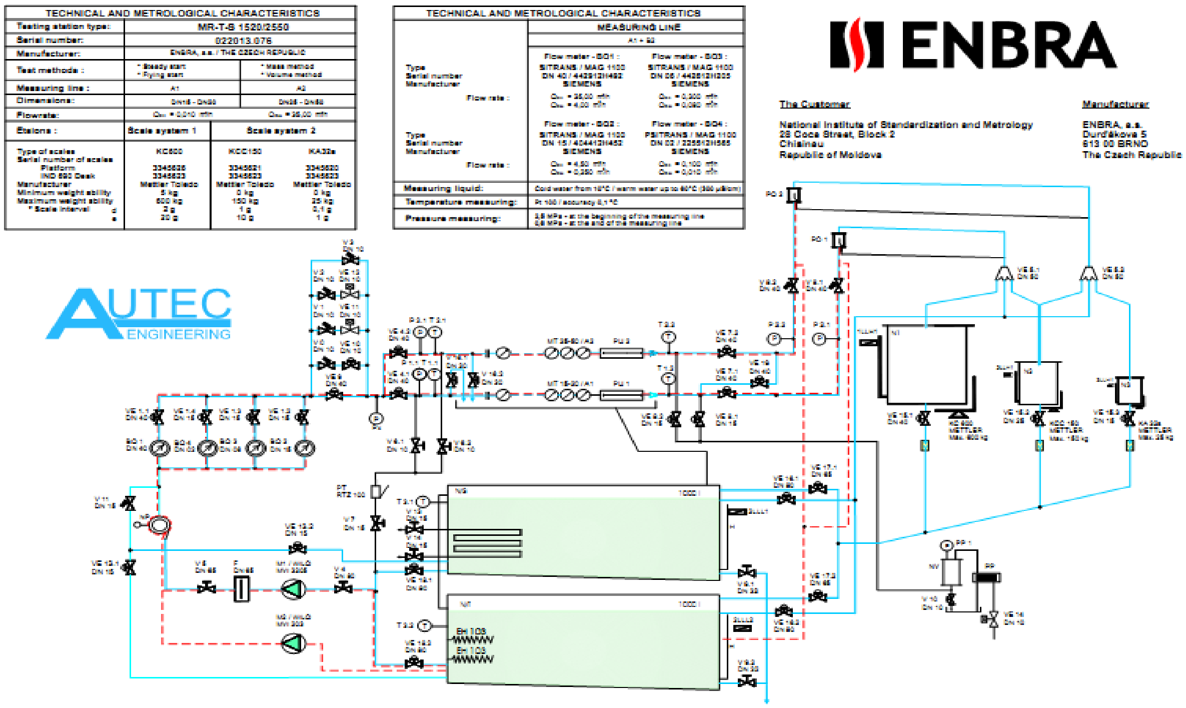
Scales	
Scales 1: Made by Weighing range (kg)	KC 600, S/N 3345262 METTLER TOLEDO 600
Value of division (g)	2.0
Scales 2: Made by Weighing range (kg) Value of division (g)	KC 150, S/N 3345261 METTLER TOLEDO 150 1

Scales 3: Made by Weighing range (kg) Value of division (g)	KA 32s, S/N 3345260 METTLER TOLEDO 25 0.1
Display of scales – common to all weighing sistems	IND 690 – S/N 3345263

Flowmeters	
1. Electromagnetic flowmeter BQ1 Made by Serial number Flow: Qmax (m³/h) Qmin (m³/h)	Ду 40; MAG 1100 SIEMENS 432912H492/7ME61102RA202AA1 35.00 4.000
2. Electromagnetic flowmeter BQ2 Made by Serial number Flow: Qmax (m³/h) Qmin (m³/h)	Ду 15; MAG 1100 SIEMENS 404412H452/7ME61101VA202AA1 4.50 0.250
3. Electromagnetic flowmeter BQ3 Made by Serial number Flow: Qmax (m³/h) Qmin (m³/h)	Ду 6; MAG 1100 SIEMENS 442612H205/7ME61101MA202AA1 0.300 0.80
4. Electromagnetic flowmeter BQ4 Made by Serial number Flow: Qmax (m³/h)	Ду 2; MAG 1100 SIEMENS 225512H565/7ME61101DA202AA1 0.100

