EURAMET PROJECT No 1046

"Inter-Comparison of Electromagnetic Flow Meters"

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Abstract

This work comprises the contribution of the Hellenic Institute of Metrology (EIM) to an international comparison between several European national metrology institutions on the calibration of two electromagnetic flow meters. The experimental procedure applied as well as the facility used for calibration is described. The mean relative error, E [%], of each reference 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.

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1. Description of test facility

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 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 ^{o}C
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 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 80D (Fig. 2).

Figure 2. 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 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.

After a 1-hour long preconditioning stage the signal of the transfer standard is checked with an oscilloscope for its shape and frequency as shown in Fig. 3.

The calibration is launched starting with the highest flow rate. 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. They are recovered from that database and are given in detail in the excel file named "EIM_Data_EURAMET1046.xls" accompanying this report.

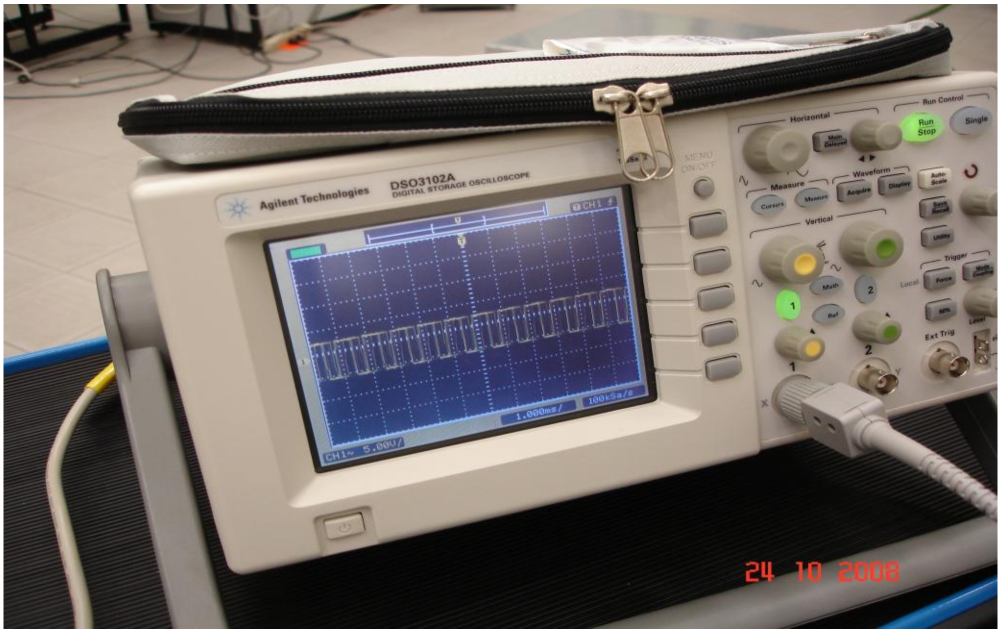

Figure 3. The shape of the pulse output signal of the transfer standard as depicted with an oscilloscope connected in parallel with the signal input channel of the test bench

3. Results

The results of this exercise are reported in the excel file entitled "EIM_Data_EURAMET1046.xls" and the corresponding calibration curves obtained for TS 857 and TS 858 are shown in Figures 4 and 5, respectively.

