Report on EURAMET.M.M-S2

Supplementary comparison of 100 gram, 10 gram, 500 microgram, 200 microgram and 100 microgram weights.

(EURAMET project number 1054).

Abstract

A comparison of sub-milligram mass standards was undertaken between NPL (as the pilot laboratory), LNE and PTB. The nominal values of the weights circulated were 500 micrograms, 200 micrograms and 100 micrograms. All participants demonstrated equivalence with the calculated reference values at the stated level of uncertainty, which was less than 0.2 micrograms for participants' results. However, it was noted that instability in the transfer standards was a significant factor in the comparison results and care needs to be taken in the transport and handling of such sub-milligram weights to ensure the success of future comparisons.

In additional to the sub-milligram weights, weights of nominal value 100 grams and 10 grams were circulated as a means to validate CMC data. All participants demonstrated equivalence to the calculated reference value for both transfer standards.

1 Introduction

The lower level of the mass scale for calibration by comparison with standard weights has traditionally been 1 milligram. Both NPL and LNE have recently produced and calibrated mass standards in the range 100 micrograms to 1 milligram. The sub-milligram standards have been used for the scale assessment of primary 1-kilogram mass comparators. Sub-milligram standards have also been manufactured and calibrated for research laboratories in the UK and it is envisaged that the requirement for such standards will grow in the future.

A bilateral comparison of sub-milligram weights between NPL and LNE was proposed at the beginning of 2008. Additional weights of 10 grams and 100 grams were included to allow LNE to demonstrate improved capability at these weights in support of proposed new CMC declarations. Towards the end of 2008 the PTB expressed an interest in participating in the sub-milligram comparisons and for completeness the 10 gram and 100 gram transfer standards were also measured by the PTB.

Details of the participating laboratories are listed in Table 1.

Table 1: List of Participating Laboratories

Laboratory		**Country**
Laboratoire National de Métrologie et d'Essais	LNE	France
Physikalisch-Technische Bundesanstalt	PTB	Germany
National Physical Laboratory	NPL	United Kingdom

The Institute for Reference Materials and Measurements (IRMM) acted as coordinator for the results of the comparison.

2 Description of the Transfer Standards

A set of five transfer standards was used for this comparison. The set consisted of the following nominal values;

100 grams
10 grams
0.5 milligrams
0.2 milligrams
0.1 milligrams

The 100 gram and 10 gram weights were made from non-magnetic stainless steel and with the form and quality recommended by OIML [1] for weights of accuracy Class E_1. The sub-milligram weights were manufactured at LNE from aluminium wire.

Full details of the transfer standards and the measurement protocol are given in Appendix 2.

3 Comparison Schedule

The weights were circulated among the participants during the period June 2008 to July 2009. The schedule of the measurements is outlined in Table 2. Transportation was undertaken by hand, with the weights being carried within purpose-built boxes.

Table 2: Measurement Schedule

Laboratory	Date of Measurements
LNE	11/06/2008
NPL	15/07/2008
LNE	30/07/2008
LNE	25/11/2008
PTB	03/06/2009
LNE	16/07/2009

4 Procedures and Equipment

Each participant calibrated the transfer standards according to their normal calibration procedure using appropriate mass comparators. Details of the procedures and equipment used by the three participating laboratories are given in this section of the report.

4.1 LNE

Measurements at LNE were performed by direct comparison with primary stainless steel standards (100 g and 10 g weights) and with primary aluminium-silicon standards (500 µg, 200 µg and 100 µg weights). Weighings were performed on Mettler M-one, AT106 and A5 mass comparators. Details of the comparators are given in Table 3.

Table 3: Comparators used by LNE for the calibration of the transfer standards.

Manufacturer	Type	Capacity	Resolution	Standard deviation	Notes
Mettler	M-one	1 kg	0.1 µg	0.17 µg	Used in automatic comparison mode
Mettler	AT106	100 g	1 µg	0.31 µg	Used in automatic comparison mode
Mettler	A5	5 g	0.1 µg	0.3 µg	Used in automatic comparison mode

4.2 NPL

Measurements at NPL were performed by direct comparison with primary stainless steel standards (100 g and 10 g weights) and by sub-division from 1 gram primary stainless steel standards (500 µg, 200 µg and 100 µg weights). Weighings were performed on a Mettler AT106 mass comparator and a Sartorius C5S mass comparator. Details of the comparators are given in Table 4.

Table 4: Comparators used by NPL for the calibration of the transfer standards.

Manufacturer	Type	Capacity	Resolution	Standard deviation	Notes
Mettler	AT106	100 g	0.1 µg	0.5 µg	Used in manual comparison mode
Sartorius	C5S	5 g	0.1 µg	0.3 µg	Used in manual comparison mode

4.3 PTB

Details of the mass comparators used at PTB are given in Table 5. The mass determinations of the 100 g and 10 g weights were performed by direct comparison with reference standards (stainless steel). The 500 µg, 200 µg and 100 µg weights were determined by sub-division from a 1 mg reference standard (aluminium).

Table 5: Comparators used by PTB for the calibration of the transfer standards.

Manufacturer	Type	Capacity	Resolution	Standard deviation	Notes
Mettler	HK1000	1 kg	0,1 µg	1,6 µg	
Mettler	AX106H	100 g	1 µg	0.7 µg	
Mettler	UMT5	5 g	0,1 µg	0.3 µg	

5 Results of the Comparison

Each participant reported their measured true mass difference from the nominal value for the transfer standards together with an associated uncertainty for each of the five weights, calculated according to the Guide to the Expression of Uncertainty in Measurement (GUM) [2]. The results were reported to the IRMM, which acted as an independent collator for the measurement results. The results of the participants together with their associated uncertainties are reported in Table 6.

Table 6: Results of the comparison for the five transfer standards

Transfer Standard	Meas. No.	Laboratory ID	Date of Meas.	Results	
				Measured mass Δm / g	Estimated uncertainty / mg
100 g	1	LNE1	11/06/2008	100.000 091 30	0.003 10
	2	NPL	15/07/2008	100.000 090 10	0.001 66
	3	LNE2	30/07/2008	100.000 088 80	0.003 10
	4	LNE3	25/11/2008	100.000 088 45	0.003 10
	5	PTB	03/06/2009	100.000 081 60	0.002 30
	6	LNE4	16/07/2009	100.000 084 10	0.003 10
10 g	1	LNE1	11/06/2008	10.000 012 86	0.001 40
	2	NPL	15/07/2008	10.000 013 10	0.000 81
	3	LNE2	30/07/2008	10.000 012 39	0.001 40
	4	LNE3	25/11/2008	10.000 012 65	0.001 40
	5	PTB	03/06/2009	10.000 011 80	0.001 70
	6	LNE4	16/07/2009	10.000 012 20	0.001 40
0.000 5g	1	LNE1	11/06/2008	0.000 500 49	0.000 18
	2	NPL	15/07/2008	0.000 500 46	0.000 13
	3	LNE2	30/07/2008	0.000 501 28	0.000 18
	4	LNE3	25/11/2008	0.000 500 93	0.000 18
	5	PTB	03/06/2009	0.000 500 90	0.000 15
	6	LNE4	16/07/2009	0.000 500 59	0.000 18
0.000 2 g	1	LNE1	11/06/2008	0.000 201 45	0.000 15
	2	NPL	15/07/2008	0.000 201 27	0.000 13
	3	LNE2	30/07/2008	0.000 201 77	0.000 15
	4	LNE3	25/11/2008	0.000 201 43	0.000 15
	5	PTB	03/06/2009	0.000 201 55	0.000 14
	6	LNE4	16/07/2009	0.000 201 46	0.000 15
0.000 1 g	1	LNE1	11/06/2008	0.000 103 51	0.000 14
	2	NPL	15/07/2008	0.000 104 02	0.000 11
	3	LNE2	30/07/2008	0.000 104 15	0.000 14
	4	LNE3	25/11/2008	0.000 104 23	0.000 14
	5	PTB	03/06/2009	0.000 104 02	0.000 14
	6	LNE4	16/07/2009	0.000 104 13	0.000 14

6 Calculation of Reference Values and Data Analysis

Initially a reference value was calculated based on all six measurements at each nominal value using a least squares analysis of the measurement data [3]. There has been assumed to be no correlation between the results of the three participants. The four results reported by LNE for each of the transfer standards have been assumed to be correlated to a degree which varies with the nominal value of the transfer standard and the traceability route for the measurement standards. The covariances and correlation coefficients (*r*) calculated for the LNE results are given in table 7.