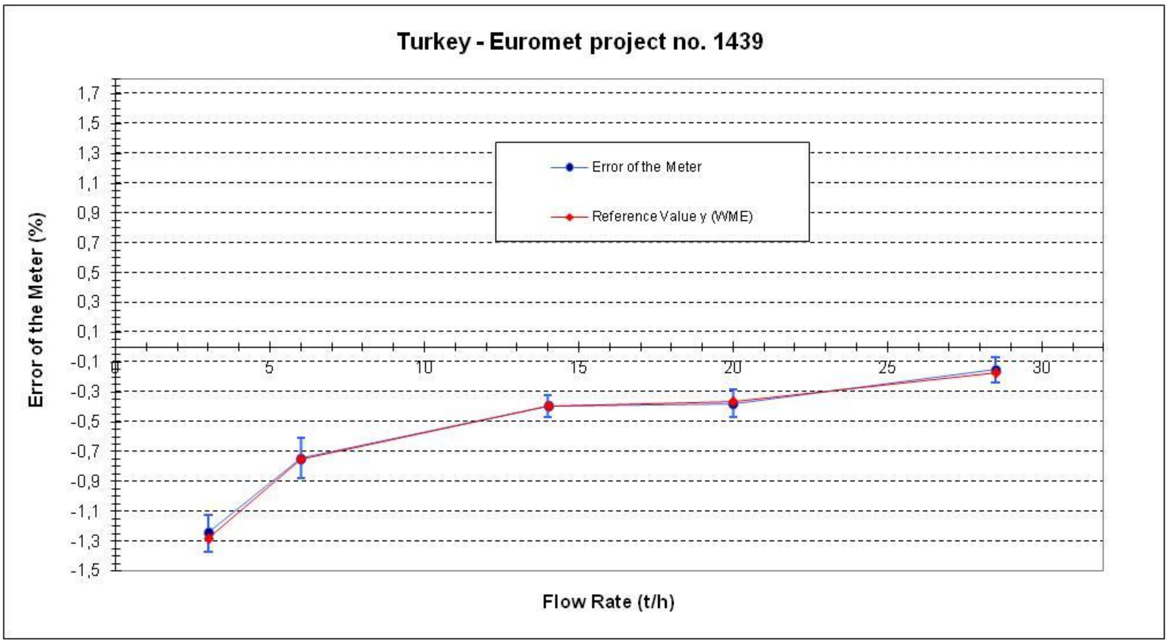
Qmin (m³/h)	0.010

Temperature transducer	
Type	Pt 100
Error	0.1 ^{0}C

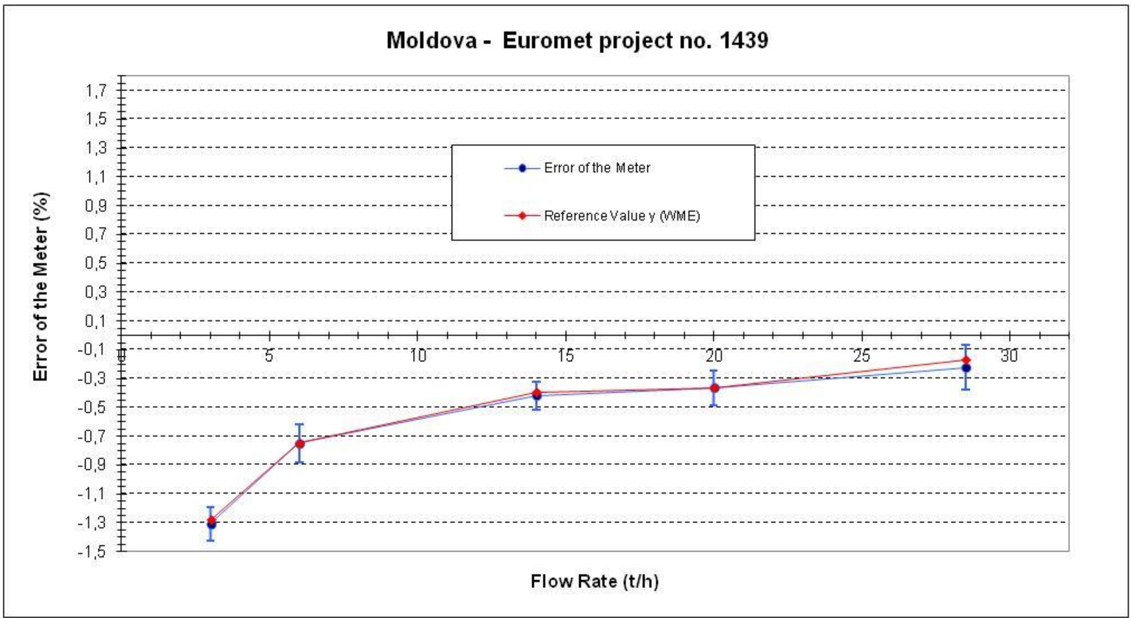

TECHNICAL AND METROLOGICAL CHARACTERISTICS
Testing station type:
MR-T-S 1520/2550
Serial number:
022013.076
Manufacturer:
ENBRA, a.s. / THE CZECH REPUBLIC
Test methods :
Measuring line :
Dimensions:
Flowrate:
Etalons :
Scale system 1
Scale system 2
KC600
KCC150
KA32s
Mettler Toledo
TECHNICAL AND METROLOGICAL CHARACTERISTICS
MEASURING LINE
Measuring liquid:
Temperature measuring:
Pressure measuring:
ENBRA
The Customer
National Institute of Standardization and Metrology
28 Coca Street, Block 2
Chisinau
Republic of Moldova
Manufacturer
ENBRA, a.s.
Durďákova 5
613 00 BRNO
The Czech Republic
AUTEC
ENGINEERING

Appendix B – Graphical representation of relative error and expanded uncertainty

TURKEY					
Flow rate of the transfer standard	Relative error of the transfer standard	Expanded uncertainty of measurement declared by laboratory U_{xi} (%)	Expanded uncertainty of measurement extended by stability U_{st} (%)	***d**i*	$\lvert E_i \rvert$
