National Metrology Laboratory Ireland

EUROMET Supplementary Comparison

Calibration of Gauge Blocks by Mechanical Comparison

Final Report

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1. Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM or by the regional metrology organizations in collaboration with the Consultative Committees.
At its meeting in September 1999 the EUROMET LENGTH CONTACT PERSONS GROUP decided that a supplementary comparison on gauge block measurement by mechanical comparison should be undertaken. The comparison commenced in april 2001 and was coordinated by NML, Enterprise Ireland.

The results of this international comparison will contribute and be included in the agreement for establishing metrological equivalence.

2. Organisation

The technical protocol was drafted by the pilot laboratory, NML-Enterprise Ireland with assistance from METAS and NPL. The technical protocol was issued to all participants prior to commencement of the comparison.

2.1 Participants

Participation in the comparison was open to all members of the EUROMET TC-L group. In all 13 NMIs participated in the comparison.

The participating NMIs are listed in table 1 below:

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Table 1 Participating NMIs

2.2 Schedule

Due to carnet requirements the comparison was carried out in two circulation loops. After the standards having been circulated to EU member states, they were sent back to the pilot laboratory before circulation to the non EU member states.
Each laboratory was allowed approx one month in which to make its measurements and to prepare for transportation to the next participant. At the end of the second loop the gauges were again measured at the Pilot Laboratory to establish the degree of drift , wear, etc in the gauge blocks. EIM, Greece requested to be added to the comparison and after agreement by the other participants, the gauge blocks were sent from the Pilot Laboratory to EIM at the end of the second loop. The gauges were returned from EIM to the Pilot Laboratory. The circulation scheme completed is given in Table 2. below.

Laboratory	Country	Date
NML	IE	APR 2 – 27 APR, 2001
NPL	UK	APR 30 – 25 MAY, 2001
MIKES	FI	MAY 28 – 22 JUN, 2001
BEV	AT	JUN 26 – 25 JULY, 2001
Pilot Lab – NML	IE	30 JULY, 2001
JV	NO	SEP 12 – 12 OCT, 2001
GUM	PL	OCT 29 – 23 NOV, 2001
CMI	CZ	NOV 26 – 21 DEC, 2001
OHM	HU	JAN 7 – 1 FEB, 2002
MIRS	SI	FEB 6 – 8 MAR, 2002
UME	TR	MAR 14 – 15 APR, 2002
VMC	LT	APR 20 – 18 MAY, 2002
NCM	BG	MAY 25 – 25 JUN, 2002
Pilot Lab- NML	IE	JULY 1- 29 JULY, 2002
EIM	GR	AUG 5 – 6 SEPT , 2002
Pilot Lab-NML	IE	13 SEPT, 2002

Table 2 Circulation Scheme

3. Description of the Standards

Eight gauge blocks made of steel were circulated. The gauge blocks, which were donated by the Pilot Laboratory, were grade K and of rectangular cross section, according to the international standard ISO 3650. The thermal expansion had been provided by the manufacturer of the gauge blocks. The participating laboratories were only informed of the nominal length of the gauge block, as marked on their faces, the gauge material and the pre-determined expansion coefficients.
The nominal length of each gauge block was determined in advance of the comparison by interferometry at NPL, UK.

Identification	Nominal length (mm)	Expansion coeff. (10^{-6} K^{-1})	Manufacturer
8'52005	0.5	11.7 ± 0.3	CARY
5'70252	1	11.7 ± 0.3	CARY
20'60646	2	11.7 ± 0.3	CARY
3'60351	10	11.7 ± 0.3	CARY
11'60661	25	11.7 ± 0.3	CARY
27'60509	50	11.7 ± 0.3	CARY
19'70004	75	11.7 ± 0.3	CARY
31'60452	100	11.7 ± 0.3	CARY

Table 3 Standards used in the Comparison

The standards were packed in a wooden box with with slots cut out to make a tight fit with the gauge blocks, to prevent any motion of the blocks during transport. For transportation purposes the wooden box was placed in an aluminium case.

The gauge blocks were sent by air freight between each participant. Hand carrying of the standards was not required.

4. Measurement Instructions

On receipt of the gauge blocks and prior to commencement of calibration, each participating laboratory carried out an inspection of each block for damage of the measurement surfaces. Any scratches, rust spots and other damage had to be documented by a drawing using forms appended to the protocol. The gauges had to be de-greased prior to measurement.

The primary measurement quantity was the deviation in the central length of the gauge block from its nominal length, as defined in ISO 3650. The central length was determined by mechanical comparison against the laboratory reference gauge blocks using an appropriate comparator. Where possible, the participants also determined the variation in length across the surface of each gauge by undertaking measurements at five points on the surface of each

gauge against the central length of the laboratory reference gauge block. The positioning and orientation of the gauges to be measured was described in detail in the technical protocol.

After the measurements, the gauge blocks had to be cleaned and greased prior to destapch to the next participating laboratory.

The uncertainty of measurement had to be calculated and reported as would be normal for mechanical comparison according to the *ISO Guide for the Expression of Uncertainty in Measurement*.

The measurement instructions of the technical protocol are appended in Annex 1.

5. Measurement Methods and Instruments used by Participants

Measurements were made by all participants by mechanical comparison with reference gauge blocks using a gauge block comparator. A range of comparators were used, with the most common being the Tesa Sa UPC comparator and the Mahr 826 Comparator. All comparators used had a resolution of 0.01µm.
All participants used Grade K, Grade 00 or equivalent gauge blocks as their reference.

Table 4 below is a summary of the equipment used by each participant.

Participant	Comparator	Ref. gauge blocks	Temperature range
NML, IE	Tesa Sa UPC	Grade K	20°C ± 0.2 °C
NPL, UK	Cary IVC/150	Reference grade	19.88 – 20.2 °C
MIKES, FI	Tesa Sa UPC	Grade K	20°C ± 0.5 °C
BEV, AT	Mahr 826	Grade K	20°C ± 0.2 °C
JV, NO	Tesa UPC	GradeK	19.95 – 20.09 °C
GUM, PL	Tesa Sa UPC	Grade K	19.604 – 19.687 °C
CMI, CZ	Tesa Sa UPC	Grade 00	20°C ± 0.3 °C
OMH, HU	Cary IVC/154	Reference grade	20°C ± 0.5 °C
MIRS, SI	Mahr 826	Grade K	20°C ± 0.2 °C
UME, TR	Tesa Sa UPC	Grade K	20°C ± 0.2 °C
VMT, LT	Mahr 826	Grade K	20°C ± 0.2 °C
NCM, BG	KSVEB	Grade 00	20°C ± 0.2 °C
EIM, GR	Mahr 826	Grade K	20°C ± 0.1 °C

Table 4 Standards used by Participants

6. Stability and Condition of the Gauge Blocks

The gauge blocks selected by the Pilot Laboratory were unused blocks with surfaces which were in good condition. The Pilot Laboratory monitored the contral length stability of the blocks by undertaking measurements at the beginning of the comparison, after completion of the first loop and at the end of the comparison. Figures 1(a), 1(b) and 1(c) below show the

deviation in central length for three blocks in the set over the period of the comparison. The NML uncertainty bars are included.