Table 7: Covariances and correlation coefficients of LNE results for transfer standards

Nominal value	100 g	10 g	500 µg	200 µg	100 µg
Covariance (µg²)	$(2.2)^2$	$(0.8)^2$	$(0.1)^2$	$(0.04)^2$	$(0.02)^2$
Correlation Coefficient	0.5	0.33	0.31	0.07	0.02

The reference mass ($\boldsymbol{m}_{ref}$), taking into account any change in value during the period of the comparison, was modelled by the equation;

$$m_{ref} = a_1 + a_2 t + \delta m \qquad (1)$$

Where t is the time of measurement (in days), a_1 and a_2 are constants and δm is a time dependant variable with expectation 0 and variance σ^2 which describes random changes in the mass of the transfer standard with time.

For the 10 gram, 0.5 milligram, 0.2 milligram and 0.1 milligram weights, chi-square analysis of a least squares fit of the data showed that the measurement data was consistent with a model with zero deterministic drift and no random change in the values of the standards (i.e. values of $a_2 = 0$ and $\sigma^2 = 0$).

A chi-square test of the data for the 100 gram weight failed for a reference value based on a model without a deterministic drift. Since the results of the participants indicated that the value of the weight had drifted during the period of the comparison the evaluation was repeated for a model with constant temporal drift ($a_2 \neq 0$). The least square fit of the data gave a drift value for a_2 of -2.013×10^{-8} g/day.

Reference values were calculated for the five transfer standards by least squares analysis of the measurement results taking into account the uncertainties of the measured values and the estimated covariances of these values. Normalised deviations from the reference value for each result were calculated from the difference between the measured value and the reference value divided by the standard uncertainty of the difference.

$$d = \frac{(m - m_{ref})}{u(m - m_{ref})} \qquad (2)$$

The normalised deviation has been used to identify results which are discrepant compared with the reference value. Results are considered discrepant (at a 5% level of significance) where the normalised deviation is greater than 2.

6.1 100 grams

Table 8 gives the results of the least squares analysis calculation of the reference value for the 100 gram transfer standard taking into account the calculated drift in the weight during the period of the participants' measurements ($\boldsymbol{m}_{ref}$) together with the participants' data ($\boldsymbol{m}$) and their associated standard uncertainties. Normalised deviations have been calculated for each result. The results are plotted in Figure 1.

Table 8: Results, reference values and normalised deviations for the 100 gram transfer standard.

Meas. No.	Lab ID	Date	Result / g		Reference value / g		Norm. dev.
I		*t*	*m*	*u*(*m*)	m_{ref}	$u(m_{ref})$	*d*
1	LNE	11/06/2008	100.000 091 3	0.000 003 1	100.000 090 4	0.000 001 5	0.344
2	NPL	15/07/2008	100.000 090 1	0.000 001 7	100.000 089 7	0.000 001 4	0.414
3	LNE	30/07/2008	100.000 088 8	0.000 003 1	100.000 089 4	0.000 001 3	-0.208
4	LNE	25/11/2008	100.000 088 5	0.000 003 1	100.000 087 0	0.000 001 2	0.504
5	PTB	03/06/2009	100.000 081 6	0.000 002 3	100.000 083 2	0.000 001 7	-0.988
6	LNE	16/07/2009	100.000 084 1	0.000 003 1	100.000 082 3	0.000 001 8	0.714

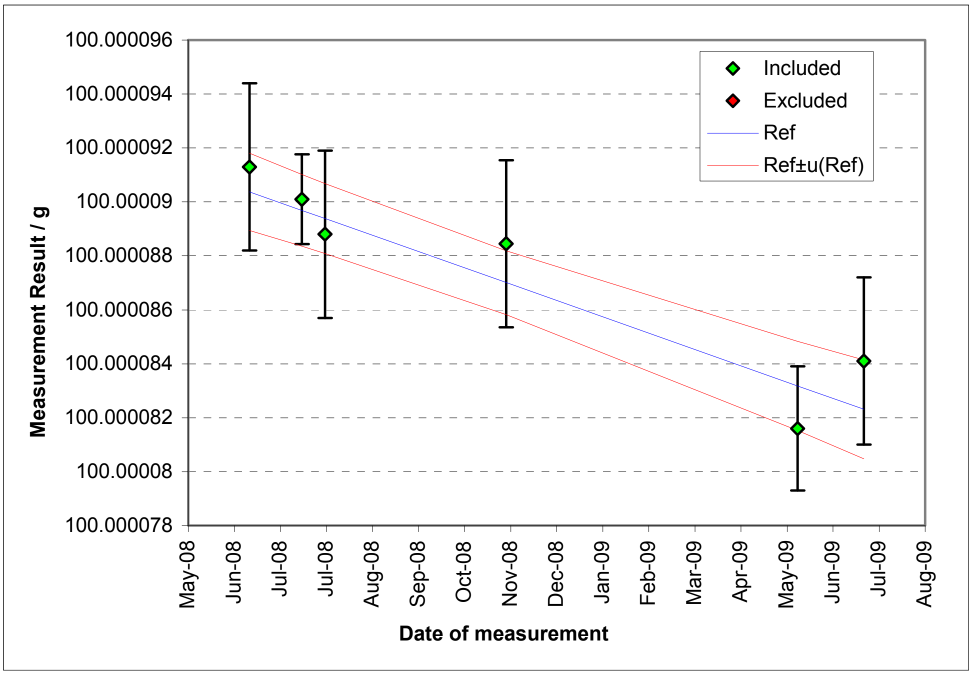


Figure 1: Results of the comparison for the 100 gram standard

6.2 10 grams

Table 9 gives the reference value for the 10 gram weight together with the participants' results and the associated standard uncertainties. The results are plotted in Figure 2.

Table 9: Results, reference values and normalised deviations for the 10 gram transfer standard.