28.5	-0.151	0.050	0.086	0.019	0.35
20	-0.376	0.050	0.089	-0.013	0.22
14	-0.395	0.070	0.073	-0.001	0.03
6	-0.746	0.070	0.135	0.001	0.01
3	-1.247	0.080	0.123	0.033	0.34



MOLDOVA					
Flow rate of the transfer standard	Relative error of the transfer standard	Expanded uncertainty of measurement declared by laboratory U_{xi} (%)	Expanded uncertainty of measurement extended by stability U_{st} (%)	d_i	$\vert E_i \vert$
28.5	-0.223	0.140	0.157	-0.053	-0.37
20	-0.364	0.094	0.120	-0.001	-0.01
14	-0.418	0.093	0.096	-0.025	-0.31
6	-0.747	0.064	0.132	0.000	0.00
3	-1.306	0.067	0.115	-0.026	-0.29



ROMANIA					
Flow rate of the transfer standard	Relative error of the transfer standard	Expanded *uncertainty* of measurement declared by laboratory U_{xi} (%)	Expanded uncertainty of measurement extended by stability U_{st} (%)	d_i	$\lvert E_i \rvert$
28.5	-0.178	0.12	0.148	-0.008	-0.06
20	-0.327	0.12	0.141	0.035	0.28
14	-0.349	0.12	0.122	0.044	0.40
6	-0.749	0.12	0.167	-0.002	-0.01
3	-1.287	0.13	0.152	-0.006	-0.05