EURAMET PROJECT No 1162

"Inter-Comparison of Water Meter Reference Standard"

February 2011

Abstract

This work comprises the contribution of the Hellenic Institute of Metrology (EIM) to an inter-laboratory comparison between several European national metrology institutions on the calibration of a turbine water reference meter. The experimental procedure applied as well as the facility used for calibration is described. The mean relative error, E [%], of the flow meter is determined at five test flow rates during at least 10 repetitions performed under identical experimental conditions. A detailed analysis of the measurement uncertainty in the value of E [%] is also presented.

HELLENIC INSTITUTE OF METROLOGY
Mechanical Measurements Department
Flow & Volume Laboratory
Dr Zoe Metaxiotou, Laboratory Head

Postal address:
Industrial Area of Thessaloniki
Block 45, Sindos
GR-57 022
GREECE
Phone: +30 2310 56 99 62, +30 2310 56 99 99
Fax: +30 2310 56 99 96
E-mail address: zoe@eim.gr

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1. Description of test facility

The primary 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 standard 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 SSS 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 Table 1.

Table 1. Specifications of VEMIT Kalibro water flow test facility

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)
Traceability:	National mass and temperature standards of Greece
Thermal stability :	Double piping, thermal insulation, air & water circulation in the test section
Test flow meter installation :	Hydraulic compression
Operation :	Fully automated

An overview of the facility is given in figure 1.

Figure 1. Overview of VEMIT Kalibro water flow test facility

2. Calibration 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 65D.
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. However, the reference meter itself is equipped with it's own flow straightener which is installed before the meter. 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 pulse counter and signal converter of the transfer standard are powered to allow for stabilization of the electronics.
In the mean time, the flow rates 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.
The calibration is launched starting with the highest flow rate. The calibration cycle is repeated 10 times. All calibration raw data are automatically stored in a database. They are recovered from that database and are given in detail in the excel file named "EURAMET1162_EIM_Data.xls" accompanying this report.

3. Results

The results of this exercise are reported in the excel file entitled "EURAMET1162_EIM_Data.xls" and the corresponding calibration curve obtained for the reference meter is given in Figure 2. In the same excel file the Type A and Type B uncertainties involved in the calculation of the error, E[%], of the meter under test are also given. The analysis of those uncertainty contributions is described in the next section. The experimental data are also given in Appendix I.

The mean error, E[%], and the corresponding total expanded uncertainty of the transfer standard at each tested flow rate is given in Table 2.

Table 2. Summarized inter-comparison results

Flow Rate	Bopp & Reuther Turbine meter (S/N: 19148)	
[m3/h]	E[%]	± U(E) [%]
3,6	0,15	0,072
5,0	0,18	0,071
10,0	0,28	0,071
20,0	0,15	0,072
29,3	-0,07	0,074

