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Bilateral comparison between EIM and IMBiH in resistance

Calibration of Resistance standards of 1 Ω, 100 Ω and 10 kΩ

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1. INTRODUCTION

The present intercomparison was proposed by the Institute of Metrology of Bosnia and Herzegovina (IMBiH), with the motive of supporting its CMCs in the quantity of resistance. The Hellenic Institute of Metrology (EIM) - laboratory of Low Frequency of the Electrical Measurements Department accepted to provide the travelling standards and be the pilot of the intercomparison.

The steps for the transport of standards, the timetable of measurements and the reporting formulations were described in the protocol of the intercomparison, which was prepared following the CCEM guidelines.

2. DETAILS

2.1 Participants

The Pilot laboratory was the Low Frequency laboratory of the Hellenic Institute of Metrology:

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The participating laboratory was IMBiH:
Institute of Metrology of Bosnia and Herzegovina (IMBiH)
Laboratory for electrical quantities and T&F
Augusta Brauna 2
71000, Sarajevo
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web: www.met.gov.ba

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2.2 Timetable

The measurements were performed according to the following timetable:

Time table of the Measurments

Institute	Action	Time period
EIM	Perform initial EIM measurements	April 2015
IMBiH	Perform IMBiH measurements	July 2015
EIM	Perform final EIM measurements	August 2015

2.3 Travelling standards

The travelling standards were provided by EIM and were the following:

Resistor A

Device: Resistor

Nominal value: 1 Ohm

Manufacturer: Guildline

Type: 9334

Serial Number: 63534

Resistor B

Device: Resistor

Nominal value: 100 Ohm

Manufacturer: Guildline

Type: 9334

Serial Number: 61944

Resistor C

Device: Resistor

Nominal value: 10 kOhm

Manufacturer: Guildline

Type: 9334

3. MEASUREMENTS

3.1 Methods of measurement

The participating laboratory described the method of measurement and the environmental conditions within its report, as it was requested in the protocol of the comparison. The calibration was performed as follows:

The measurements were made using a direct current comparator bridge MI 6010D and standard resistors 1 Ohm, 100 Ohm and 1 kOhm all calibrated at CMI.

The pilot laboratory performed two calibrations: one before the IMBiH measurements and one afterwards. The Measurements International MI 6010B and Guildline 6625 Direct Current Comparator bridges were used at 1:1 ratio. As reference standards Tinsley 5685A resistors 1Ω, 100 Ω and 10 kΩ were used, all having traceability in EIM.

3.2 IMBiH Results

The results of IMBiH resistance measurements were as follows:

IMBiH Results 1 Ω

Standard Serial no.	Date of measurement	Temperature (ºC)	Uncertainty of temperature (ºC)	Current of measurement	Measurement result (ratio)	Type A uncertainty of measurement
7273-01	09.07.2015	22.98	0.2	20 mA	0.999 978 015 474 7	7.16837E-09
7273-01	10.07.2015	23.00	0.2	20 mA	0.999 978 023 556 2	6.99677E-09
7273-01	11.07.2015	22.95	0.2	20 mA	0.999 978 029 006 0	6.72535E-09
7273-01	12.07.2015	23.00	0.2	20 mA	0.999 978 035 008 8	6.19617E-09
7273-01	13.07.2015	22.97	0.2	20 mA	0.999 978 039 826 9	5.6883E-09

IMBiH

Date	Resistance (Ω)	uc (Ω)	*U* (*k*=2)
11/07/2015	0.99998304	3.28E-07	7E-07

IMBiH Results 100 Ω

Standard Serial no.	Date of measurement	Temperature (ºC)	Uncertainty of temperature (ºC)	Current of measurement	Measurement result (ratio)	Type A uncertainty of measurement
10755_01	09.07.2015	22.97	0.2	3 mA	1.000 005 664 640	4.64965E-09
10755_01	10.07.2015	22.98	0.2	3 mA	1.000 005 661 191	5.3513E-09
10755_01	11.07.2015	22.98	0.2	3 mA	1.000 005 658 329	4.42697E-09
10755_01	12.07.2015	22.95	0.2	3 mA	1.000 005 661 351	4.18881E-09
10755_01	13.07.2015	22.99	0.2	3 mA	1.000 005 657 385	5.10578E-09

