Report on Key Comparison EURAMET.L-K1.2011
Measurement of gauge blocks by interferometry

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Bundesamt für Eich- und
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Measurement of gauge blocks by interferometry

EURAMET project #1218

Final Report

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Contents

1 Document control 4
2 Introduction 4
3 Organization 4
3.1 Participants 4
3.2 Schedule 7
4 Artefacts 9
4.1 Description of the standards 9
5 Measuring instructions 11
5.1 Handling of artefacts 11
5.2 Traceability 11
5.3 The measurand 11
5.4 Measurement uncertainty 12
5.4.1 Reporting of measurement uncertainty 12
6 Stability of Artefacts 12
6.1 Condition of artefacts at start/end of comparison (wear marks) 12
6.2 Dimensional stability of artefacts (Drift) 13
7 Results 14
7.1 Reporting of results 14
7.2 Treatment of potentially discrepant results during circulation 14
7.3 Results and standard uncertainties as reported by participants 15
8 Analysis of the measurement results 15
8.1 Calculation of the KCRV for the principal measurand e_c 15
8.1.1 Calculation of the KCRV for artefacts without significant drift 16
8.1.2 Calculation of the KCRV for artefacts with significant drift 17
8.1.3 Correlation coefficients for linking laboratories 18
8.1.4 Degree of Equivalence (DoE) 19
8.1.5 Statistical consistency 20

8.1.6 Compilation of reference values 21
8.2 Calculation of the reference value for the auxiliary measurand d_c 21
9 Results, Reference values and degrees of Equivalence 22
9.1 The principal measurand e_c 22
9.2 The auxiliary measurand d_c 41
9.3 Discussion of results 52
9.4 Changes to results after Draft A.1 report 52
9.5 Comments received after Draft B.1 report 53
9.5.1 NPL comment from 29.07.2015 53
9.5.2 METAS comment from 30.07.2015 54
9.5.3 GUM comment from 31.08.2015 54
9.5.4 DFM comment from 04.09.2015 54
9.5.5 DFM comment from 14.09.2015 54
9.6 Linking of result to other comparisons 55
10 Conclusion 55
Appendix A Equipment and measuring processes of the participants 56
Appendix B Time dependent KCRVs 56
Appendix C Additional measurements not contributing to the KCRV 57
SP measurement on 3 mm steel block 58
Expansion coefficient – Complementary Measurements by CMI 59
Appendix D Measurement faces – Compilation of images 59
Appendix E CMCs as declared by the laboratories in the CIPM-MRA 62
References 63

1 Document control

Version Draft A.1	Issued on 16. October 2014.
Version Draft B.1	Issued on 29. July 2015.
Version Draft B.2	Issued on 21. October 2015, accounting for participant’s recommendations
Version Draft B.3	Issued on 27. November 2015, minor editorial change
Version Draft B.4	Issued on 17. December 2015, including UME´s requests on instruments
Version Draft B.5	Issued on 21. December 2015, including UME´s requests for CMC table
Final Version	Issued on 27. January 2016, email of CEM corrected

2 Introduction

The metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs). At its meeting in September 2008, the Consultative Committee for Length, CCL, identified several key comparisons in the field of dimensional metrology. In particular, it decided that the formally individual key comparisons on short gauge blocks and on length bars (long gauge blocks) should be combined under the designation CCL-K1.

The key comparison detailed in this document, EURAMET.L-K1.2011, is parallel to the CIPM key comparison CCL-K1.2011 which is piloted by CENAM and NRC. Key Comparison EURAMET.L-K1 was instigated following a decision at the 2010 meeting of the EURAMET Length contact persons held at SP Technical Research Institute of Sweden.

The sets of gauge blocks used in both the CCL and EURAMET key comparisons have almost the same composition, i.e. steel and ceramic gauges ranging from 0,5 mm to 500 mm in length.