Meas. No.	Lab ID	Date	Result / g		Reference value / g		Norm. dev.
i		*t*	*m*	$u(m)$	m_{ref}	$u(m_{ref})$	*d*
1	LNE	11/06/2008	10.000 012 9	0.000 001 4	10.000 012 74	0.000 000 59	0.094
2	NPL	15/07/2008	10.000 013 1	0.000 000 8	10.000 012 74	0.000 000 59	0.644
3	LNE	30/07/2008	10.000 012 4	0.000 001 4	10.000 012 74	0.000 000 59	-0.276
4	LNE	25/11/2008	10.000 012 7	0.000 001 4	10.000 012 74	0.000 000 59	-0.072
5	PTB	03/06/2009	10.000 011 8	0.000 001 7	10.000 012 74	0.000 000 59	-0.590
6	LNE	16/07/2009	10.000 012 2	0.000 001 4	10.000 01274	0.000 000 59	-0.426

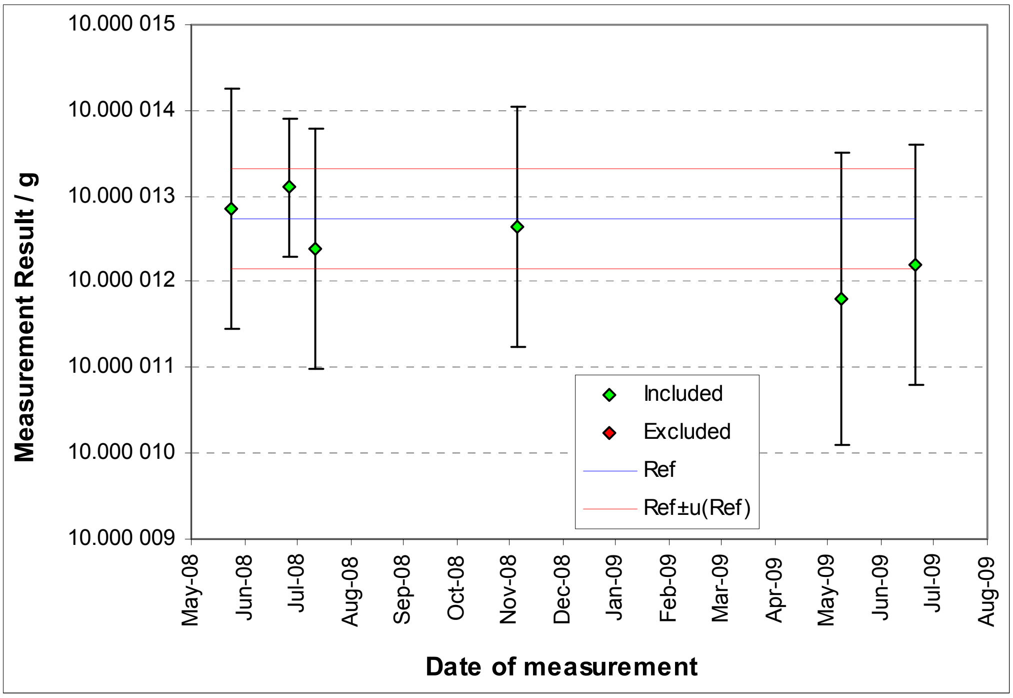


Figure 2: Results of the comparison for the 10 gram standard

6.3 0.000 5 grams

Table 10 gives the reference value for the 0.5 milligram weight together with the participants' results and the associated standard uncertainties. The results are plotted in Figure 3. Measurement number 3 has not been included in the calculation of the reference value as it was found to be discrepant (|*d*| > 2).

Table 10: Results, reference values and normalised deviations for the 0.5 milligram transfer standard.

Meas. No.	Lab ID	Date	Result / g		Reference value / g		Norm. dev.
i		t	m	$u(m)$	m_{ref}	$u(m_{ref})$	d
1	LNE	11/06/2008	0.000 500 49	0.000 000 18	0.000 500 656	0.000 000 079	-1.028
2	NPL	15/07/2008	0.000 500 46	0.000 000 13	0.000 500 656	0.000 000 079	-1.899
3	LNE	30/07/2008	0.000 501 28	0.000 000 18	0.000 500 656	0.000 000 079	3.515
4	LNE	25/11/2008	0.000 500 93	0.000 000 18	0.000 500 656	0.000 000 079	1.692
5	PTB	03/06/2009	0.000 500 90	0.000 000 15	0.000 500 656	0.000 000 079	1.910
6	LNE	16/07/2009	0.000 500 59	0.000 000 18	0.000 500 656	0.000 000 079	-0.410

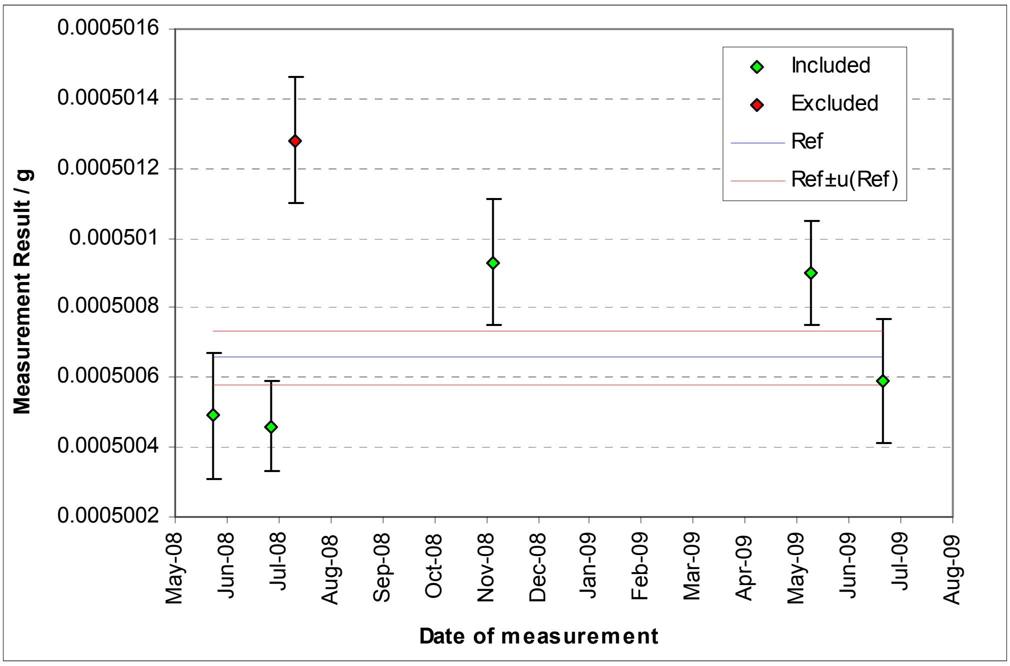


Figure 3: Results of the comparison for the 0.5 milligram standard

6.4 0.000 2 grams

Table 11 gives the reference value for the 0.2 milligram weight together with the participants' results and the associated standard uncertainties. The results are plotted in Figure 4. Measurement number 3 has not been included in the calculation of the reference value as it was found to be discrepant (|*d*| > 2).

Table 11: Results, reference values and normalised deviations for the 0.2 milligram transfer standard.

Meas. No.	Lab ID	Date	Result / g		Reference value / g		Norm. dev.
i		t	m	$u(m)$	m_{ref}	$u(m_{ref})$	d
1	LNE	11/06/2008	0.000 201 45	0.000 000 15	0.000 201 424	0.000 000 066	0.194
2	NPL	15/07/2008	0.000 201 27	0.000 000 13	0.000 201 424	0.000 000 066	-1.376
3	LNE	30/07/2008	0.000 201 77	0.000 000 15	0.000 201 424	0.000 000 066	2.177
4	LNE	25/11/2008	0.000 201 43	0.000 000 15	0.000 201 424	0.000 000 066	0.046
5	PTB	03/06/2009	0.000 201 55	0.000 000 14	0.000 201 424	0.000 000 066	1.023
6	LNE	16/07/2009	0.000 201 46	0.000 000 15	0.000 201 424	0.000 000 066	0.269