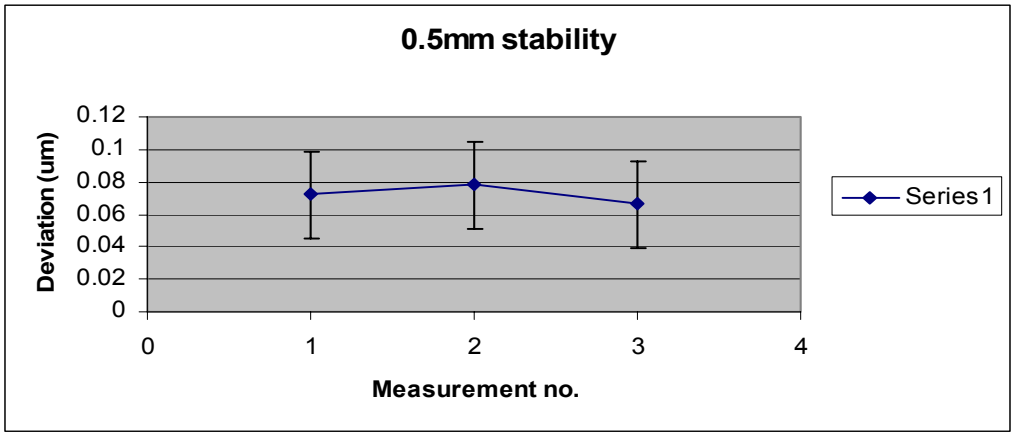


Figure 1(a) Deviation in Central Length

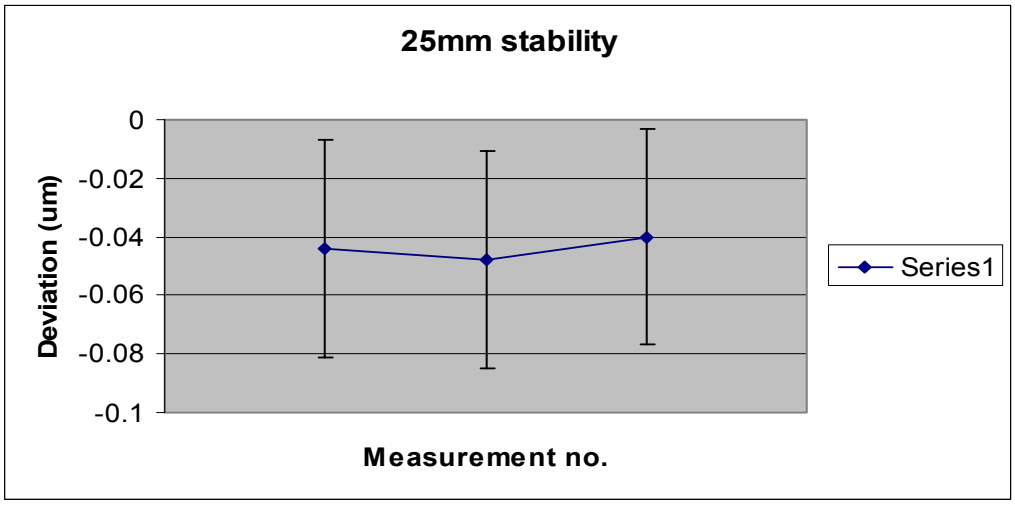


Figure 1(b) Deviation in Central Length

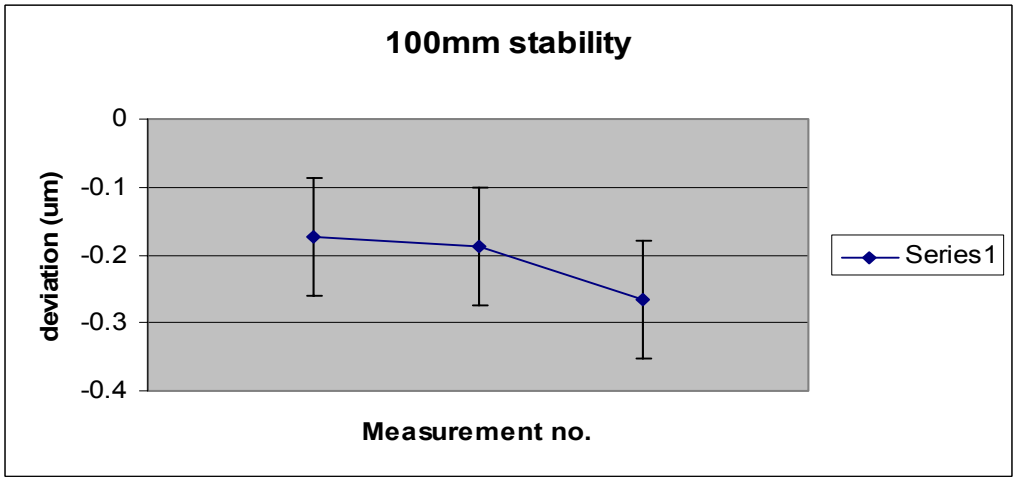


Figure 1(c) Deviation in Central Length

The Pilot Laboratory used the same equipment, operator and calibration method for all three measurements. From the results obtained and taking into account the calibration uncertainty of the Pilot Laboratory there was no significant deviation in the central length of the blocks throughout the comparison.

The gauge blocks were essentuially free from any damage at the beginning of the comparison**.** The participating laboratories were asked to document any scratches or other damage which were observed on the measuring faces of the blocks by a drawing. This was reported by some participants. While some markings and sxcratches occurred, it was not considered to be excessive.

7. Measurement Results

Each participating laboratory supplied measurement results on all gauges in the set. These results included:

- deviation in central length of each gauge block from its nominal value as a result of mechanical comparison with a reference gauge block
- variation in length for each block across its surface by measuring its deviation at five points over the face of the gauge block.

Each participant supplied its measurement uncertainty associated with each measured value reported. The results were analysed and compiled by the Pilot Laboratory.

7.1 Central Deviation Results

For each gauge block the reported 'Central deviation from nominal length' and the associated measurement uncertainty (at k=1) in µm was recored for each participant.
The mean deviation was calculated by taking the mean of all the participants values.
The deviation from the calculated mean was then calculated for each participant.
Finally the uncertainty of this deviation from the calculated mean was calculated
This uncertainty was calculated using standard statistical guidelines *i.e.* taking into account the fact that the mean is correlated with each result so the square root of the DIFFERENCE of the two uncertainties (participant, mean) rather than the square root of the sum was taken. The procedure used in the CCL-K1 report was adopted (see Figure 2a below):

The arithmetic mean value x_{ref} is calculated by the average of all measurement values x_i:

$$x_{ref} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The standard uncertainty $u(x_{ref})$ of the arithmetic mean can either be determined by application of the error propagation law, i.e. by taking into account the uncertainties $u(x_i)$ of the individual results or by the spread of the results, i.e. by the standard deviation divided by the square root of the number n of
results contributing to the mean:

$$u(x_{ref}) = \frac{1}{n}\sqrt{\sum_{i=1}^{n} u^2(x_i)}$$

For calculating the uncertainty of the difference Δx between an individual result and the reference value (arithmetic mean), the corresponding uncertainties $u(x_i)$ and $u(x_{ref})$ cannot simply be geometrically added, because the values x_i and x_{ref} are correlated. It can be shown, that for the arithmetic mean approach, the uncertainty $u(\Delta x)$ is given by

$$u(\Delta x) = \sqrt{\left(1-\frac{2}{n}\right)u^2(x_i) + \frac{1}{n^2}\sum_{j=1}^{n} u^2(x_j)}$$

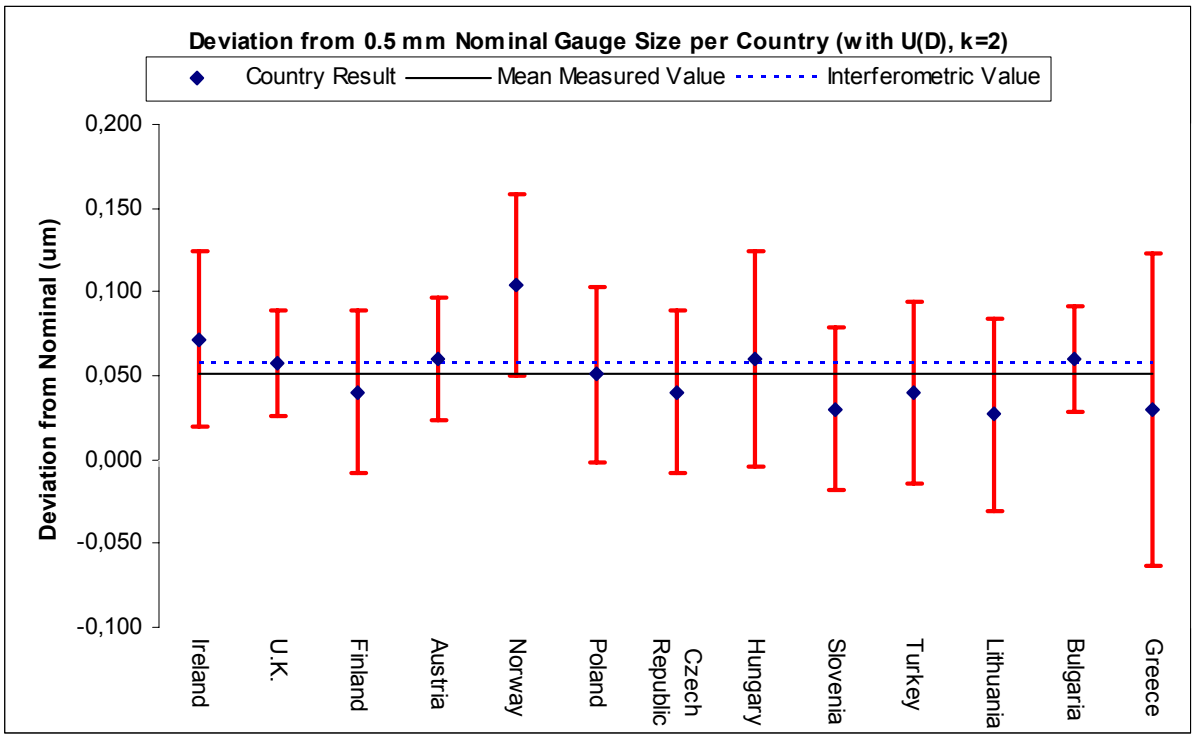
Figure 2a CCL-K1 Procedure

Tables 5(a) to5(h) and associated graphs 2(a) to 2(h) below give the results compiled for each gauge block measured in the comparison.