BEV (AT) acts as pilot laboratory for EURAMET.L-K1 with substantial help by PTB (DE) for the stability measurements on long gauge blocks. It should be noted that PTB is not a participant of this very comparison (instead it will take part in the corresponding COOMET.L-K1 loop of CCL-K1.2011)

A goal of the CCL key comparisons for topics in dimensional metrology is to demonstrate the equivalence of routine calibration services offered by NMIs to clients, as listed in Appendix C of the Mutual Recognition Arrangement (MRA) [1]. To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

3 Organization

The comparison was coordinated by the BEV (AT) as the pilot laboratory with substantial help by PTB (DE) for the long gauge blocks stability measurements. Due to the large number of participants the comparison was performed in two concurrent loops. Laboratories outside the EU (with any kind of customs barriers) were pooled in loop A. (METAS also in loop B for linking reasons)

3.1 Participants

The list of participants was prepared by the pilot laboratory after soliciting participation from any interested EURAMET NMIs. All participants must be able to demonstrate traceability to the realization of the metre. Moreover they must be capable to calibrate the gauge blocks using an interferometric (or other primary) technique. Calibration by comparison to standard gauge blocks of similar nominal size is not a topic of this project.

Contact persons changed in the course of the project for IPQ, UME, NIS, DFM, and LNE.

Table 1. List of participant laboratories and their contacts.

Laboratory Code	Contact person, Laboratory	Phone, Fax, email
BEV (pilot)	Michael Matus Bundesamt für Eich- und Vermessungswesen BEV Arltgasse 35, 1160 Wien Austria	Tel. ++43 1 21110 6540 Fax ++43 1 21110 996000 e-mail: michael.matus@bev.gv.at
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Laboratory Code	Contact person, Laboratory	Phone, Fax, email
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Laboratory Code	Contact person, Laboratory	Phone, Fax, email
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3.2 Schedule

The participating laboratories were asked to specify a preferred timetable slot for their own measurements of the gauge blocks – the timetable given in table 2 of the technical protocol has been drawn up taking these preferences into account. It was subject to a number of revisions during the project. Each laboratory had six weeks that include customs clearance, calibration and transportation to the following participant. With its confirmation to participate, each laboratory is obliged to perform the measurements in the allocated period and to allow enough time in advance for transportation so that the following participant receives them in time. If a laboratory has technical problems to perform the measurements or customs clearance takes too long, the laboratory has to contact the pilot laboratory as soon as possible and, according to whatever it decides, it might eventually be obliged to send the standards directly to the next participant before completing the measurements or even without doing any measurements.

The comparison was carried out with at least one pilot intermediate measurement check during the circulation. The settled dates for both loops are indicated in table 2. This table shows the final version as valid near the end of the measurements. During the course of the project it was subject to a number of revisions as detailed below.

- IPQ originally scheduled for loop A, period 4 asked for a later timeslot due to problems with their green laser. IPQ was shifted to period 18, loop 2 finally. (16.02.2012)
- After receiving the artefacts (period 5, loop B) SMD reported problems with their green laser and asked for a later timeslot, too. However they measured the three long blocks by comparison. Shifted to period 15 (only gauges up to 300 mm). (27.07.2012)
- DFM (period 6, loop A) after having measured all gauge blocks encountered stability problems with their instrument. Results were not sent and DFM was rescheduled to period 19. (05.09.2012)
- JV and DMDM (period 11 and 13, respectively) swapped their timeslots on request by JV (14.01.2013)

- INRIM informed pilot about problems with the short gauge block interferometer and asked for new and later timeslot → period 19. (21.02.2013)

- Finally INRIM withdrew completely from the comparison due to staff problems. This is unfortunate as INRIM is a link to CCL-K1. (27.02.2014)

- BEV as a pilot performed measurements in various free timeslots between transportation and stability measurements to regain lost time. Also the interferometer for long gauge blocks was not operational at the scheduled period. The actual measurement time (in units of periods) is documented in the evaluation Excel file (as is for all participants).

- MKEH finally informed the pilot that they will not send results for their measurements performed in period 2 since the respective service has been stopped and CMC will be deleted. (26.09.2014)

Table 2. Time schedule. Entries marked in red were allocated for the stability measurements. Data from the green entries are used for the intra-comparison linking. All periods started on a Monday, respectively.