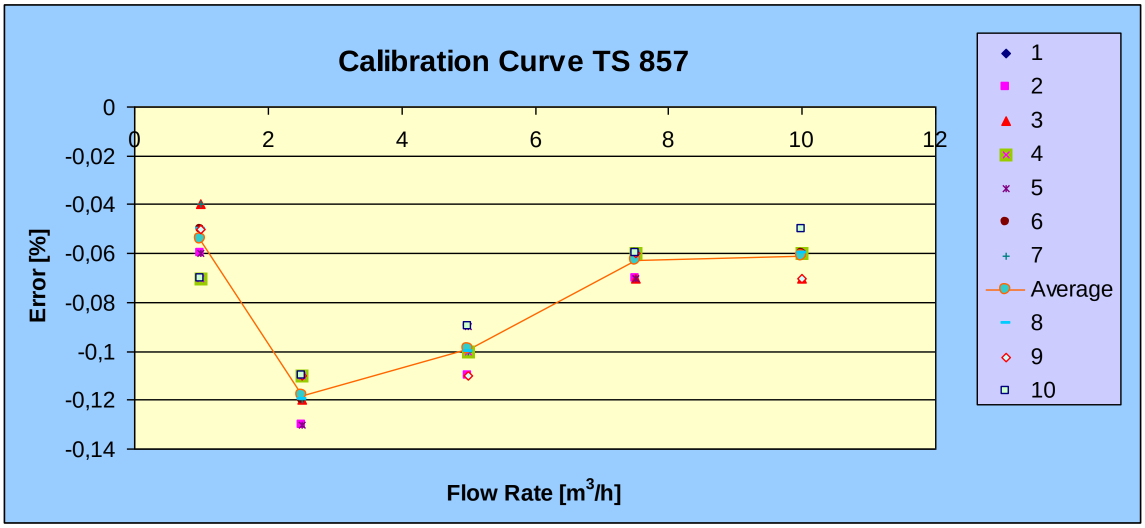

Figure 4. Calibration results for TS No 857

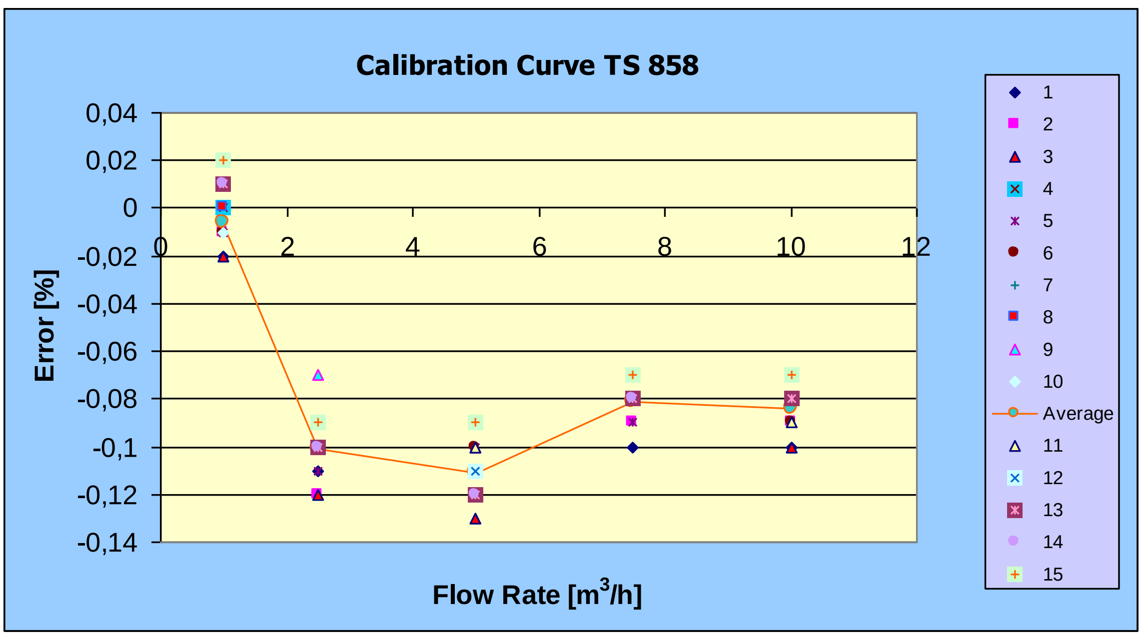

Figure 5. Calibration results for TS No 858

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

Table 2. Summarized inter-comparison results

Flow Rate [m3/h]	TS No 857		TS No 858	
	E[%]	± U(E) [%]	E[%]	± U(E) [%]
10	-0,06	0,06	-0,08	0,06
7,5	-0,06	0,06	-0,08	0,06
5	-0,10	0,06	-0,11	0,06
2,5	-0,12	0,06	-0,10	0,06
1	-0,06	0,06	0,00	0,06

In the same excel file the Type A and Type B uncertainties involved in the calculation of the error, E[%], of the meters under test are also given. The analysis of those uncertainty contributions is described in the next section.

4. Uncertainty analysis

The estimation of the uncertainty in the value of the mean relative error, E[%], of the meters 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 of the flow reference

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

$$U_A = \frac{\underset{i=1}{\overset{N}{S}}\left(E_i\right)}{\sqrt{N}} \qquad (2).$$

The Type B uncertainty contribution to the total uncertainty of E[%] 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 (see excel file "EIM_Data_EURAMET1046.xls). 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 are representing a "worst case" scenario for the operation of this flow facility.

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**