The interfermetric values obtained at NPL prior to the comparison are included in the graphs solely for information.

(P1) 0.5 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D=x-x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	0.072	0.027	0.020	0.052	0.390
U.K.	0.058	0.015	0.006	0.032	0.199
Finland	0.040	0.025	-0.012	0.049	-0.241
Austria	0.060	0.018	0.008	0.037	0.227
Norway	0.104	0.028	0.052	0.054	0.972
Poland	0.051	0.027	-0.001	0.052	-0.013
Czech Republic	0.040	0.025	-0.012	0.049	-0.241
Hungary	0.060	0.034	0.008	0.064	0.129
Slovenia	0.030	0.025	-0.022	0.049	-0.447
Turkey	0.040	0.028	-0.012	0.054	-0.217
Lithuania	0.027	0.030	-0.025	0.058	-0.426
Bulgaria	0.060	0.015	0.008	0.032	0.258
Greece	0.030	0.050	-0.022	0.093	-0.233
Mean Deviation, x_{mean}	**0.052**				

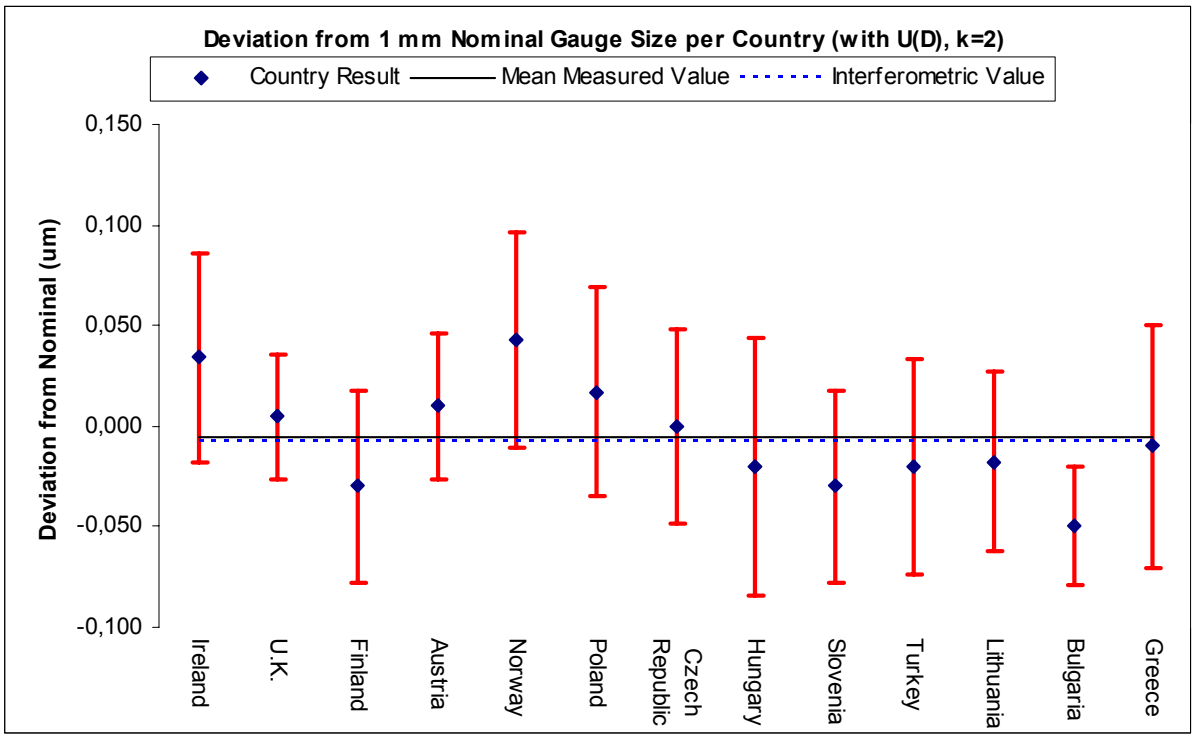
Table 5a P1 Deviation from 0.5 mm Nominal Gauge Size



Graph 2a P1 Deviation from 0.5 mm Nominal Gauge Size

(P1) 1.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D=x-x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	0.034	0.027	0.039	0.052	0.761
U.K.	0.005	0.015	0.010	0.031	0.333
Finland	-0.030	0.025	-0.025	0.048	-0.513
Austria	0.010	0.018	0.015	0.036	0.425
Norway	0.043	0.028	0.048	0.053	0.905
Poland	0.017	0.027	0.022	0.052	0.432
Czech Republic	0.000	0.025	0.005	0.048	0.110
Hungary	-0.020	0.034	-0.015	0.064	-0.229
Slovenia	-0.030	0.025	-0.025	0.048	-0.513
Turkey	-0.020	0.028	-0.015	0.053	-0.275
Lithuania	-0.018	0.023	-0.013	0.045	-0.280
Bulgaria	-0.050	0.014	-0.045	0.030	-1.498
Greece	-0.010	0.032	-0.005	0.061	-0.078
Mean Deviation, x_{mean}	**-0.005**				

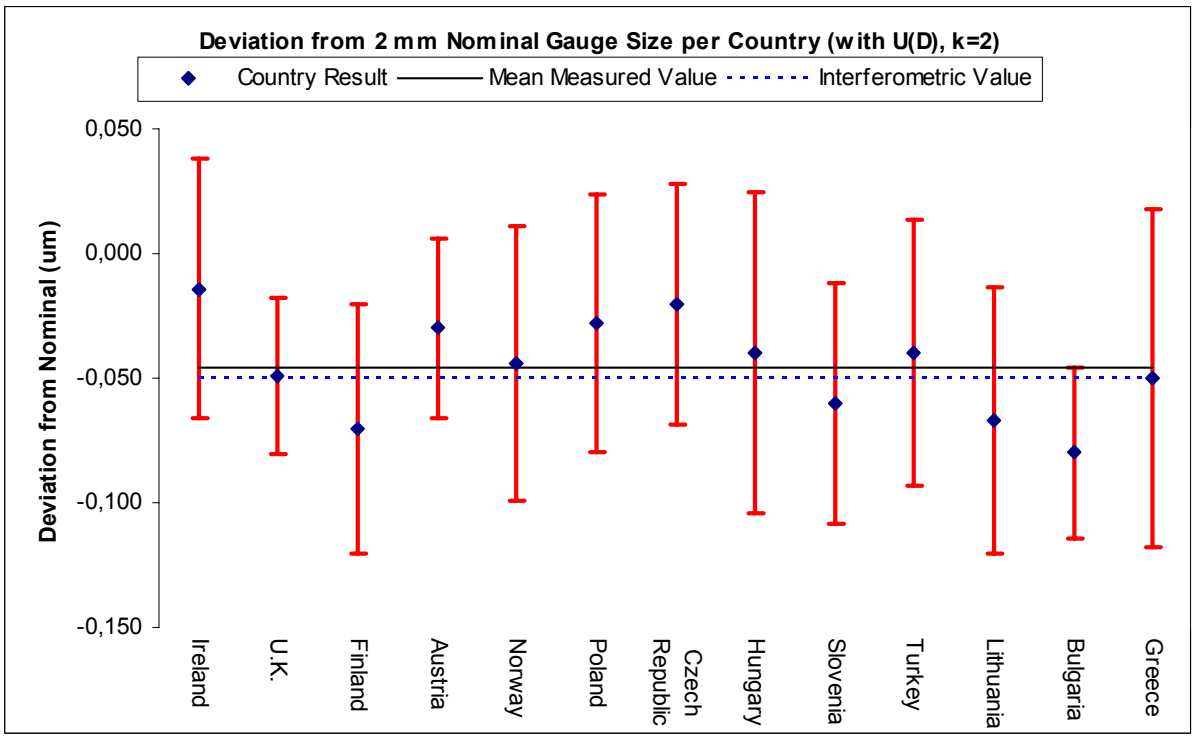
Table 5b P1 Deviation from 1.0 mm Nominal Gauge Size