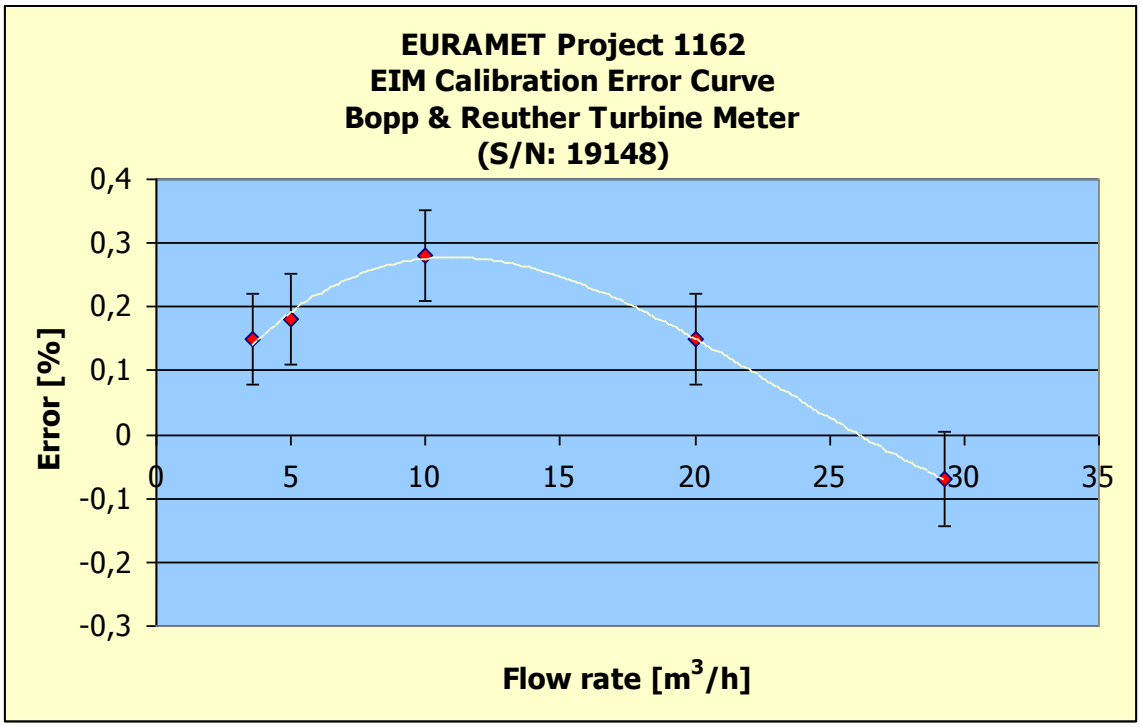

Figure 2. Calibration results for EURAMET 1162 transfer standard

4. Uncertainty analysis

The estimation of the uncertainty in the value of the mean relative error, E[%], of the meter was done according to the principles of the *Guide to Expression of Uncertainty in Measurement* (ISO, Geneva, 1995).
In particular, the total expanded uncertainty in E[%] is estimated as

$$U = 2 \times \sqrt{U_A^2 + U_B^2} \qquad (1),$$

where:

U_A : Type A standard uncertainty component of E[%]
U_B : Type B standard uncertainty component comprised of:

- the uncertainty in pulse counting device of the meter (Type B_m)
- the uncertainty of the primary facility (Type B_{ref})

The Type A uncertainty component of E[%] is estimated as the standard deviation of the mean of the sample of N measurements taken for each test flow rate and is given by

$$U_A = \frac{\sum_{i=1}^{N} (E_i)}{\sqrt{N}} \qquad (2).$$

The Type B uncertainty contribution to the total uncertainty of E[%] is given by

$$U_B = \sqrt{(TypeB_m)^2 + (TypeB_{ref})^2} \qquad (3),$$

and is a combination of two components:

1. Type B_m: Refers to the uncertainty due to the error in the pulse counting device of the meter and it is assumed to be maximum 1 pulse.
2. Type B_{ref}: Refers to the uncertainty of the primary facility

Type B_{ref} is obtained by a detailed uncertainty analysis of all uncertainty sources in the measurement of flow in the reference facility. These components and their combination are given in a detailed uncertainty budget in Table 3. The budget refers to a measured mass of 575 kg which is a mass representative for most of the measurements in the present exercise. The mass is measured on the largest scale and the water temperature is assumed to be 20 ^{o} C. The uncertainty is calculated for flow rates higher than 1 m^3/h as it is the case in this exercise. It should be noticed that the reported uncertainties Type B_{ref} in the excel file entitled "EURAMET1162_EIM_Data.xls" are slightly increased compared to the uncertainty given in Table 3 representing a "worst case" scenario for the operation of this flow facility due to the fact that the measurements were performed in the SSS mode.

Table 3. Uncertainty budget for gravimetric water flow test facility VEMIT Kalibro

Uncertainty Source	Symbol	Uncertainty	Distribution	Relative Uncertainty Contribution, U_i^2 [%]
Calibration of scale	U_1	105g	Normal	0.000083
Error of scale at the beginning of weighing	U_2	60g	Rectangular	0.000036
Error of scale at the beginning of weighing	U_3	60g	Rectangular	0.000036
Uncertainty due to reading of pulses of reference meters in the beginning of the measurement	U_4	Minimun freq=300Hz, minimum time 60 sec: 1 / 18000 pulses	Rectangular	0.000010
Uncertainty due to reading of pulses of reference meters at the end of the measurement	U_5	Minimun freq=300Hz, minimum time 60 sec: 1 / 18000 pulses	Rectangular	0.000010
Uncertainty due to water density	U_6	0.020%	Rectangular	0.0000133
Uncertainty due to temperature measurement	U_7	0.2 °C	Rectangular	0.000033
Uncertainty due to the temperature difference between the measuring volume and the buffer volume after the measuring area	U_8	0.3 °C	Rectangular	0.000019
Uncertainty due to water evaporation	U_9	0.005%	Rectangular	0.000008
Uncertainty due to diverter	U_{10}	0.030%	Rectangular	0.00030
Uncertainty due to long term stability of scales	U_{11}	0.030%	Rectangular	0.00030
			ΣU_i^2 =	0.000970
			$U_B = 2 \times \sqrt{\sum U_i^2}$ =	**0.062**