IMBiH

Date	Resistance (Ω)	uc (Ω)	*U* (*k*=2)
11/07/2015	100.0004721	3.0E-05	6E-05

IMBiH Results 10 kΩ

Standard Serial no.	Date of measurement	Temperature (ºC)	Uncertainty of temperature (ºC)	Current of measurement	Measurement result (ratio)	Type A uncertainty of measurement
5871-01	09.07.2015	22.97	0.2	0.3 mA	0.100 000 763 430 20	4.40176E-09
5871-01	10.07.2015	23.06	0.2	0.3 mA	0.100 000 763 445 27	4.54324E-09
5871-01	11.07.2015	22.93	0.2	0.3 mA	0.100 000 762 289 04	4.21959E-09
5871-01	12.07.2015	22.96	0.2	0.3 mA	0.100 000 759 880 23	3.66248E-09
5871-01	13.07.2015	22.93	0.2	0.3 mA	0.100 000 761 616 78	4.62749E-09

IMBiH

Date	Resistance (Ω)	uc (Ω)	*U* (*k*=2)
11/07/2015	9999.921706	3.0E-03	0.006

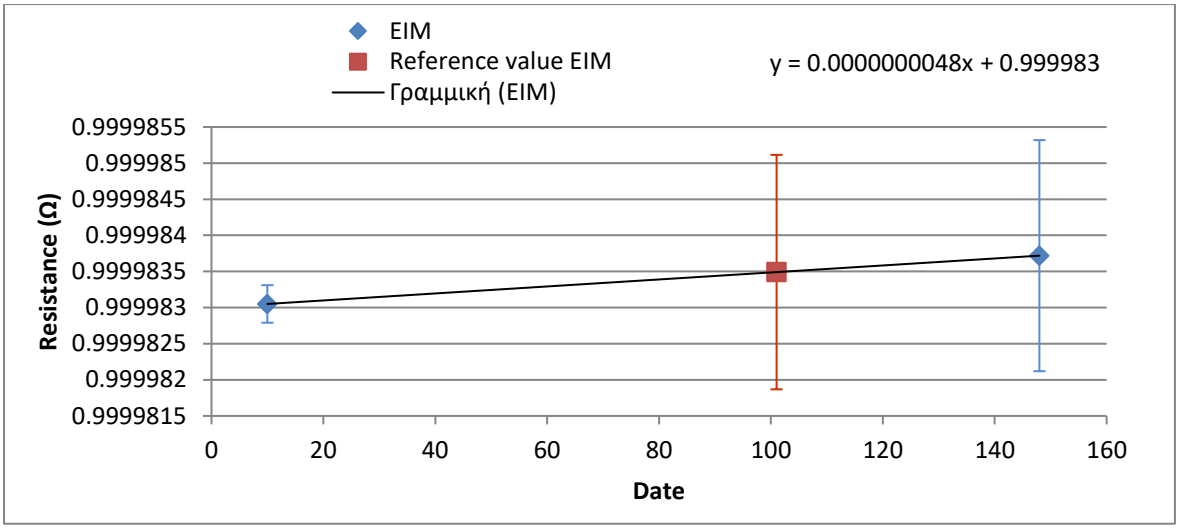
3.3 EIM Reference value

EIM performed measurements of the transport resistors two times: before and after the calibration in IMBiH. A linear regression between these two measurements results in the a, b constants of the line connecting the two measurements. Using the constants a and b the value of the resistance at the chronological point of the IMBiH measurements can be computed. This is taken as the reference value of the resistance corresponding to the reference date. The results are presented below:

EIM 1 Ω Reference value

Date	Resistance (Ω)	*U* (*k*=2)	
10/04/2015	0.99998305	5.19991E-07	a= 4.8 E-09 Ω/day
28/08/2015	0.999983719	0.0000032	b= 0.999983 Ω