Graph 2b P1 Deviation from 1.0 mm Nominal Gauge Size

(P1) 2.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D = x - x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.014	0.027	0.032	0.052	0.609
U.K.	-0.049	0.015	-0.003	0.031	-0.111
Finland	-0.070	0.026	-0.024	0.050	-0.489
Austria	-0.030	0.018	0.016	0.036	0.429
Norway	-0.044	0.029	0.002	0.055	0.028
Poland	-0.028	0.027	0.018	0.052	0.339
Czech Republic	-0.020	0.025	0.026	0.048	0.529
Hungary	-0.040	0.034	0.006	0.064	0.086
Slovenia	-0.060	0.025	-0.014	0.048	-0.300
Turkey	-0.040	0.028	0.006	0.054	0.103
Lithuania	-0.067	0.028	-0.021	0.053	-0.402
Bulgaria	-0.080	0.017	-0.034	0.034	-1.005
Greece	-0.050	0.036	-0.004	0.068	-0.066
Mean Deviation, x_{mean}	**-0.046**				

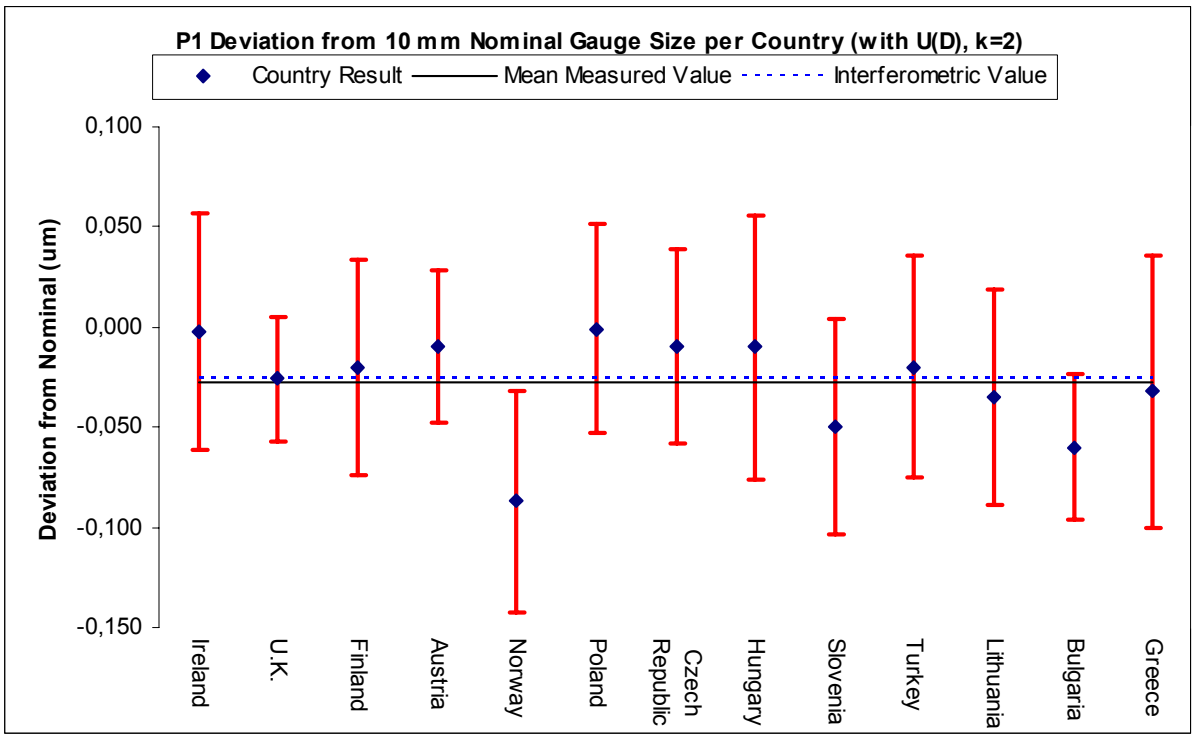
Table 5c P1 Deviation from 2.0 mm Nominal Gauge Size



Graph 2c P1 Deviation from 2.0 mm Nominal Gauge Size

(P1) 10.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D = x - x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.002	0.031	0.026	0.059	0.439
U.K.	-0.026	0.015	0.002	0.032	0.061
Finland	-0.020	0.028	0.008	0.054	0.148
Austria	-0.010	0.019	0.018	0.038	0.470
Norway	-0.087	0.029	-0.059	0.055	-1.065
Poland	-0.001	0.027	0.027	0.052	0.518
Czech Republic	-0.010	0.025	0.018	0.048	0.370
Hungary	-0.010	0.035	0.018	0.066	0.271
Slovenia	-0.050	0.028	-0.022	0.054	-0.411
Turkey	-0.020	0.029	0.008	0.055	0.143
Lithuania	-0.035	0.028	-0.007	0.053	-0.133
Bulgaria	-0.060	0.018	-0.032	0.036	-0.886
Greece	-0.032	0.036	-0.004	0.068	-0.060
Mean Deviation, x_{mean}	**-0.028**				

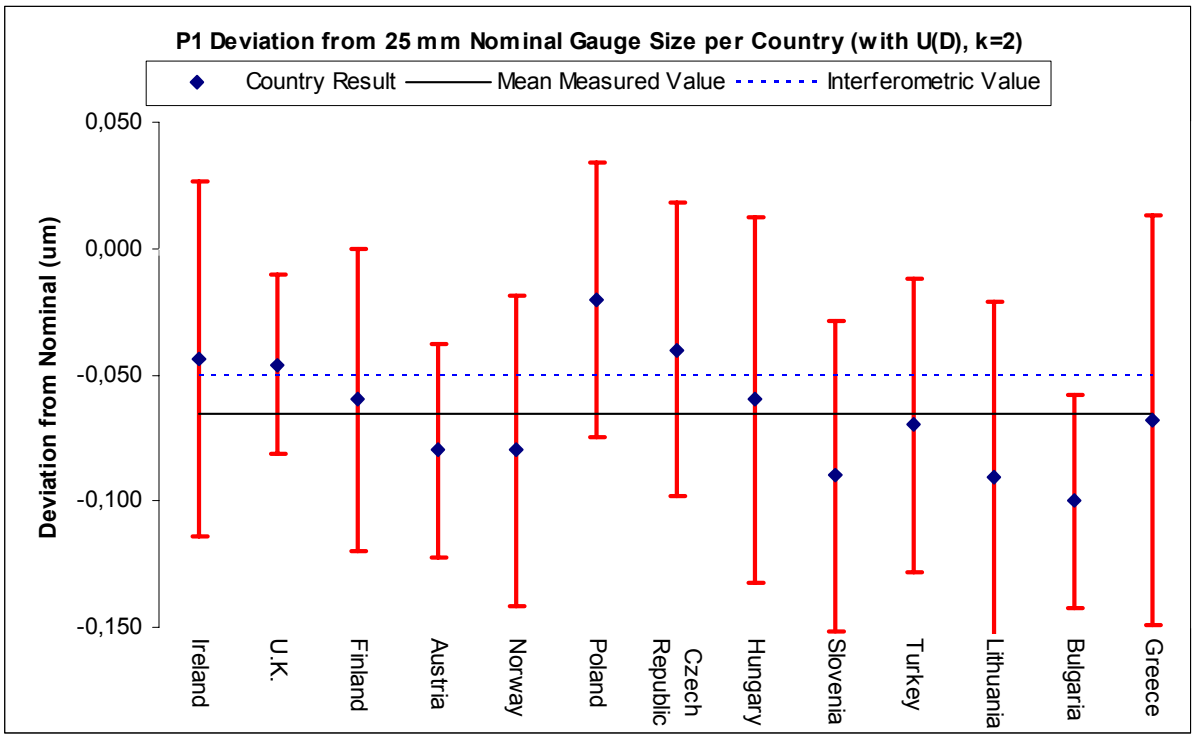
Table 5d P1 Deviation from 10.0 mm Nominal Gauge Size



Graph 2d P1 Deviation from 10.0 mm Nominal Gauge Size

(P1) 25.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D=x-x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.044	0.037	0.021	0.070	0.303
U.K.	-0.046	0.017	0.019	0.036	0.540
Finland	-0.060	0.031	0.005	0.060	0.089
Austria	-0.080	0.021	-0.015	0.042	-0.347
Norway	-0.080	0.032	-0.015	0.061	-0.239
Poland	-0.020	0.028	0.045	0.054	0.833
Czech Republic	-0.040	0.030	0.025	0.058	0.437
Hungary	-0.060	0.038	0.005	0.072	0.074
Slovenia	-0.090	0.032	-0.025	0.061	-0.402
Turkey	-0.070	0.030	-0.005	0.058	-0.081
Lithuania	-0.091	0.037	-0.026	0.070	-0.367
Bulgaria	-0.100	0.021	-0.035	0.042	-0.829
Greece	-0.068	0.043	-0.003	0.081	-0.033
Mean Deviation, x_{mean}	**-0.065**				