APPENDIX I

Table of Experimetal Data & Results

EURAMET PROJECT No 1162
Intercomparison of Water Meter Refrence Standard

NMI:	HELLENIC INSTITUTE OF METROLOGY (EIM)
Primary Standard:	National Primary Flow Facility (VEMIT Kalibro water test rig)
Contact person:	Zoe Metaxiotou (E-mail address: zoe@eim.gr)
Date:	January, 2011

Nominal Flow Rate	Water Temp.	Water Density	Outlet pressure at the TS	Meter Pulses	Volume of Reference Standard	Volume of Transfer Meter	Error of the meter	Mean Error	Type A Uncert.	Type B Uncert.	Total Uncertainty
[m^3/h]	[^oC]	[kg/m^3]	[bar]		[L]	[L]	[%]	[%]	[%]	[%]	[%]
3,6	21,63	0,99793	4,34	29350	516,94	517,97	0,20	0,15	0,008	0,035	0,072
	22,09	0,99780	4,34	29329	515,951	516,839	0,17				
	22,61	0,99765	4,34	29265	519,729	520,584	0,16				
	23,06	0,99752	4,34	29477	518,137	519,029	0,17				
	23,41	0,99741	4,34	29389	518,483	519,171	0,13				
	24,02	0,99722	4,34	29397	519,202	519,93	0,14				
	24,43	0,99709	4,34	29440	519,679	520,354	0,13				
	24,89	0,99694	4,34	29464	518,111	518,764	0,13				
	25,29	0,99680	4,34	29374	517,219	517,864	0,12				
	23,05	0,99752	4,34	29323	517,410	518,341	0,18				
5	21,48	0,99797	4,33	39096	689,763	691,15	0,20	0,18	0,007	0,035	0,071
	21,94	0,99784	4,33	39135	689,614	690,974	0,20				
	22,45	0,99770	4,33	39125	693,132	694,382	0,18				
	22,92	0,99756	4,33	39318	690,735	692,086	0,20				
	23,63	0,99734	4,33	39188	691,964	692,916	0,14				
	23,87	0,99727	4,33	39235	693,971	695,159	0,17				
	24,29	0,99713	4,33	39362	692,797	694,153	0,20				
	24,76	0,99698	4,34	39305	693,663	694,93	0,18				
	25,14	0,99685	4,34	39349	692,203	693,375	0,17				
	22,9	0,99756	4,33	39261	689,0141	690,461	0,21				
10	21,31	0,99802	4,3	44311	767,254	769,617	0,31	0,28	0,006	0,035	0,071
	21,78	0,99789	4,3	43578	777,104	779,418	0,30				
	22,31	0,99774	4,31	44133	778,504	780,76	0,29				
	22,77	0,99760	4,31	44209	774,567	776,822	0,29				
	23,21	0,99747	4,31	43986	777,946	780,019	0,27				
	23,74	0,99731	4,31	44167	769,9	772,036	0,28				
	24,15	0,99718	4,31	43715	769,718	771,824	0,27				
	24,63	0,99702	4,31	43703	770,072	772,124	0,27				
	25,02	0,99689	4,31	43720	777,451	779,471	0,26				
	22,75	0,99761	4,31	44136	780,1436	782,562	0,31				
20	21,22	0,99804	4,24	50364	905,723	907,387	0,18	0,15	0,009	0,035	0,072
	21,69	0,99791	4,24	51379	888,971	890,61	0,18				
	22,22	0,99776	4,24	50429	894,063	895,519	0,16				
	22,67	0,99763	4,29	50707	896,308	897,692	0,15				
	23,12	0,99750	4,24	50831	897,288	899,016	0,19				
	23,65	0,99734	4,24	50905	902,089	903,414	0,15				
	24,06	0,99721	4,24	51154	901,779	902,99	0,13				
	24,56	0,99705	4,23	51130	893,303	894,425	0,13				
	24,94	0,99692	4,23	50645	893,752	894,672	0,10				
	22,65	0,99764	4,24	50659	888,0411	889,462	0,16				
29,3	21,15	0,99806	4,16	51132	887,596	887,537	-0,01	-0,07	0,012	0,035	0,074
	21,61	0,99793	4,2	50255	890,379	890,168	-0,02				
	22,14	0,99779	4,17	50404	890,346	889,903	-0,05				
	22,59	0,99766	4,16	50389	894,36	893,789	-0,06				
	23,05	0,99752	4,17	50609	915,531	914,54	-0,11				
	23,58	0,99736	4,17	51784	892,46	891,669	-0,09				
	24	0,99723	4,18	50489	896,774	895,873	-0,10				
	24,36	0,99711	4,31	50727	918,733	917,86	-0,10				
	24,87	0,99694	4,21	51972	894,255	893,241	-0,11				
	22,55	0,99767	4,18	50578	903,3864	903,025	-0,04				