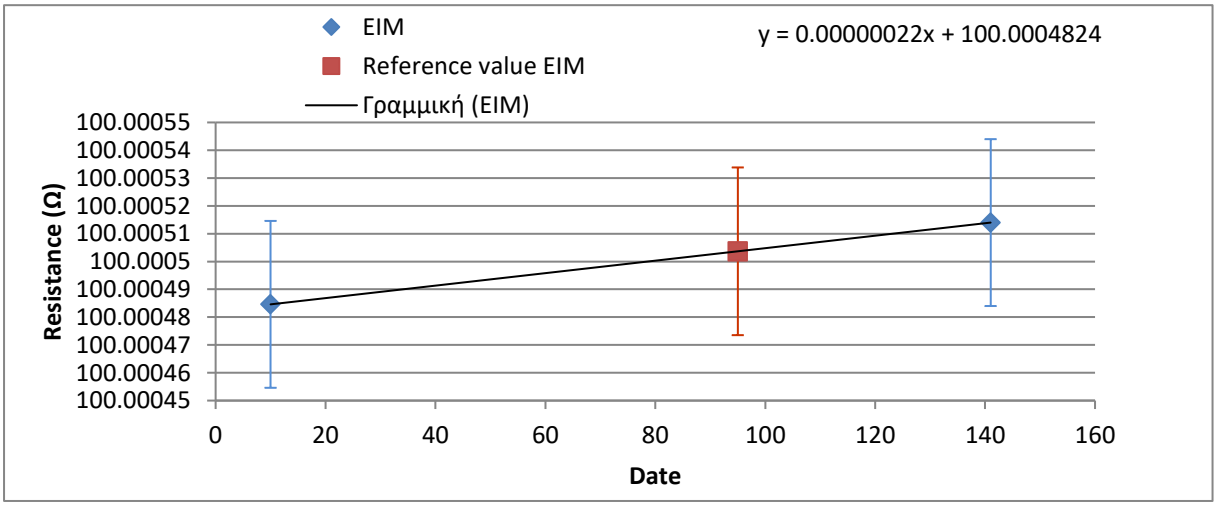
Reference Date	Reference value (Ω)	*U* (Ω) (*k*=2)
11/07/2015	0.999983491	0.0000032



EIM 100 Ω Reference value

Date	Resistance (Ω)	*U* (*k*=2)		
16/04/2015	100.0004846	6.00003E-05	a=	2.2E-07
27/08/2015	100.000514	6.00003E-05	b=	100.0004824

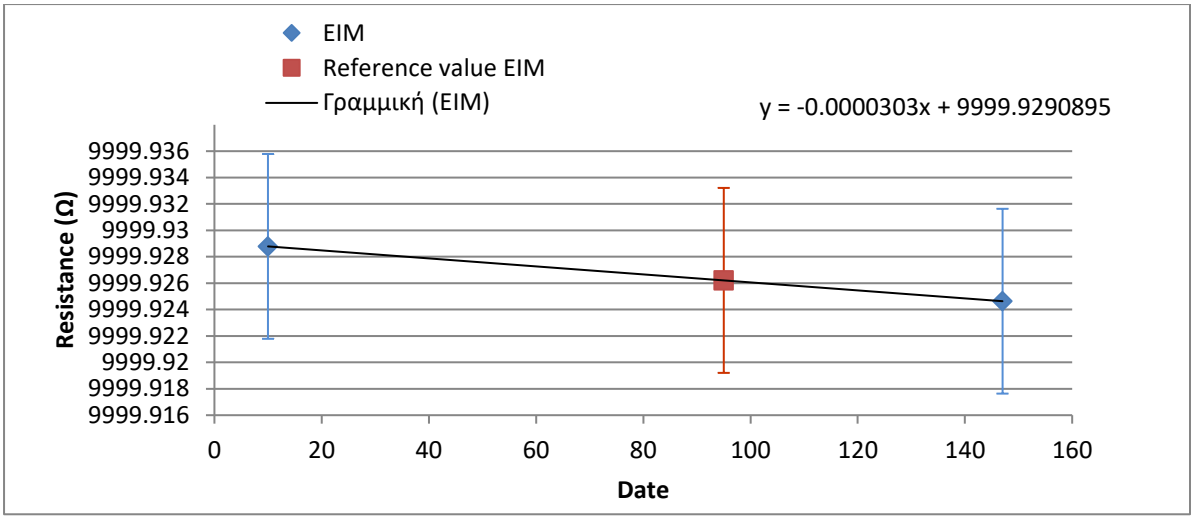
Reference Date	Reference value (Ω)	*U* (Ω) (*k*=2)
11/07/2015	100.0005037	0.0000603