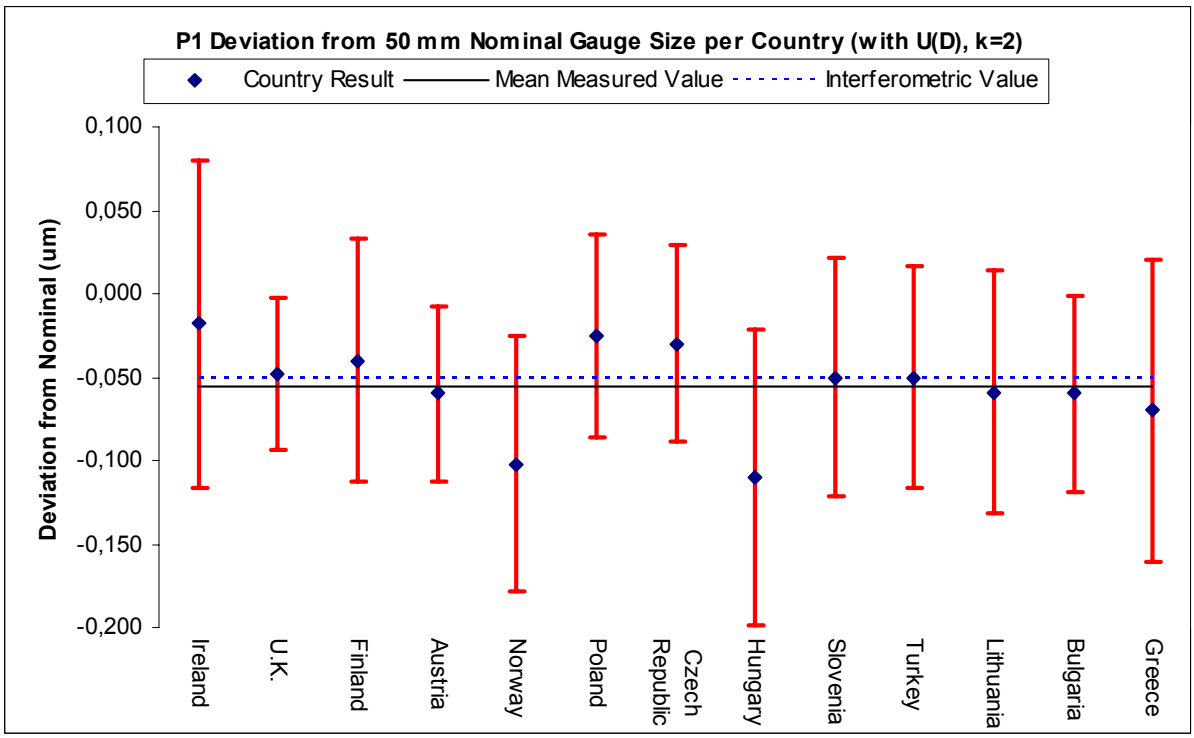
Table 5e P1 Deviation from 25.0 mm Nominal Gauge Size



Graph 2e P1 Deviation from 25.0 mm Nominal Gauge Size

(P1) 50.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D = x - x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.018	0.052	0.038	0.098	0.383
U.K.	-0.048	0.022	0.008	0.045	0.166
Finland	-0.040	0.038	0.016	0.073	0.213
Austria	-0.060	0.026	-0.004	0.052	0.086
Norway	-0.102	0.040	-0.046	0.076	0.608
Poland	-0.025	0.031	0.031	0.061	0.503
Czech Republic	-0.030	0.030	0.026	0.059	0.433
Hungary	-0.110	0.047	-0.054	0.089	0.612
Slovenia	-0.050	0.037	0.006	0.071	0.078
Turkey	-0.050	0.034	0.006	0.066	0.084
Lithuania	-0.059	0.038	-0.003	0.073	0.047
Bulgaria	-0.060	0.030	-0.004	0.059	0.076
Greece	-0.070	0.048	-0.014	0.091	0.159
Mean Deviation, x_{mean}	**-0.056**				

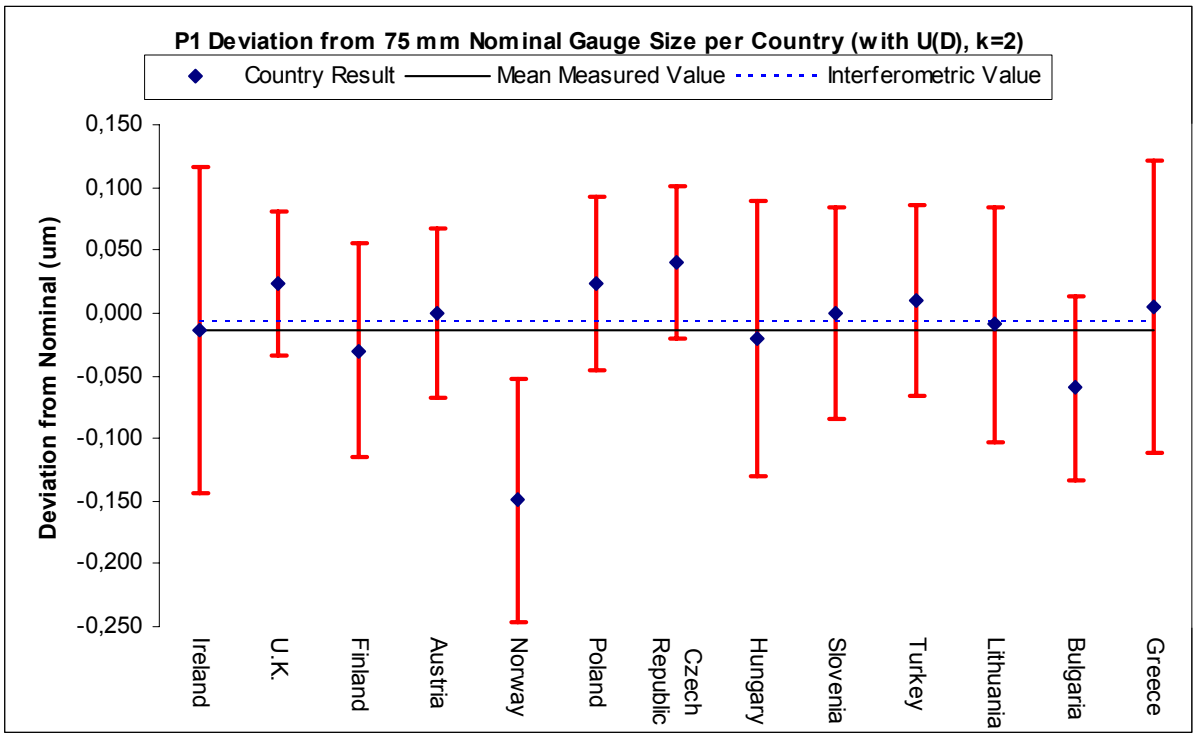
Table 5f P1 Deviation from 50.0 mm Nominal Gauge Size



Graph 2f P1 Deviation from 50.0 mm Nominal Gauge Size

(P1) 75.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D=x-x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.014	0.069	0.000	0.130	-0.001
U.K.	0.023	0.028	0.037	0.058	0.640
Finland	-0.030	0.044	-0.016	0.085	-0.190
Austria	0.000	0.034	0.014	0.068	0.205
Norway	-0.149	0.051	-0.135	0.097	-1.390
Poland	0.024	0.035	0.038	0.069	0.546
Czech Republic	0.040	0.030	0.054	0.061	0.885
Hungary	-0.020	0.058	-0.006	0.110	-0.056
Slovenia	0.000	0.044	0.014	0.085	0.163
Turkey	0.010	0.039	0.024	0.076	0.313
Lithuania	-0.009	0.049	0.005	0.093	0.052
Bulgaria	-0.060	0.037	-0.046	0.073	-0.637
Greece	0.005	0.062	0.019	0.117	0.161
Mean Deviation, x_{mean}	**-0.014**				