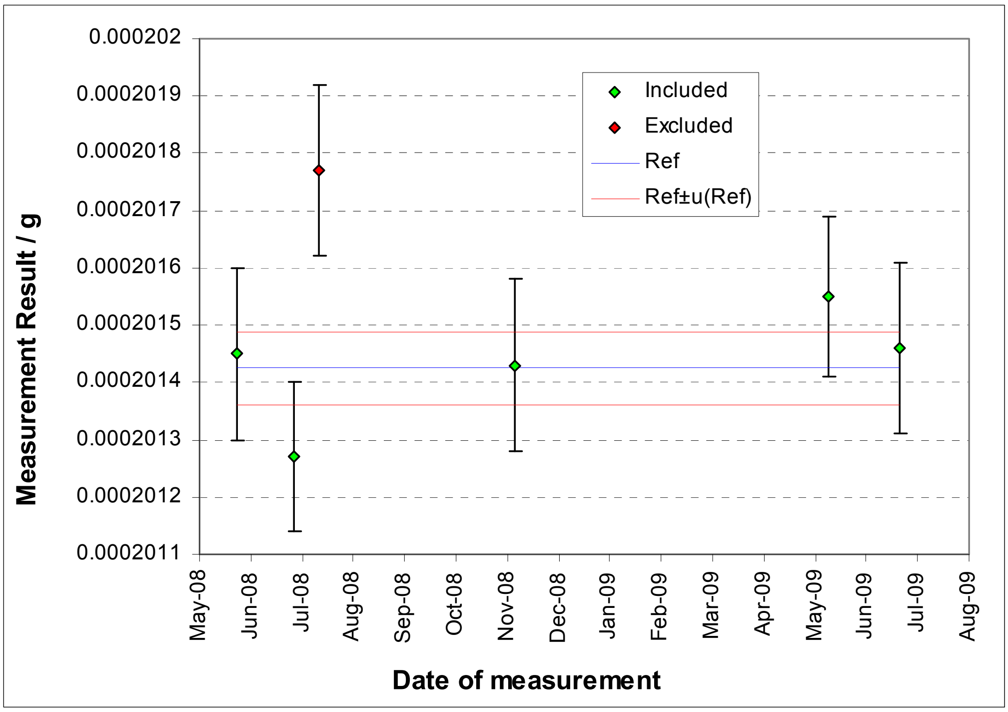


Figure 4: Results of the comparison for the 0.2 milligram standard

6.5 0.000 1 grams

Table 12 gives the reference value for the 0.1 milligram weight together with the participants’ results and the associated standard uncertainties. The results are plotted in Figure 5. Measurement number 1 has not been included in the calculation of the reference value as it was found to be discrepant (|*d*| > 2).

Table 12: Results, reference values and normalised deviations for the 0.1 milligram transfer standard.

Meas. No.	Lab ID	Date	Result / g		Reference value / g		Norm. dev.
i		*t*	*m*	*u*(*m*)	m_{ref}	$u(m_{ref})$	*d*
1	LNE	11/06/2008	0.000 103 51	0.000 000 14	0.000 104 099	0.000 000 060	-3.902
2	NPL	15/07/2008	0.000 104 02	0.000 000 11	0.000 104 099	0.000 000 060	-0.851
3	LNE	30/07/2008	0.000 104 15	0.000 000 14	0.000 104 099	0.000 000 060	0.406
4	LNE	25/11/2008	0.000 104 23	0.000 000 14	0.000 104 099	0.000 000 060	1.037
5	PTB	03/06/2009	0.000 104 02	0.000 000 14	0.000 104 099	0.000 000 060	-0.621
6	LNE	16/07/2009	0.000 104 13	0.000 000 14	0.000 104 099	0.000 000 060	0.248

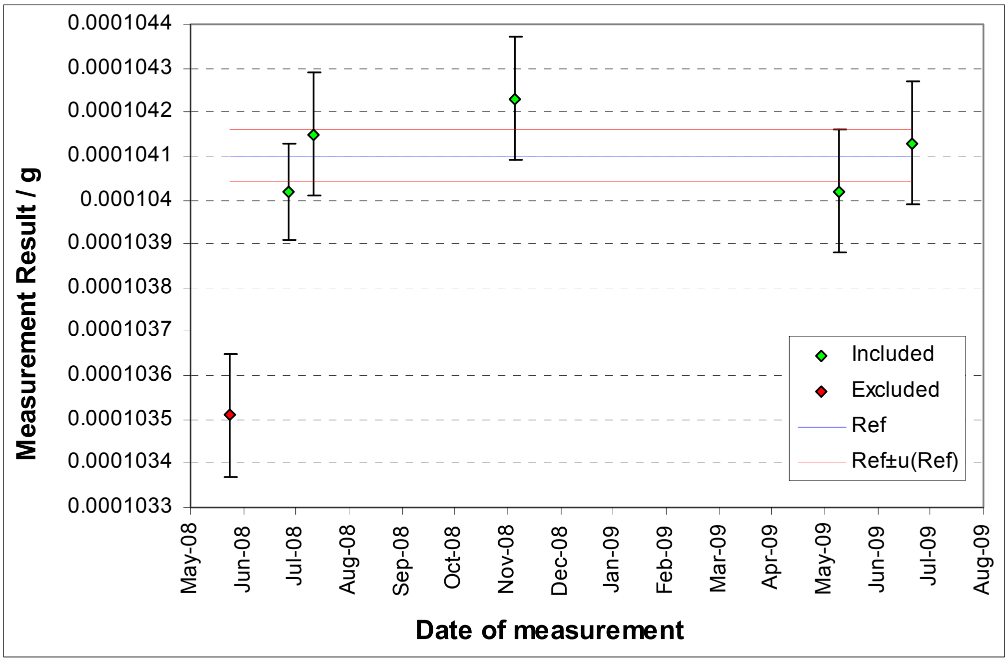


Figure 5: Results of the comparison for the 0.1 milligram standard

7 Interpretation of the Results

The majority of the measurement results of the participants are consistent with the calculated reference values of the five transfer standards.

The 100 gram transfer standard exhibited a linear drift in its value during the period of the comparison which was taken into account when calculating the reference value for the weight. Given the drift in the transfer standard all the measured values of the participants are consistent with the calculated reference value.

The reference values for the remaining transfer standards (10 gram, 0.5 milligram, 0.2 milligram and 0.1 milligram) were calculated to have zero drift during the period of the comparison based on a least squares analysis of the measurement data. In the case of the 0.5 milligram, 0.2 milligram and 0.1 milligram standards one of the (six) participants' results was found to be discrepant with the reference value and excluded from the evaluation.

The results for the 10 gram transfer standard show excellent agreement between the participants. With the exclusion of the three results identified the results for the three sub-milligram weights also show reasonable agreement between the participants.

Examining the results for the 0.1 milligram transfer standard it may be supposed that the weight underwent a step change in its value between measurements 1 and 2. The results of measurements 2 to 6 are in good agreement.

For the 0.5 milligram and 0.2 milligram weights measurement 3 was found to be discrepant and has been excluded from the analysis. The remaining results for the 0.2 milligram weight are again in good agreement. The remaining results for the 0.5 milligram weight are in less good agreement and may be indicative of an instability in the transfer standard during the comparison process. Past measurements of the sub-milligram transfer standards by LNE [4] have shown that a stability of better than 0.2 micrograms is achievable over a period of 3 months.

8 Degree of Equivalence between Participants

For completeness, the degree of equivalence between the participants' individual results has been calculated for all the transfer standards. The degree of equivalence has been calculated as the deviation D, where;

$$D = \Delta m - \Delta m_{ref} \qquad (3)$$

Where Δm is the deviation of the individual result from the nominal value and Δm_{ref} is the deviation of the reference value from the nominal value.

Additionally, since LNE measured each weight four times the average degree of equivalence for LNE has also been calculated based on an average of all their results (including the results that had been excluded from the calculation of the reference values). The results of the analysis of the participants' degree of equivalence are given in Appendix 1.

9 Conclusions

All participants have demonstrated their capability of measuring the transfer standards to their stated level of uncertainty. Agreement between the participants and the calculated reference values for the 100 gram and 10 gram transfer standards was excellent. Agreement for the sub-milligram weights was less good but all participants again demonstrated equivalence with the reference values.