EIM 10 kΩ Reference value

Date	Resistance (Ω)	*U* (*k*=2)		
16/04/2015	9999.928786	0.0139999	a=	-3.03 E-05
03/09/2015	9999.924634	0.013999894	b=	9999.9290895

Reference Date	Reference value (Ω)	*U* (Ω) (*k*=2)
11/07/2015	9999.92621	0.0140128



4. UNCERTAINTY

The uncertainty of the measurements was calculated by both laboratories according to the international standards ISO "Guide to the Expression of Uncertainty in Measurement", 1995 and the standard EA-4/02. The uncertainty budgets of IMBiH are presented in the Appendix.

4.1 Expanded Uncertainty

The expanded uncertainty for a level of confidence of 95% is given by the relation:

U=1,96 u

Where u is the combined standard uncertainty.

5. EVALUATION OF THE RESULTS

5.1 Table of the results

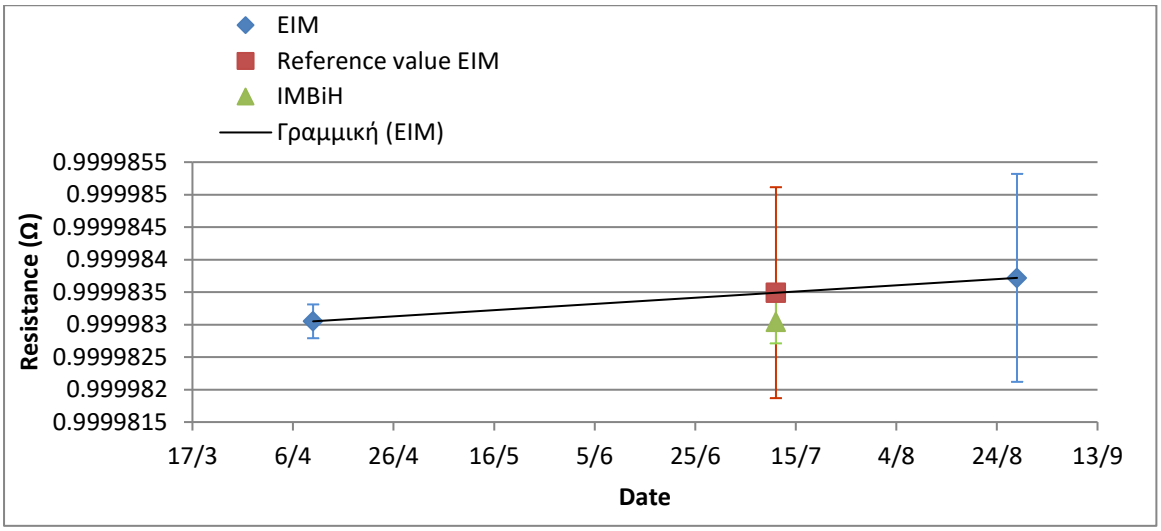
The difference of the IMBiH results from the reference values are given in the next table.