Period	(starting date)	Loop A	Loop B
1	02. Jan. 2012	BEV (PTB)	BEV (PTB)
2	13. Feb. 2012	MKEH	SP
3	26. Mar. 2012	SMU	MIKES
4	07. May 2012	BEV	VSL
5	18. Jun. 2012	EIM	SMD
6	30. Jul. 2012	DFM	LNE
7	10. Sep. 2012	BEV (PTB)	BEV (PTB)
8	22. Oct. 2012	BEV	METAS
9	03. Dec. 2012	METAS	NPL
10	14. Jan. 2013	HMI/FSB-LPMD	CEM
11	25. Feb. 2013	DMDM	INRIM
12	08. Apr. 2013	UME	CMI
13	20. May 2013	JV	GUM
14	01. Jul. 2013	BEV	INM
15	12. Aug. 2013	MIKES	BEV
16	23. Sep. 2013	BEV (PTB)	BEV (PTB)
17	11. Nov. 2013	NIS	BIM
18	27. Jan. 2014	SMD	IPQ
19	3. Mar. 2014	DFM	INRIM

The “Period” stated in the first column of Table 2 is used throughout of this document to set up a numerical chronology of events. 1 period corresponds to roughly 6 weeks (44,4 days or 3,8 Ms) on average. This unit is used for drift estimation and the time dependent KCRV (see 8.1.2).

4 Artefacts

4.1 Description of the standards

Each of the two transportation packages contains 19 gauge blocks (Figure 1). The gauge blocks are of rectangular cross section and comply with the calibration grade K of the standard [2]. The gauge blocks were selected for good quality of the faces and small variation in length, the limit deviation t_e from nominal length is not met by some of the artifacts.

Figure 1 – Transporting cases

The rationale behind the selection of the gauge blocks was as follows: Timely availability, option to the stack method for optical phase change correction, possibility to apply a link to CCL-K1, same nominal lengths for steel versus ceramic gauge blocks to reduce uncertainty of stability measurements by mechanical comparison.

Table 3. Gauge blocks for the two loops.

Class	Nominal length / mm	α / 10^{-6} K^{-1}	Manufacturer	Identification number Loop A	Identification number Loop B
short, steel	0,5	11,9	KOBA	88286	88287
	1,15	11,9	KOBA	87050	87051
	3	11,9	KOBA	88286	87646**
	5	11,9	KOBA	88286	88287
	7	11,9	KOBA	88286	88287
	23,5	11,9	KOBA	88286	88287
	80	11,9	KOBA	88286	88287
	100	11,9	KOBA	88286	88287
short, ceramic	0,5	9,3	KOBA	10485	10550
	1,15	9,3	KOBA	10314	10329
	3	9,3	KOBA	10942	10932
	5	9,3	KOBA	10978	10982
	7	9,3	KOBA	10745	10710
	23,5	9,3	KOBA	10060	10071
	80	9,3	KOBA	10340	10315
	100	9,3	KOBA	10600	10399
long, steel	150	11,6*	Hoffmann	110146	110147
	300	11,6*	Hoffmann	110146	110147
	500	11,5*	Hoffmann	110146	110147

* The CTE of these 6 blocks were determined by PTB with low uncertainty. In the table the values are intentionally stated less accurate. The participants should use them like manufacturer's data.
** was No.: 88287 for the first participant only. Replaced after accident.

The coefficients of thermal expansion stated in the technical protocol and in the table 3 are obtained by the manufacturers and should be used as such. Following a decision by the WGDM (now CCL WG-MRA) a pre-determination of this important artifact parameter is not to be communicated to the participants.

For the stability measurements of the six long gauge blocks PTB determined the linear thermal expansion coefficient with low uncertainty. The values are presented in table 4. With the exception of the pilot they were not known by the participants prior to this report.

Table 4. Coefficients of linear thermal expansion for the six long gauge blocks as measured by PTB. The number following the symbol ± is the numerical value of the expanded (k=2) uncertainty.

Identification	Nominal length / mm	α / 10^{-6} K^{-1}
Loop A Nr. 110146	150	11,706 ± 0,050
	300	11,577 ± 0,084
	500	11,529 ± 0,055
Loop B Nr. 110147	150	11,573 ± 0,050
	300	11,589 ± 0,084
	500	11,550 ± 0,055

CMI as a participant reported the linear thermal expansion coefficient for the three long gauge blocks of loop B. The values were not used for the analysis of this comparison but are reported in Appendix C for information only.