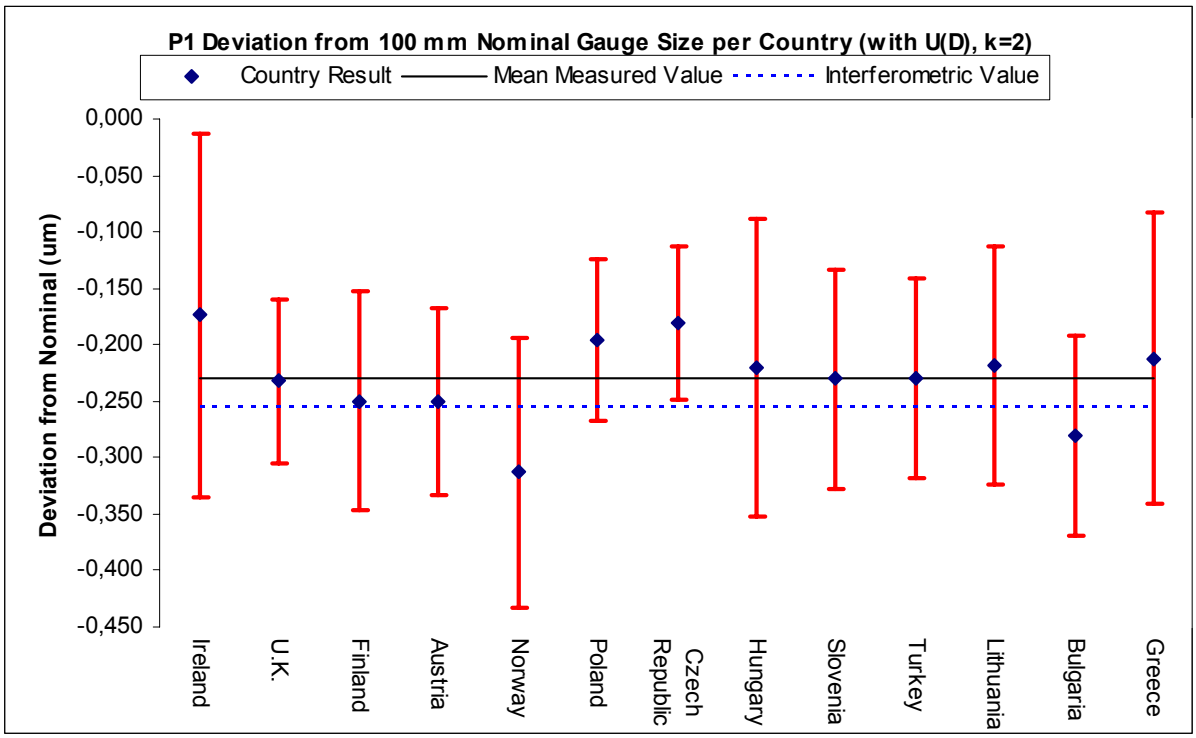
Table 5g P1 Deviation from 75.0 mm Nominal Gauge Size



Graph 2g P1 Deviation from 75.0 mm Nominal Gauge Size

(P1) 100.0 mm Steel Gauge Block					
Country	**Central deviation from nominal length $x = l_c - l_n$ (µm)**	**Std. Uncertainty of deviation from nominal length u(x) (µm) (k=1)**	**Degree of Equivalence $D=x-x_{mean}$ (µm)**	**Uncertainty (k=2) of degree of equivalence, U(D) (µm)**	**En = D/U(D)**
Ireland	-0.174	0.086	0.056	0.161	0.345
U.K.	-0.232	0.036	-0.002	0.073	-0.033
Finland	-0.250	0.050	-0.020	0.097	-0.211
Austria	-0.250	0.042	-0.020	0.083	-0.246
Norway	-0.313	0.063	-0.083	0.120	-0.696
Poland	-0.196	0.035	0.034	0.071	0.473
Czech Republic	-0.180	0.033	0.050	0.068	0.732
Hungary	-0.220	0.070	0.010	0.132	0.073
Slovenia	-0.230	0.050	0.000	0.097	-0.004
Turkey	-0.230	0.045	0.000	0.088	-0.004
Lithuania	-0.218	0.055	0.012	0.106	0.110
Bulgaria	-0.280	0.045	-0.050	0.088	-0.570
Greece	-0.212	0.068	0.018	0.129	0.137
Mean Deviation, x_{mean}	**-0.230**				

Table 5h P1 Deviation from 100.0 mm Nominal Gauge Size



Graph 2h P1 Deviation from 100.0 mm Nominal Gauge Size

7.2 Variation in Length

The variation in length for each gauge block was measured by each participant. This was done by undertaking comparisons between the laboratory reference gauge block and the gauge block under test at five positions (P1….P5) over the measuring face of the gauge block as detailed in the technical protocol.

The variation in length was taken as the difference between the highest and lowest measured lengths at P2…..P5 and 0. The uncertainty in the variation is reported here as the root sum square of the individual uncertainty of the two measured values used.

Tables 6(a) to 6(h) report the results of the variation in length for each participant for each gauge block.

For 0.5 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	0.0720	-0.0480	-0.0240	-0.0440	0.0040	0.0520	0.0380
U.K.	0.0580	0.0400	-0.0330	-0.0500	0.0130	0.0900	0.0210
Finland	0.0400	0.0200	0.0200	-0.0300	-0.0100	0.0500	0.0350
Austria	0.0600	0.0400	-0.0300	-0.0400	0.0200	0.0800	0.0250
Norway	0.1040	-0.0500	-0.0350	-0.0200	-0.0700	0.0700	0.0400
Poland	0.0510	0.0380	-0.0040	-0.0230	0.0240	0.0610	0.0380
Czech Republic	0.0400	0.0300	-0.0300	-0.0500	0.0100	0.0800	0.0350
Hungary	0.0600	0.0200	-0.0500	-0.0700	0.0100	0.0900	0.0480
Slovenia	0.0300	0.0200	-0.0300	-0.0700	0.0000	0.0900	0.0350
Turkey	0.0400	0.0300	-0.0300	-0.0400	0.0200	0.0700	0.0400
Lithuania	0.0270	0.0500	-0.0220	-0.0400	0.0320	0.0900	0.0430
Bulgaria	0.0600	0.0500	0.0100	0.0100	0.0100	0.0500	0.0220
Greece	0.0300	0.0380	0.0220	-0.0400	0.0080	0.0780	0.0710

Table 6a Variation in Length for 0.5 mm Nominal Length

For 1.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	0.0340	0.0080	-0.0100	0.0160	0.0100	0.0260	0.0380
U.K.	0.0050	0.0280	-0.0050	0.0050	0.0300	0.0350	0.0210
Finland	-0.0300	0.0500	0.0100	0.000	0.0000	0.0500	0.0350
Austria	0.0100	0.0200	-0.0100	0.0000	0.0200	0.0300	0.0250
Norway	0.0430	-0.0260	-0.0250	-0.0060	-0.026	0.0260	0.0400
Poland	0.0170	0.0350	0.0040	0.0120	0.0220	0.0350	0.0380
Czech Republic	0.0000	0.0200	0.0000	0.0000	0.0200	0.0200	0.0350
Hungary	-0.0200	0.0100	-0.0200	-0.0100	0.0100	0.0300	0.0480
Slovenia	-0.0300	0.0200	0.0000	0.0000	0.0100	0.0200	0.0350
Turkey	-0.0200	0.0300	-0.0200	0.0000	0.0200	0.0500	0.0400
Lithuania	-0.0180	0.0080	-0.0240	-0.0100	0.0200	0.0440	0.0330
Bulgaria	-0.0500	0.0400	0.0100	0.0100	0.0100	0.0400	0.0200
Greece	-0.0100	0.0230	0.0030	0.0080	0.0070	0,0230	0.0450

Table 6b Variation in Length for 1.0 mm Nominal Length

For 2.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.0140	-0.0340	-0.0180	0.0020	-0.0080	0.0360	0.0380
U.K.	-0.0490	-0.0070	0.0300	0.0070	0.0130	0.0370	0.0210
Finland	-0.0700	0.0300	0.0000	0.0000	0.0100	0.0300	0.0370
Austria	-0.0300	0.0000	0.0100	0.0100	0.0100	0.0100	0.0250
Norway	-0.0440	0.0140	0.0100	0.0140	0.0100	0.0140	0.0410
Poland	-0.0280	0.0100	0.0170	0.0120	0.0160	0.0170	0.0380
Czech Republic	-0.0200	0.0100	0.0000	0.0100	0.0100	0.0100	0.0350
Hungary	-0.0400	-0.0100	-0.0100	0.0100	0.0200	0.0300	0.0480
Slovenia	-0.0600	0.0000	0.0100	0.0000	0.0100	0.0100	0.0350
Turkey	-0.0400	0.0000	-0.0100	0.0000	0.0100	0.0200	0.0400
Lithuania	-0.0670	-0.0060	-0.0020	-0.0040	0.0080	0.0140	0.0390
Bulgaria	-0.0800	0.0200	0.0400	0.0300	0.0200	0.0400	0.0240
Greece	-0.0500	-0.0020	0.0300	0.0240	0.0040	0.0320	0.0510