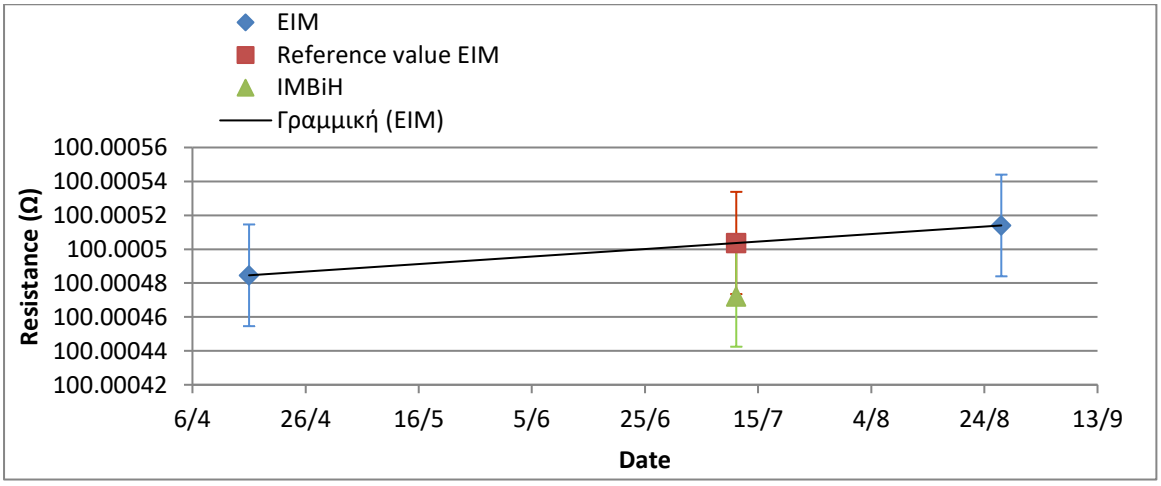
Comparison EIM-IMBiH

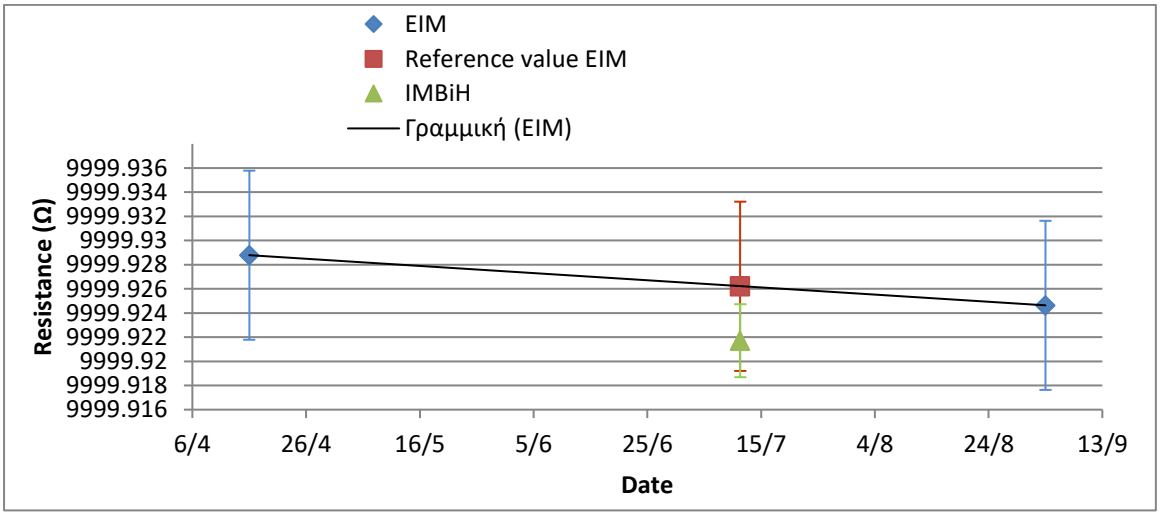
Nominal Resistance	IMBiH-EIM Difference (Ω)	IMBiH-EIM Difference (ppm)
1 Ω	-4.514E-07	-0.5
100 Ω	-3.161E-05	-0.3
10 kΩ	-0.0045041	-0.5

5.2 Graph of the results

In the next graph the results of the participating laboratory and the pilot laboratory are presented with the corresponding uncertainties as error bars.







5.3 Index E_n

According to the directive EA-2/03 “Interlaboratry Comparisons”, the evaluation of the measurement results is performed with the estimation of the parameter E_n, which is defined as:

$$E_n = \frac{\varepsilon_{LAB} - \varepsilon_{EIM}}{\sqrt{U^2(\varepsilon_{LAB}) + U^2(\varepsilon_{EIM})}}$$ where,

ε_{LAB} is the error measured by the participating lab

ε_{EIM} is the error measured by the pilot lab

$U(\varepsilon_{LAB})$ is the expanded uncertainty of the participating lab and

$U(\varepsilon_{EIM})$ is the expanded uncertainty of the pilot lab.

All the values of En are expected to be less than unity: $|E_n| < 1$.

In the next table all the values of En are presented for the participating laboratory.

***En* values of the intercomparison**

Nominal value	*En*
1 Ω	-0.14
100 Ω	-0.37
10 kΩ	-0.30

5.4 Conclusion

The values of the index En are less than unity for all the testing points, i.e. $|En| < 1$ as it is expected.