5 Measuring instructions

The gauge blocks shall be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers. The "A" surface is the marked measuring face for gauge blocks with nominal length < 6 mm and the right hand measuring face for gauge blocks with a nominal length ≥ 6 mm, respectively (see Figure 2). This nomenclature was used in accordance with CCL-K1 [5].

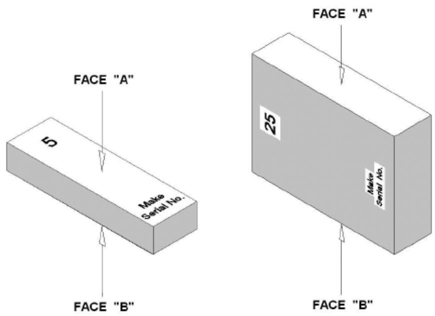


Figure 2 – Nomenclature of faces

5.1 Handling of artefacts

The gauge blocks should only be handled by authorized persons and stored in such a way as to prevent damage. Before making the measurements, the gauge blocks need to be checked to verify that their measuring surfaces are not damaged and do not present severe scratches and/or rust that may affect the measurement result. The condition of the blocks before measurement should be registered in the form provided in appendix B and appendix C (refers to technical protocol). Laboratories should attempt to measure all gauge blocks unless doing so would damage their equipment. If a gauge block will not wring readily, the participant shall inform the pilot about this problem, stating the respective gauge block and face. No participant shall try to re-finish measuring faces by burring, lapping, stoning, or whatsoever. The measurement of the face concerned or the complete gauge block shall be omitted.

5.2 Traceability

Length measurements should be traceable to the latest realisation of the metre as set out in the current "*Mise en Pratique*". Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90).

5.3 The measurand

The principal measurand to be reported is the deviation e_c of the central length l_c from the nominal length l_n of a gauge block. In this project the arithmetic mean of the two values for wringing on both faces is considered as representative for e_c (see equation (1), the superscripts label the face wrung to the platen). In cases where only one face could be wrung the corresponding value should be reported as the result.

$$e_c = \left(e_c^A + e_c^B\right)/2 \quad \text{with} \quad e_c^A = l_c^A - l_n \quad \text{and} \quad e_c^B = l_c^B - l_n \qquad (1)$$

As an auxiliary measurand the difference of the found deviations d_c when the block is wrung to face A and face B, respectively, should be reported according to equation (2). Care has to be taken to use the correct sign.

$$d_c = e_c^A - e_c^B = l_c^A - l_c^B \tag{2}$$

5.4 Measurement uncertainty

The uncertainty of measurement shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement [3]. Although comparability is sacrificed by not giving an explicit model equation, the participating laboratories are encouraged to use their usual model for the uncertainty calculation. Examples for model equations might be found in [4, 5, 6].

All measurement uncertainties shall be stated as standard uncertainties. If appropriate the corresponding effective degree of freedom might be stated by the participants. If none is given, ∞ is assumed. (Note: for principal reasons the concept of degree of freedom is undefined in presence of covariance and it is in general a questionable concept [12]. Anyway it will not be taken into account for the analysis.) For efficient evaluation and subsequent assessment of CMC claims an uncertainty statement in the functional form (3) is preferred.

$$u(e_c) = Q[a, b \cdot l_n] = \sqrt{a^2 + (b \cdot l_n)^2} \tag{3}$$

5.4.1 <u>Reporting of measurement uncertainty</u>

In this document we use the following notation for the reporting of uncertainties. For expanded uncertainties (which are essentially coverage intervals) the ± sign is used, like 234 nm ± 44 nm. Standard uncertainties and standard deviations are reported using the parenthesis notation: 234(22) nm. In any case care is taken to avoid ambiguities.

Throughout this report expanded uncertainties are exclusively stated with an expansion factor of k = 2.

$$U(x) = 2 \cdot u(x) \tag{4}$$

6 Stability of Artefacts

6.1 Condition of artefacts at start/end of comparison (wear marks)

All gauge blocks were freshly acquired with unused measurement faces. Former comparisons of this type have shown that the faces experienced progressive wear eventually making them unwringeable. Moreover the drawings requested from the participants were seldom significant. To document the wear in a more objective way, it was decided to take micrographic images whenever possible for this comparison. Unfortunately the microscopes were not ready at the start of the circulation consequently there are no images of the fresh faces.