Given the small uncertainties claimed by the participants for the sub-milligram weights (less than 0.2 micrograms in all cases) the stability of the transfer standards is likely to be a significant factor in the consistency of the results. Care must be taken with the storage, transfer and handling of such standards for the success of future comparisons at the sub-milligram level.

10 References

[1] Weights of classes E_1, E_2, F_1, F_2, M_1, $M1_{-2}$, M_2, M_{-23}, M_3, International recommendation OIML R111-1, **OIML, 2004**

[2] Guide to the Expression of Uncertainty in Measurement, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, J**CGM 100:2008**

[3] Nielsen, L. "Evaluation of measurement intercomparisons by the method of least squares", DFM-99-R39 (2000)

[4] Tanguy Madec, et al, "Micro-mass standards to calibrate the sensitivity of mass comparators", Metrologia **44** (2007) 266–274

APPENDIX 1: Degree of Equivalence of Participants

A1.1 Individual results of the participants

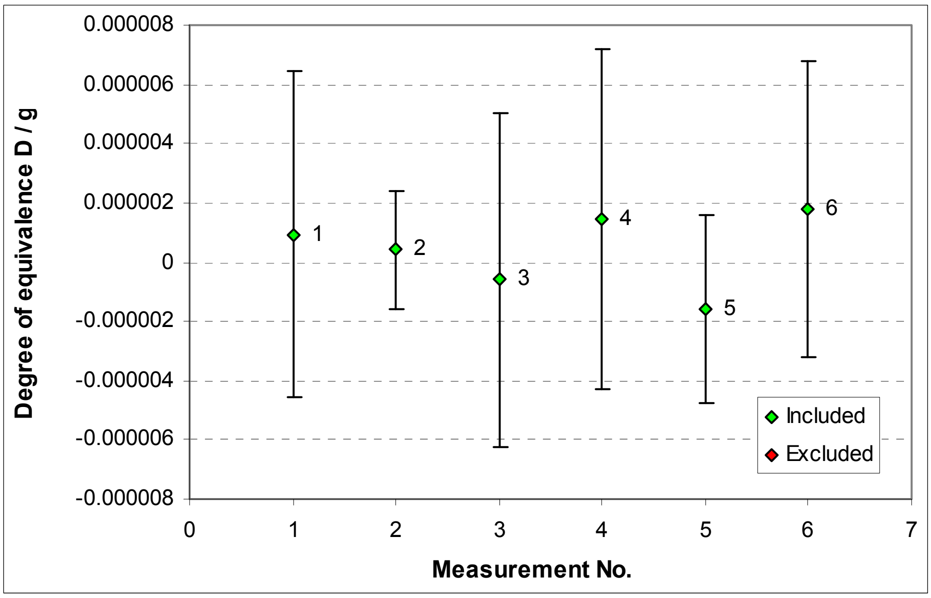


Figure A1.1 Degrees of equivalence for 100 g transfer standard and expanded (*k*=2) uncertainty

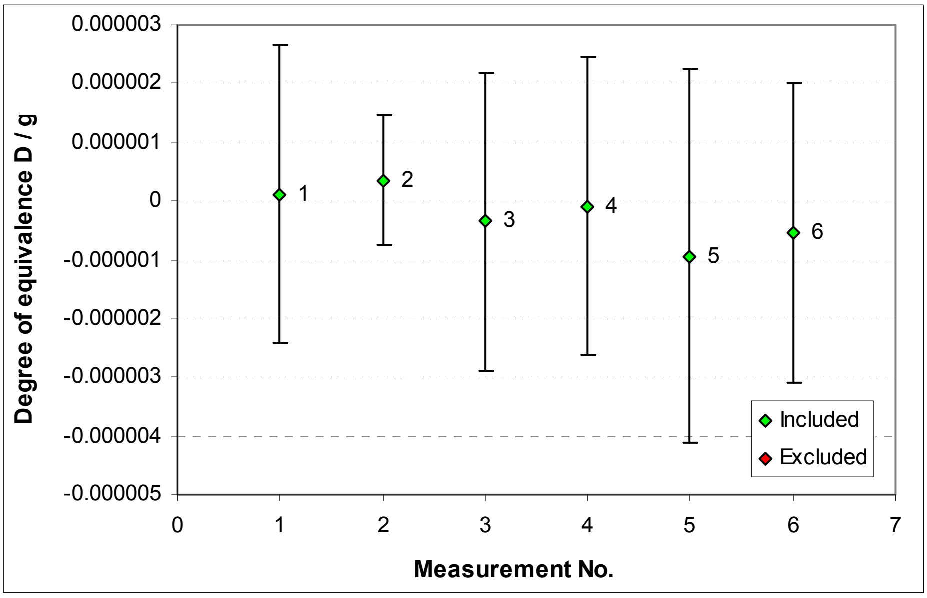


Figure A1.2 Degrees of equivalence for 10 g transfer standard and expanded (*k*=2) uncertainty

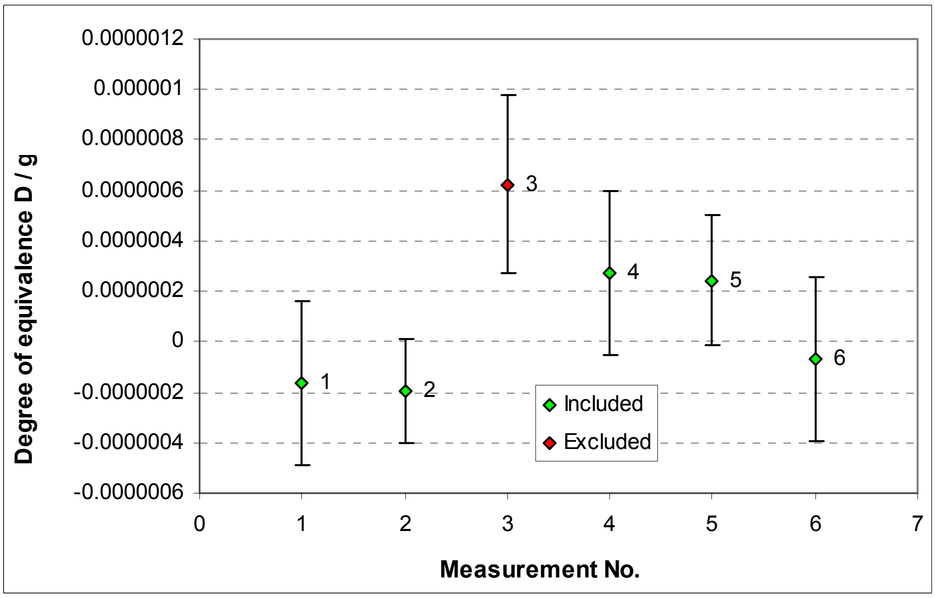


Figure A1.3 Degrees of equivalence for 0.5 mg transfer standard and expanded (*k*=2) uncertainty