Table 6c Variation in Length for 2.0 mm Nominal Length

For 10.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.0020	-0.0340	-0.0540	-0.0530	-0.0120	0.0540	0.0450
U.K.	-0.0260	-0.0600	-0.0800	-0.0570	-0.0270	0.0800	0.0210
Finland	-0.0200	0.0100	-0.0300	-0.0500	-0.0500	0.0600	0.0400
Austria	-0.0100	-0.0700	-0.0900	-0.0600	-0.0300	0.0900	0.0270
Norway	-0.0870	0.0000	-0.0160	0.0270	0.0490	0.0650	0.0410
Poland	-0.0010	-0.0290	-0.0470	-0.0320	-0.0110	0.0470	0.0380
Czech Republic	-0.0100	-0.0300	-0.0500	-0.0400	-0.0200	0.0500	0.0350
Hungary	-0.0100	-0.0700	-0.0900	-0.0600	-0.0300	0.0900	0.0490
Slovenia	-0.0500	-0.0500	-0.0700	-0.0600	-0.0300	0.0700	0.0400
Turkey	-0.0200	-0.0400	-0.0600	-0.0400	-0.0200	0.0600	0.0410
Lithuania	-0.0350	-0.0700	-0.0900	-0.0700	-0.0480	0.0900	0.0390
Bulgaria	-0.0600	-0.0300	-0.0300	-0.0200	-0.0200	0.0300	0.0250
Greece	-0.0320	-0.0710	-0.0610	-0.0390	-0.0430	0.0710	0.0510

Table 6d Variation in Length for 10.0 mm Nominal Length

For 25.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.0440	-0.0020	-0.0440	-0.0240	-0.0280	0.0440	0.0520
U.K.	-0.0460	-0.0300	-0.0600	-0.0400	-0.0470	0.0600	0.0240
Finland	-0.0600	0.0000	-0.0300	-0.0400	-0.0300	0.0400	0.0440
Austria	-0.0800	-0.0300	-0.0800	-0.0400	-0.0200	0.0800	0.0300
Norway	-0.0800	-0.0470	0.0130	-0.0130	-0.0170	0.0600	0.0450
Poland	-0.0200	-0.0050	-0.0390	-0.0240	-0.0140	0.0390	0.0400
Czech Republic	-0.0400	-0.0100	-0.0300	-0.0200	-0.0100	0.0300	0.0420
Hungary	-0.0600	-0.0200	-0.0800	-0.0500	-0.0300	0.0800	0.0540
Slovenia	-0.0900	-0.0200	-0.0700	-0.0500	-0.0400	0.0700	0.0450
Turkey	-0.0700	-0.0100	-0.0400	-0.0300	-0.0200	0.0400	0.0420
Lithuania	-0.0910	-0.0380	-0.0780	-0.0540	-0.0460	0.0780	0.0520
Bulgaria	-0.1000	0.0200	0.0200	0.0100	0.0100	0.0200	0.0290
Greece	-0.0680	-0.0380	-0.0480	-0.0240	-0.0500	0.0500	0.0610

Table 6e Variation in Length for 25.0 mm Nominal Length

For 50.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.0180	-0.0520	-0.0260	-0.0660	-0.0920	0.0920	0.0740
U.K.	-0.0480	-0.0750	-0.0350	-0.0780	-0.0920	0.0920	0.0310
Finland	-0.0400	-0.0300	-0.0500	-0.0600	-0.0100	0.0600	0.0540
Austria	-0.0600	-0.0600	-0.0500	-0.0900	-0.0900	0.0900	0.0370
Norway	-0.1020	0.0130	0.0530	-0.0270	-0.0240	0.0800	0.0570
Poland	-0.0250	-0.0380	-0.0230	-0.0600	-0.0610	0.0610	0.0440
Czech Republic	-0.0300	-0.0400	-0.0300	-0.0600	-0.0700	0.0700	0.0420
Hungary	-0.1100	-0.0600	-0.0500	-0.1000	-0.0900	0.1000	0.0660
Slovenia	-0.0500	-0.0500	-0.0400	-0.1000	-0.0900	0.1000	0.0520
Turkey	-0.0500	-0.0500	-0.0300	-0.0800	-0.0800	0.0800	0.0480
Lithuania	-0.0590	-0.0800	-0.0500	-0.1000	-0.1140	0.1140	0.0540
Bulgaria	-0.0600	-0.0100	0.0200	-0.0200	-0.0400	0.0600	0.0420
Greece	-0.0700	-0.0680	-0.0100	-0.0600	-0.1080	0.1080	0.0680

Table 6f Variation in Length for 50.0 mm Nominal Length

For 75.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.0140	-0.1120	-0.1040	-0.0440	-0.0800	0.1120	0.0980
U.K.	0.0230	-0.1480	-0.1380	-0.0580	-0.0780	0.1480	0.0400
Finland	-0.0300	-0.0800	-0.0500	-0.0600	-0.0800	0.0800	0.0620
Austria	0.0000	-0.1300	-0.1200	-0.0600	-0.0600	0.1300	0.0480
Norway	-0.1490	-0.0030	0.1250	0.0570	0.06700	0.1280	0.0720
Poland	0.0240	-0.1000	-0.1030	-0.0480	-0.0590	0.1030	0.0490
Czech Republic	0.0400	-0.1000	-0.1100	-0.0500	-0.0500	0.1100	0.0420
Hungary	-0.0200	-0.1500	-0.1200	-0.0700	-0.0700	0.1500	0.0820
Slovenia	0.0000	-0.1200	-0.1200	-0.0600	-0.0500	0.1200	0.0620
Turkey	0.0100	-0.1200	-0.1200	-0.0400	-0.0600	0.1200	0.0550
Lithuania	-0.0090	-0.1560	-0.1500	-0.0740	-0.0720	0.1560	0.0690
Bulgaria	-0.0600	-0.0600	-0.0600	-0.0100	-0.0300	0.0600	0.0520
Greece	0.0050	-0.1490	-0.1190	-0.0330	-0.0870	0.1490	0.0880

Table 6g Variation in Length for 75.0 mm Nominal Length

For 100.0 mm Nominal Length	Central deviation from nominal length $x = l_c - l_n$ P1 (μm)	$x = l_2 - l_c$ P2 (μm)	$x = l_3 - l_c$ P3 (μm)	$x = l_4 - l_c$ P4 (μm)	$x = l_5 - l_c$ P5 (μm)	Variation in Length (μm)	Uncertainty of Variation (μm)
Ireland	-0.1740	-0.1260	-0.1420	-0.1140	-0.0560	0.1420	0.1220
U.K.	-0.2320	-0.1230	-0.1570	-0.1130	-0.0530	0.1570	0.0510
Finland	-0.2500	-0.0800	-0.0300	-0.1100	-0.1100	0.1100	0.0710
Austria	-0.2500	-0.1200	-0.1700	-0.1200	-0.0500	0.1700	0.0590
Norway	-0.3130	-0.0360	0.1020	0.0700	0.0100	0.1380	0.0890
Poland	-0.1960	-0.0850	-0.1150	-0.0860	-0.0120	0.1150	0.0490
Czech Republic	-0.1800	-0.0800	-0.1200	-0.0900	-0.0300	0.1200	0.0420
Hungary	-0.2200	-0.1100	-0.1600	-0.1200	-0.0400	0.1600	0.0990
Slovenia	-0.2300	-0.1000	-0.1600	-0.1200	-0.0300	0.1600	0.0710
Turkey	-0.2300	-0.1100	-0.1400	-0.0800	-0.0400	0.1400	0.0640
Lithuania	-0.2180	-0.1420	-0.1740	-0.1240	-0.0740	0.1740	0.0780
Bulgaria	-0.2800	-0.0500	-0.0700	-0.0400	-0.0100	0.0700	0.0640
Greece	-0.2120	-0.1280	-0.1430	-0.0950	-0.0650	0.1430	0.0960

Table 6h Variation in Length for 100.0 mm Nominal Length

Annex 1

Measurement Instructions

Before calibration, the gauge blocks have to be inspected for damage to the measurement surfaces. Any scratches, rusty spots or other damages has to be documented by a drawing or sketching in the appropriate form in the annex (A2).

The gauges should be in the laboratory environment for an adequate period to allow temperature stabilisation.

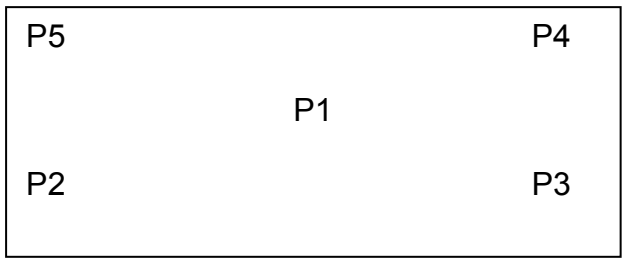
The gauge block temperature and/or surface plate temperature should be recorded at the beginning and end of the calibration.