A standard optical microscope was used to document the faces of gauge blocks up to 23,5 mm (Zeiss Imager.M2m, 5x/0,13 DIC). For longer blocks (up to 150 mm) a Leica M80 binocular microscope was used. Since the field of view for both microscopes is smaller than the measuring faces, stitching software was used to generate overview images. Blocks longer than 150 mm have not been documented by photography. An assortment of pictures is reproduced in Appendix D.

All micrographic images as taken at the original resolution by the pilot are stored on Google Drive, sorted by loop number, gauge block, face and period:

https://drive.google.com/folderview?id=0B5DBrJH86ttOY1dJOHVsano5R0k&usp=sharing

A few participants provided micrographic images also, those can be found on the link given above. All participants have been asked to document (by drawing) the conditions of the faces in advance of performing the actual calibration. Copies of these reports can be found in Appendix A.

6.2 Dimensional stability of artefacts (Drift)

Since the artifacts were freshly acquired (no history), all the blocks have been calibrated several times by BEV and PTB, respectively. This data (and only this data) was fitted by straight lines (per gauge block, see equations (19) and (20)). The slopes β and the expanded measurement uncertainties $U(\beta)$ of these lines are then used to decide if a significant drift is present according to equation (5):

$$\text{Iff } |\beta| > U(\beta) \text{ significant drift present, else no drift.} \quad (5)$$

According to this criterion only the eight steel gauge blocks with nominal lengths ≥ 100 mm show a significant drift. The remaining ones are considered as stable for the evaluation of the KCRV. Plots of typical examples of each type are presented in fig. 3.

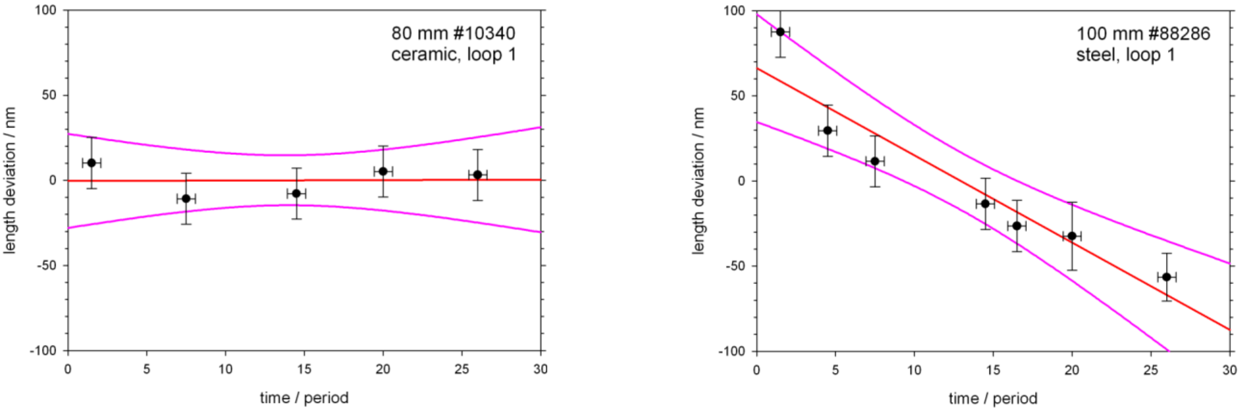


Figure 3 – Stability measurements on a 80 mm ceramic and a 100 mm steel gauge block, respectively. Lengths are referenced to an arbitrary value, error bars represent standard uncertainties. Pink lines show the 95 % confidence interval.

Table 5. Dimensional drift β of the gauge blocks for the two loops.