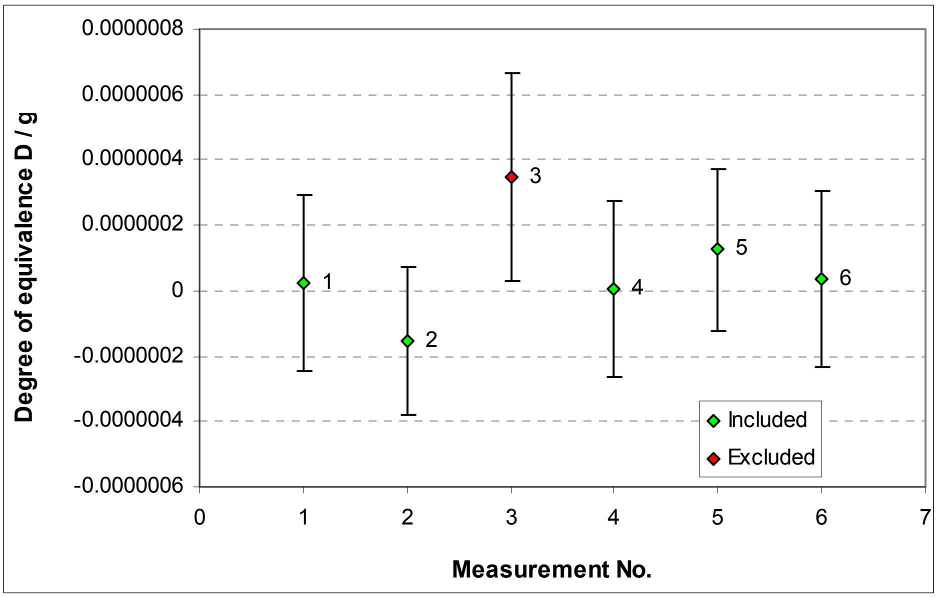


Figure A1.4 Degrees of equivalence for 0.2 mg transfer standard and expanded (*k*=2) uncertainty

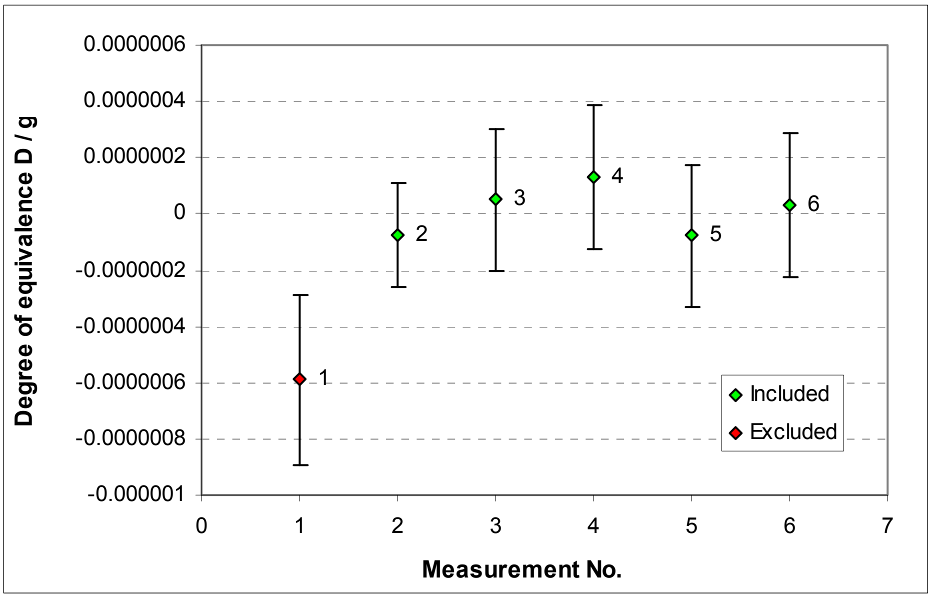


Figure A1.5 Degrees of equivalence for 0.1 mg transfer standard and expanded (k=2) uncertainty

A1.2 Average degree of equivalence for participants

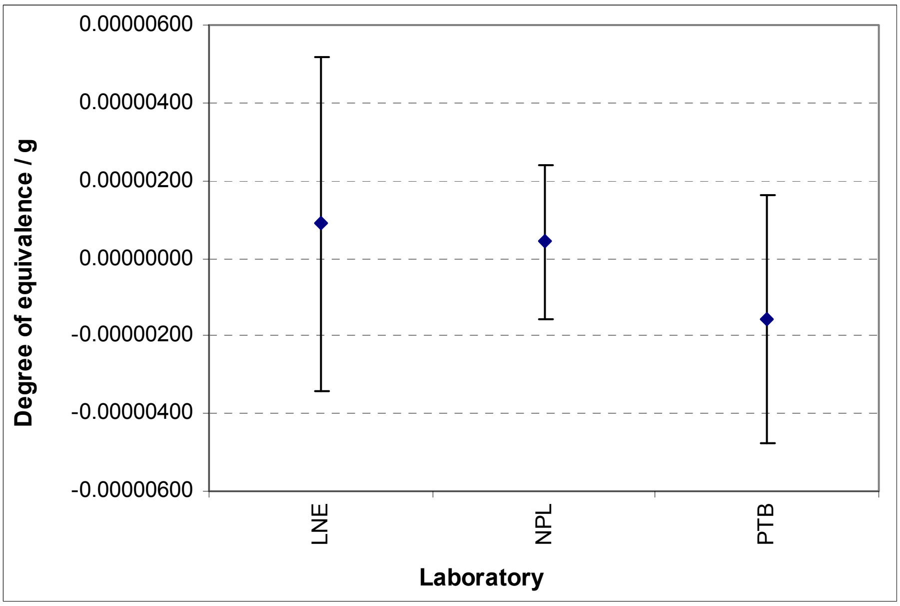


Figure A1.6 Average degrees of equivalence for 100 g transfer standard and expanded (k=2) uncertainty

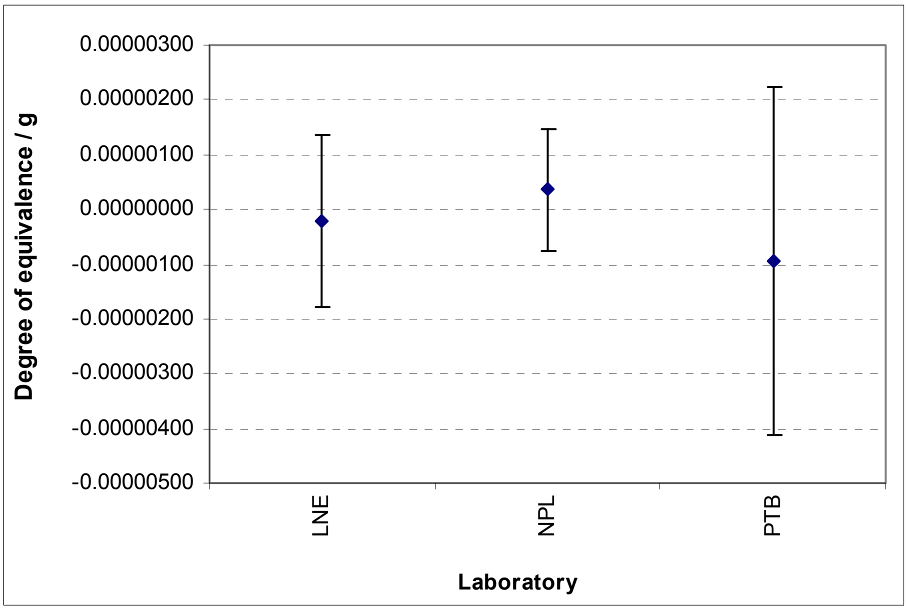


Figure A1.7 Average degrees of equivalence for 10 g transfer standard and expanded (k=2) uncertainty