APPENDIX

IMBiH Uncertainty Budgets

1Ω Uncertainty Budget IMBiH

Quantity X_i	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability distribution / method of evaluation (A, B)	Sensitivity coefficient c_i	Relative uncertainty contribution $u(R_i)$	Degree of freedom v_i
Calibration Rs (Certificate) R_{STD}	1.000 005 01	0.08	Normal	1	8.00E-08	∞
Drift Rs, 1 year δR_{drift}	0	0.32	Rectangular	1	3.18E-07	∞
Temperature coefficient Rs δR_{temp}	0	0.012	Rectangular	1	1.15E-08	∞
Power Coeff. Rs, ppm/W δR_w	0	3.46	Rectangular	1	1.39E-09	∞
Measured ratio r	0.999 978 03	0.002 9	Normal	1	2.90E-09	199
Bridge linearity, ppm FS r_{lin}	0	0.003	Rectangular	1	2.89E-09	∞
Resolution, ppm FS r_{resb}	0	0.000 6	Rectangular	1	5.77E-10	∞
Bridge Uncertainty r_{acc}	0	0.023	Rectangular	1	2.31E-08	∞
R_x	0.999 983 04					
		Combined standard uncertainty:			*0.000 000 33*	
		Degrees of freedom:			*3.28E+10*	
		Expanded uncertainty (coverage factor 95%):			*0.000 000 66*	

100 Ω Uncertainty Budget IMBiH

Quantity X_i	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability distribution / method of evaluation (A, B)	Sensitivity coefficient c_i	Relative uncertainty contribution $u(R_i)$	Degree of freedom v_i
Calibration Rs (Certificate) R_{STD}	99.999 906	0.06	Normal	1	6.00E-06	∞
Drift Rs, 1 year δR_{drift}	0	0.29	Rectangular	1	2.89E-05	∞
Temperature coefficient Rs δR_{temp}	0	0.012	Rectangular	1	1.15E-06	∞

Power Coeff. Rs, ppm/W δR_w	0	3.46	Rectangular	1	3.12E-09	∞
Measured ratio r	1.000 006	0.002	Normal	100	2.10E-07	199
Bridge linearity, ppm FS r_{lin}	0	0.003	Rectangular	100	2.89E-07	∞
Resolution, ppm FS r_{resb}	0	0.000 6	Rectangular	100	5.77E-8	∞
Bridge Uncertainty r_{acc}	0	0.023	Rectangular	100	2.31E-06	∞
R_x	100.000 472					
		Combined standard uncertainty:			*0.000 030*	
		Degrees of freedom:			*7.91E+10*	
		Expanded uncertainty (coverage factor 95%):			*0.000 059*	

10 kΩ Uncertainty Budget IMBiH

Quantity X_i	Estimate x_i	Relative standard uncertainty $u(x_i)$	Probability distribution / method of evaluation (A, B)	Sensitivity coefficient c_i	Relative uncertainty contribution $u(R_i)$	Degree of freedom v_i
Calibration Rs (Certificate) R_{STD}	999.999 790	0.06	Normal	10	6.00E-04	∞
Drift Rs, 1 year δR_{drift}	0	0.29	Rectangular	10	2.89E-03	∞
Temperature coefficient Rs δR_{temp}	0	0.012	Rectangular	10	1.15E-04	∞
Power Coeff. Rs, ppm/W δR_w	0	3.46	Rectangular	10	3.12E-07	∞
Measured ratio r	0.100 000 762	0.002	Normal	-99998.46	-1.90E-04	199
Bridge linearity, ppm FS r_{lin}	0	0.003	Rectangular	-99998.46	-2.89E-04	∞
Resolution, ppm FS r_{resb}	0	0.000 6	Rectangular	-99998.46	-5.77E-6	∞
Bridge Uncertainty r_{acc}	0	0.06	Rectangular	-99998.46	-5.77E-04	∞
R_x	9999.921 706					
		Combined standard uncertainty:			*0.003 020*	
		Degrees of freedom:			*1.28E+07*	
		Expanded uncertainty (coverage factor 95%):			*0.006 041*	