Class	Nominal length / mm	Dimensional drift ± expanded uncertainty / nm·(period)$^{-1}$ Loop A	Loop B
short, steel	0,5	−1,79 ± 2,81	+0,31 ± 2,25
	1,15	−1,43 ± 2,70	+0,34 ± 2,25
	3	−1,09 ± 2,05	−0,01 ± 2,25
	5	−0,55 ± 2,26	+0,65 ± 2,25
	7	−0,39 ± 2,05	+0,19 ± 2,25
	23,5	−0,08 ± 2,33	−0,15 ± 2,25
	80	+0,78 ± 2,33	+0,52 ± 2,25
	100	−5,11 ± 1,38	−6,05 ± 1,50
short, ceramic	0,5	−0,26 ± 1,54	−0,60 ± 1,54
	1,15	+0,11 ± 1,54	−0,41 ± 1,54
	3	−0,31 ± 1,54	+0,05 ± 1,54
	5	+0,05 ± 1,54	+0,12 ± 1,54
	7	−0,31 ± 1,54	+0,53 ± 1,66
	23,5	+0,08 ± 1,58	+0,11 ± 1,58
	80	+0,00 ± 1,62	+0,58 ± 1,62
	100	−0,39 ± 1,65	+0,30 ± 1,65
long, steel	150	−3,76 ± 1,73	−3,53 ± 1,80
	300	−1,83 ± 1,62	−3,55 ± 1,62
	500	−4,49 ± 2,16	−6,18 ± 2,26

7 Results

7.1 Reporting of results

All results had to be communicated directly to the pilot laboratory as soon as possible and certainly within six weeks of the completion of the measurements by a laboratory. Most of the participants reported within the period stipulated. A small number have heavily overdrawn the allocated time (see CCL WG-MRA Log File).

The proposed reporting form was utilized by all participants; NPL additionally sent official calibration certificates (UKAS+MRA).

7.2 Treatment of potentially discrepant results during circulation

There were a few occasions were obviously erroneous results have been reported. The respective participants have been informed by the pilot as soon as possible (but not of sign or magnitude of problem) and following actions have been taken:

- VSL: the calibration value for the 80 mm steel block was bad. The participant responded after short time: *"I looked at the exception, and directly spotted the error. In our program to calculate the length of the 80 mm gauge block based on the fringe fraction a nominal value of 79,999500 was entered by our calibration technician. This with the background that a value of 79,9997 mm was found by mechanical comparison. I should have spotted this. So the deviation from nominal value should be 186 nm – 500 nm = –314 nm."* (28.09.2012)

- INM: 4 calibration values discrepant, the participant was informed (05.08.2013). Revised results were sent, 3 values still discrepant. No explanation for revised results was provided. (07.10.2013)
- NIS: The lab was informed that 8 calibration values were discrepant (15.01.2014). NIS sent revised results – worse than before (23.01.2014). A second revision did not improve the situation. No explanation for revised results was provided. (24.01.2014)
- IPQ: 2 calibration values discrepant. Information by the pilot. (15.10.2014)

All results still discrepant after information by the pilot are included as reported. For the evaluation they are not taken in account right from the beginning.

7.3 Results and standard uncertainties as reported by participants

The results had to be reported by the participants on Word forms in tables. The principal measurands e_c (deviation from nominal length) were all copied in an Excel spread sheet `EURAMET.L-K1.2011-results.xls`. The spread sheet allows for the evaluation of the reference values, for the determination of the largest consistent subset and the degrees of equivalence, according to section 8.1 of this report.

For the auxiliary measurand d_c (difference between the two wringings) a separate Excel spread sheet `EURAMET.L-K1.2011-diff.xls` was used. Only statistical parameters were evaluated in this case as discussed in section 8.2.

The results as they were reported by the participants are shown in section 9.

8 Analysis of the measurement results

8.1 Calculation of the KCRV for the principal measurand e_c

The weighted mean is the preferred measure to be used as the KCRV (Key Comparison Reference Value) for each measurand. Before the weights can be assigned and the mean taken, it is necessary to exclude any clear outliers from the analysis. There are different ways to perform this task in an reproducible way. For this comparison the Birge ratio was chosen as the criterion since it led to the smallest number of results to be excluded. The necessary uncertainties for this criterion are calculated on a per loop basis (i.e. without the modification due to linking).

The evaluation of the KCRV has been complicated by two facts: first a numerical link between the loops is necessary and second, some artifacts show a drift of the measurand.