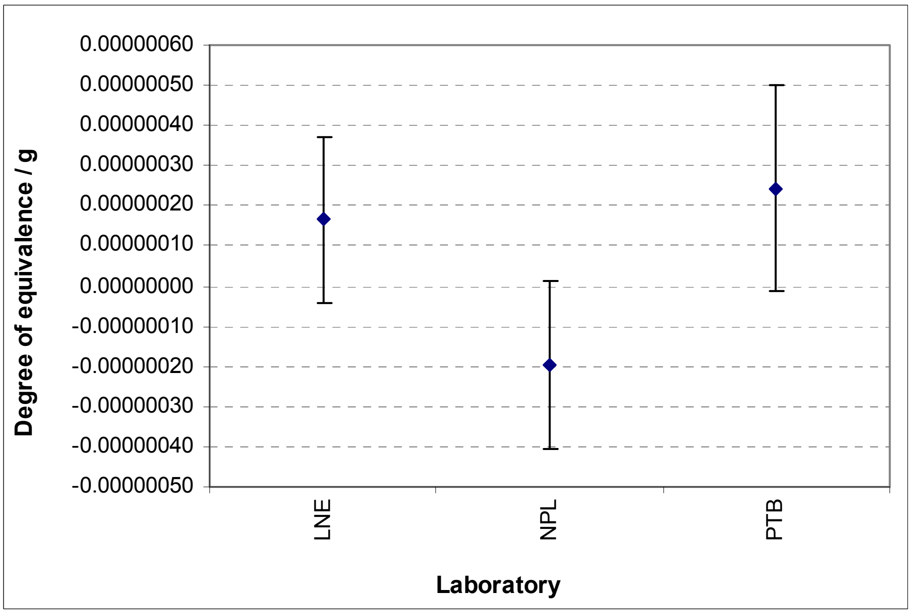


Figure A1.8 Average degrees of equivalence for 0.5 mg transfer standard and expanded (k=2) uncertainty

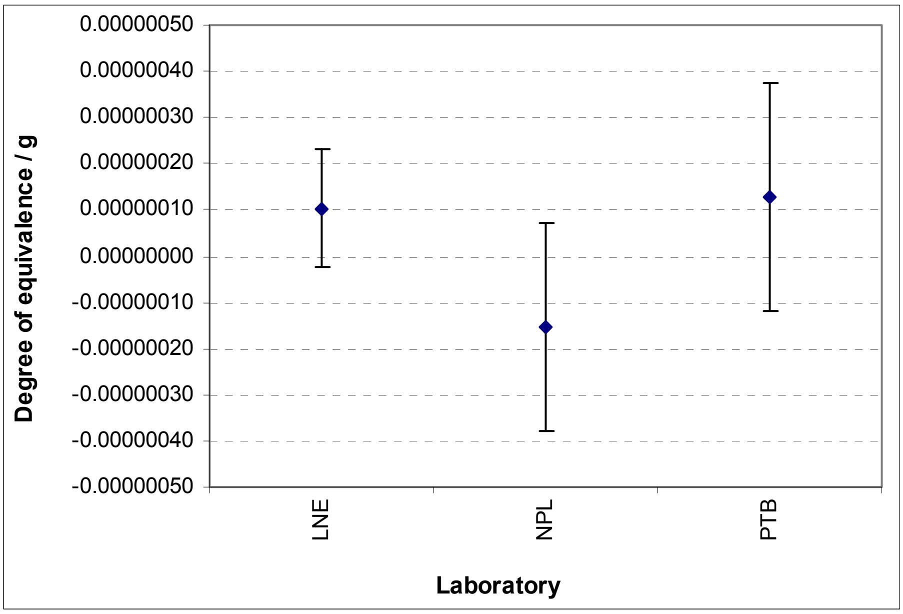


Figure A1.9 Average degrees of equivalence for 0.2 mg transfer standard and expanded (*k*=2) uncertainty

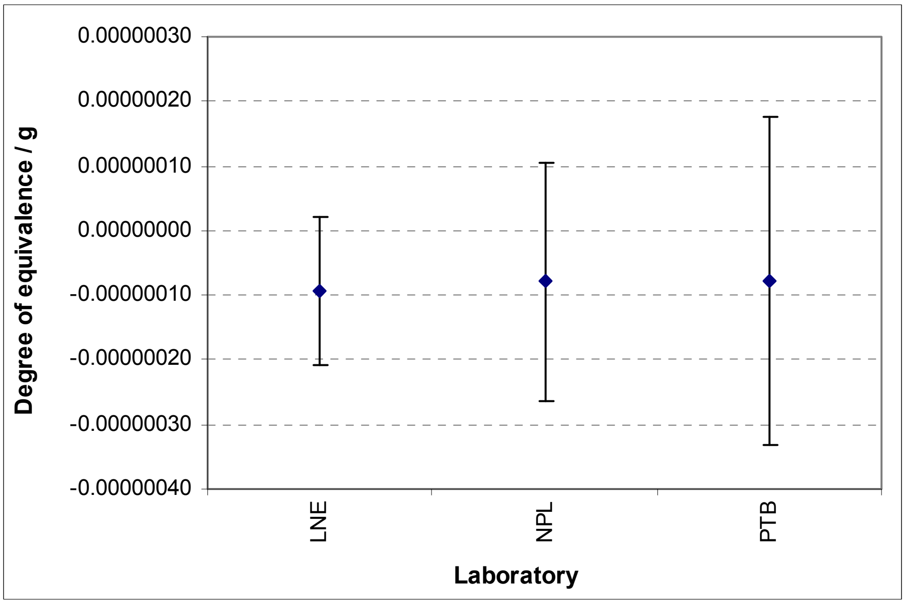


Figure A1.10 Average degrees of equivalence for 0.1 mg transfer standard and expanded (*k*=2) uncertainty

APPENDIX 2: Comparison Protocol

1 OUTLINE of SUPPLEMENTARY comparison

The NPL is the pilot laboratory, but is not in charge of collecting the measurement results. NPL will analyse the data and produce the final report.

The IRMM (Be) accepted to be helping laboratory. It is in charge of collating the data from the participants.

2 Purpose of this document

The purpose of this document is to define the organisation of the comparison and to provide instructions for the participants on the transport and handling of the transfer standards and the reporting of the measurement results.
It is defined by applying the “guidelines for CIPM key comparisons” (appendix F to the “MRA”).

3 Organisation of the comparison

Five travelling standards circulate between the participants. LNE will make measurements before and after transfer to the other two participants.

4 Description of the STANDARDS

The travelling standards were manufactured by Zwiebel from non-magnetic stainless steel.
The characteristics of the standards are as follows:

Nominal value	100 g	10 g	0.5 mg, 0.2 mg, 0.1 mg
Identification	100	10	-
Serial number	MET 1	AK	-
Shape	OIML	OIML	Wire weights
Alloy	X18M25W	X18M25W	Aluminium-silicon
Method of density calibration	Hydrostatic weighing	Hydrostatic weighing on sample	Assumed value
Density at 20°C (kg m^{-3})	7 988.76	7 984.27	2700
Uncertainty of density (kg m^{-3}) [k = 2]	± 0.60	± 0.51	± 20
Cubic coefficient of thermal expansion (°C^{-1})	3.5 x 10^{-5}	3.5 x 10^{-5}	6.9 x 10^{-5}

5 TRANSPORTATION

5.1 Organisation

Each laboratory is responsible for the organisation of the transportation to the next participant according to the circulation timetable, and to make proper arrangements for local customs formalities.
Each participating laboratory is responsible for its own costs for the transportation to the next participating laboratory and any custom charges within its own country.
Each participating laboratory shall have insurance for any damage or loss within its own country or during the travel to the next laboratory.
Before dispatching the package, the participating laboratory shall inform the pilot, giving transportation details. Each laboratory shall be informed of the incoming package at least one week in advance.
Any circumstances to which the standard is subjected during transit, which might effect its completeness, shall be reported to the pilot laboratory at the earliest opportunity.

6 Receipt of the travelling standard

6.1 Receipt of the package

After to have got the package(s), the participating laboratory sends the pilot laboratory and the dispatching laboratory by fax or emails a fulfilled “Arrival and departure form“ given in appendix B.
Any damage to the package shall be reported on this form.

6.2 Opening the package

At the arrival of the standard, **special care** shall be taken for opening the package.

6.3 Remove the standard from case

Suitable pincers should be used to remove the standards out of the travelling box.