The gauge blocks should be measured by mechanical comparision with the laboratories reference gauge blocks.

The following features are recorded for each gauge block:

- Deviation of the central lengths (P1 in figure below) from the nominal value.
- Where possible, deviation in length relative to the central length at measuring points P2, P3, P4 and P5.

The result should be recorded in Annex 1



The gauges should be positioned as follows:-

- 0.5 mm, 1 mm, 2 mm and 10 mm – the measuring face with the `CARY1` and nominal size markings should face upwards with the `CARY`mark on the left side of the gauge facing the operator.
- 25 mm, 50 mm, 75 mm and 100 mm – The side of the gauge with the `cary`and nominal size marking should be in the vertical, facing the operator with the `CARY`marking on the left side.

Measurement Uncertainty

The uncertainty of measurement shall be estimated and reported as would be normal for mechanical comparison according to the *ISO Guide for the Expression of Uncertainty in Measurement*.

Reporting

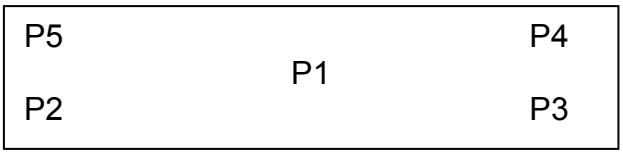
The quality of the measurement surfaces of the gauge blocks, the measurement results, instrument descriptions and a detailed evaluation of the uncertainty of measurement have to be reported using the forms enclosed in the annex. Handwritten notes are sufficient.

The measurement report forms in the annex of this document are sent by e-mail (Word document) to all participating laboratories. It would be appreciated if the report forms (in particular the results sheet) could be completed by computer and sent back electronically to the coordinator. **In any case, the signed report must also be sent in paper form by mail.** In case of any differences, the paper forms are considered to be the valid version.

The reports shall be sent **within six weeks** after completing the measurements to the pilot laboratory. No information about differences of the reported results with respect to other laboratories will be discussed before the completion of the comparison, unless large deviations of particular laboratories with respect to the preliminary reference results obtained by the pilot laboratory have been observed. In the latter case the laboratory in question will be contacted.

Within 3 months after completion of the circulation, the pilot laboratory will prepare a first draft report and send it to the participants for comment. Subsequently, the procedure outlined in the BIPM Guidelines will be followed.

Measurement Results



Steel Gauge Blocks

Id. no.	Nom. length	deviation from nominal	(Deviation from Central Length, P1)				Uncert. (1σ)
		P1	P2	P3	P4	P5	
	L (mm)	Δl (µm)	Δl(µm)	Δl (µm)	Δl (µm)	Δl (µm)	u_c (nm)
8’52005	0.5						
5’70252	1						
20’60646	2						
3’60351	10						
11’60661	25						
27’60509	50						
19’70004	75						
31’60452	100						

Please prepare a detailed uncertainty budget for the calibration of the 2 mm and 100 mm gauge blocks as per form in Annex 3 and Annex 4.

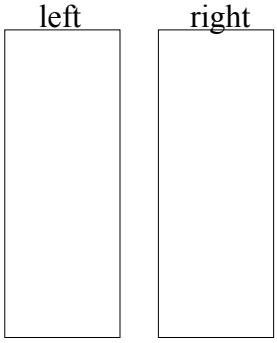
Laboratory:……

Date:……. Signature……..

Inspection of the Measurement Surfaces, Steel Gauge Blocks

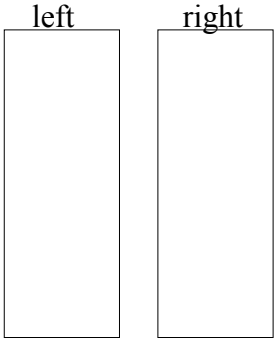
0.5mm
S/N 8’52005

left right



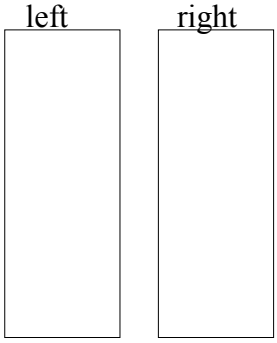
1mm
S/N 5’70252

left right



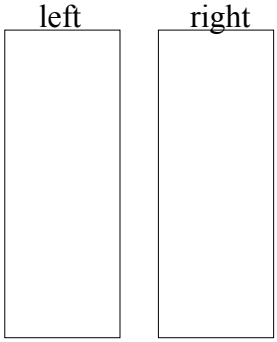
2mm
S/N 20’60646

left right



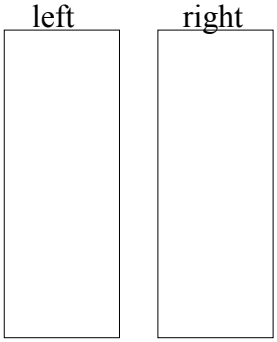
10mm
S/N 3’60351

left right



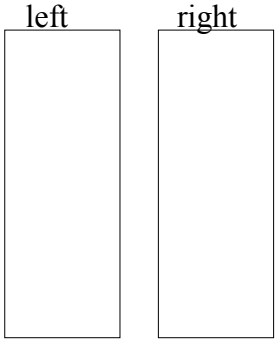
25mm
S/N 11’60661

left right



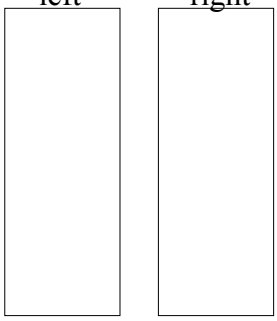
50mm
S/N 27’60509

left right



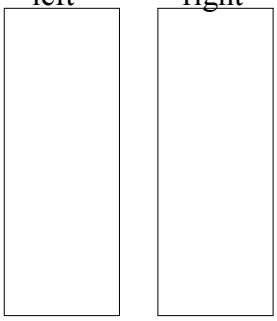
75mm
S/N 19’7004

left right



100mm
S/N 31’60452

left right



Laboratory:……

Date:……. Signature……..

Uncertainty of Measurement

Nominal Block Size = 2 mm

The statement of uncertainty in the result form in A.1 should be consistent within the ISO-Guide for the expression of uncertainty in measurement.

Please indicate below if possible, the different input quantities which have been used to estimate the reported uncertainty.

This detailed information is provided for the 2 mm and 100 mm blocks.

Input quantity (Type A evaluation)

No.	Input Quantity – Description	Value 1σ	Distribution Type
1			
2			
3			
4			

Input quantition (Type B evaluation)

No.	Input Quantity – Description	Value 1σ	Distribution Type
1			
2			
3			
4			
5			
6			
7			

Combined Uncertainty (u_c)=

Laboratory:……

Date:……. Signature……..

Uncertainty of Measurement

Nominal Block Size = 100 mm

The statement of uncertainty in the result form in A.1 should be consistent within the ISO-Guide for the expression of uncertainty in measurement.

Please indicate below if possible, the different input quantities which have been used to estimate the reported uncertainty.

This detailed information is provided for the 2 mm and 100 mm blocks.

Input quantity (Type A evaluation)

No.	Input Quantity – Description	Value 1σ	Distribution Type
1			
2			
3			
4			

Input quantition (Type B evaluation)

No.	Input Quantity – Description	Value 1σ	Distribution Type
1			
2			
3			
4			
5			
6			
7			

Combined Uncertainty (u_c)=

Laboratory:……

Date:……. Signature……..

Description of the Measurement Instrument

Make and Type of comparator .....

.....

.....

.....

.....

.....

Resolution of Compartator

.....

.....

.....

.....

.....

.....

Type and Grade of Ref. Gauge Block used

.....

.....

.....

.....

Range of gauge block temperature during measurement.....

.....

.....

.....

.....

Laboratory:……

Date:……. Signature……..

Telefax Telefax Telefax Telefax Telefax

To: **Howard McQuoid**
National Metrology Laboratory
Enterprise Ireland
Glasnevin
Dublin 9
Tel; 353 1 808 2657
Fax; 353 1 808 2026
e-mail:howard.mcquoid@enterprise-ireland.com

From: (participating laboratory)

We confirm having received the standards of the *Euromet No. 601 gauge block measurement* on.....…… (date)

After visual inspection

- ☐ no damage has been noticed.
- ☐ the following damage(s) must be reported:
  .....
  .....
  .....
  .....

Date: Signature:

....