6.4 Visual inspection

The travelling standard shall be examined on receipt, and any scratches or other marks shall be recorded on the “Travelling standard visual inspection form”, the copy of which is given in appendix C. This form is sent by fax or e-mail to the pilot laboratory within 24 hours after the inspection.

7 Measurement

7.1 Cleaning

No cleaning is applied to the standards. If necessary a light brushing can be made with a soft-haired sable brush.

7.2 Handling

Suitable pincers should be used to handle the transfer standards.

7.3 Ambient conditions

The measurements shall be made under ambient conditions of air. The parameters contributing to air density shall be recorded for each weighing and the air density shall be calculated using the CIPM -2007 formula

7.4 Weighing procedure

The laboratory applies its own weighing procedure.

8 Reporting of data

8.1 Measurements results

The following information shall be reported to the pilot laboratory using the appropriate form given in appendix D:

- D1 : movement of travelling standard and period of weighing
- table R1 : record of the dates
- record of unusual environmental conditions (if appropriate)
- D2 : results of measurement
- table R2 : measured mass
- table R3 : ambient conditions during measurement of the travelling standard
- description of the comparison design
- table R4 : components of uncertainty of measurement
- detail of the other components (if needed)
- D3 : calibration means
- table R5 : details of participant's mass standards used for measurement including additional weights
- table R6 : mass comparator used
- details of how the repeatability/reproducibility is assessed
- table R7 : details of instrumentation used to measure air density parameters
- other information (if appropriate)
- D4 : traceability route
- diagram of the traceability route
- table R8 : details of participant's traceability route

The participating laboratory shall send the helping laboratory its report within four weeks after the end of measurements.

8.2 Uncertainty of measurement

All uncertainty shall be computed and reported according to ISO "*guide to the expression of uncertainty in measurement*". They are expressed as standard-uncertainty with the effective number of degrees of freedom.

9 Departure of the standards

After measurement, wrap the standard in acid free tissue paper and return to transfer box.
After departure, the participating laboratory sends the pilot laboratory and the recipient laboratory by fax or emails the fulfilled "Arrival and departure form" given in appendix B.

11 Annexed paper and forms

- Appendix A : Participants and timetable
- Appendix C : Travelling standard visual inspection form
- Appendix D : Results form (only for helping laboratory)

TRAVELLING STANDARD VISUAL INSPECTION FORM

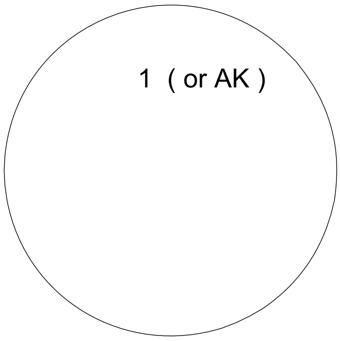
Laboratory :

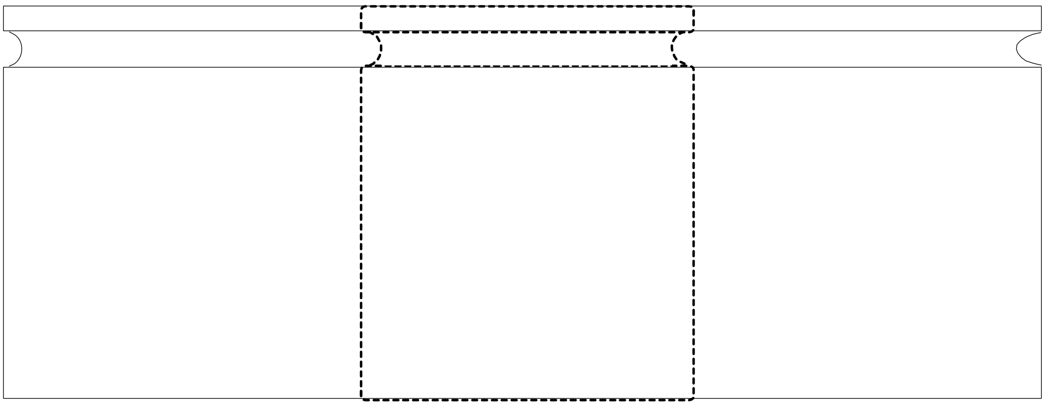
Local time (d/h/min) : Inspected by :

Record on the diagrams any marks seen (scratches, contamination...)

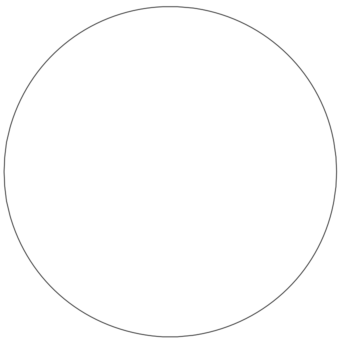
The orientation of the standard is given by the off centre position of the identification figure on the top of the standard.

TOP





BOTTOM



D1 : MOVEMENT OF THE TRAVELLING STANDARD AND PERIOD OF WEIGHING

Table R1 : record of the dates

Date of arrival of the travelling standard	
Date of departure of the travelling standard	
Date started of measurement	
Date finished of measurement	

Unusual environmental conditions experienced during transit or weighing :
(if appropriate)

D2 : RESULTS OF MEASUREMENT

Table R2 : Measured mass

Mass of travelling standard	Standard-uncertainty	number of measurement	number of degrees of freedom
100 g + µg	µg		
10 g + µg	µg		

Table R3 : Ambient conditions during measurement of the travelling standard

Parameter	100 g	10 g
air density ($kg.m^{-3}$)		
Temperature (°C)		
Pressure (kPa)		
Dp (°C) or H (%)		
CO_2 ($x10^{-6}$)		

Describe below the comparison design used to measure the travelling standard :

Table R4 : Components of uncertainty of measurement

Parameter	Standard uncertainty of component (µg)	
	100g	10g
Comparison mass standard		
Stability of comparison mass standard		
Compensating weight		
Stability of compensating weight		
Weighing reproducibility		
Position effect (automatic loading comparator)		
Comparator resolution		
Comparator sensitivity		
Air density		
Travelling standard density		
Comparison mass standard density		
Other component : specify below		
Combined standard uncertainty		

Detail of the other components (if needed) :

D3 : CALIBRATION MEANS

Table R5 : Details of participant's mass standards used for the measurement including additional weights

	nominal mass (kg) + correction (mg) and volume or density	Standard uncertainty
Identification of standard for 100g calibration :		
Mass of standard	kg mg	± mg
Volume or density		±
Mass of standard	kg mg	± mg
Volume or density		±
Identification of standard for 10g calibration :		
Mass of standard	kg mg	± mg
Volume or density		±
Mass of standard	kg mg	± mg
Volume or density		±

Table R6 : Mass comparator used

Manufacturer		
Type		
Resolution		
Standard deviation of repeatability/reproducibility of the result of one comparison process	mg	degrees of freedom :

Details of how the repeatability/reproducibility is assessed :

Manufacturer		
Type		
Resolution		
Standard deviation of repeatability/reproducibility of the result of one comparison process	mg	degrees of freedom :

Details of how the repeatability/reproducibility is assessed :

Manufacturer		
Type		
Resolution		
Standard deviation of repeatability/reproducibility of the result of one comparison process	mg	degrees of freedom :

Details of how the repeatability/reproducibility is assessed :

Table R7 : Details of instrumentation used to measure air density parameters

Instrument	Manufacturer	Type	Range	Resolution	standard uncertainty of one measurement
Temperature					
Pressure					
Humidity					
CO_2					

Other information (if appropriate) **:**

D4 : TRACEABILITY ROUTE

Diagram describing the traceability route between the mass standards described in table R5 and your Copy of the International Prototype Kilogram.

Table R8 : Details of participant's traceability route

Identification	Mass standard uncertainty	Calibration date