The available data (measurement values) are for each gauge block (indexed by g) and laboratory i:

- Measurement result $x_{g,i}$ (provided by participant).
- Standard uncertainty of measurement result $u(x_{g,i})$ (provided by participant).
- Time of measurement $t_{g,i}$ (estimated by pilot).
- Set of stability measurement results $\{x^S_g\}$ (provided by pilot).
- Set of standard uncertainties of stability measurement results $\{u(x^S_g)\}$ (provided by pilot).
- Set of stability measurement times $\{t^S_g\}$ (provided by pilot).

These data must be used to evaluate following interim results:

- Dimensional linear drift rate β_g (evaluated by pilot).
- Standard uncertainty of the drift rate $u(\beta_g)$ (evaluated by pilot).
- Covariance of the two results per linking lab $u(x_{\mathrm{A}g,i}, x_{\mathrm{B}g,i})$ (estimated by pilot).

Finally the actual KC-relevant parameters are obtained:

- The KCRV per loop $x_{\mathrm{ref,A}}$ and $x_{\mathrm{ref,B}}$ (might be time dependent).
- The standard uncertainty of the KCRV per loop $u(x_{\mathrm{ref,A}})$ and $u(x_{\mathrm{ref,B}})$ (might be time dependent).
- The deviation of the individual results $d_{g,i}$.
- Standard uncertainty of the deviation of the individual results $u(d_{g,i})$.
- The normalized deviation of the individual results E_{n}.

The mathematics used for this evaluation is detailed in the following sections.

8.1.1 Calculation of the KCRV for artefacts without significant drift

The KCRV x_{ref} for each loop (denoted by subscript A and B) is calculated with the following equations [8].

$$x_{\mathrm{ref,\,A}} = \frac{b \cdot S_1 + c \cdot S_2}{a \cdot b - c^2} \tag{6}$$

$$x_{\mathrm{ref,\,B}} = \frac{c \cdot S_1 + a \cdot S_2}{a \cdot b - c^2} \tag{7}$$

The associated standard uncertainties and the covariance are:

$$u(x_{\mathrm{ref,\,A}}) = \sqrt{\frac{b}{a \cdot b - c^2}} \tag{8}$$

$$u(x_{\mathrm{ref,\,B}}) = \sqrt{\frac{a}{a \cdot b - c^2}} \tag{9}$$

$$u(x_{\mathrm{ref,\,A}}, x_{\mathrm{ref,\,B}}) = \frac{c}{a \cdot b - c^2} \tag{10}$$

The equations (5-9) make use of the following abbreviations

$$a = \sum_{\mathrm{A \setminus B}} \frac{1}{u^2(x_{\mathrm{A},i})} + \sum_{\mathrm{A \cap B}} \frac{u^2(x_{\mathrm{B},i})}{u^2(x_{\mathrm{A},i})\,u^2(x_{\mathrm{B},i}) - u^2(x_{\mathrm{A},i}, x_{\mathrm{B},i})} \tag{11}$$

$$b = \sum_{\mathrm{B \setminus A}} \frac{1}{u^2(x_{\mathrm{B},i})} + \sum_{\mathrm{A \cap B}} \frac{u^2(x_{\mathrm{A},i})}{u^2(x_{\mathrm{A},i})\,u^2(x_{\mathrm{B},i}) - u^2(x_{\mathrm{A},i}, x_{\mathrm{B},i})} \tag{12}$$

$$c = \sum_{\mathrm{A \cap B}} \frac{u(x_{\mathrm{A},i}, x_{\mathrm{B},i})}{u^2(x_{\mathrm{A},i})\,u^2(x_{\mathrm{B},i}) - u^2(x_{\mathrm{A},i}, x_{\mathrm{B},i})} \tag{13}$$

$$S_1 = \sum_{\mathrm{A \setminus B}} \frac{x_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})} + \sum_{\mathrm{A \cap B}} \frac{u^2(x_{\mathrm{B},i})\, x_{\mathrm{A},i} - u(x_{\mathrm{A},i}, x_{\mathrm{B},i})\, x_{\mathrm{B},i}}{u^2(x_{\mathrm{A},i})\, u^2(x_{\mathrm{B},i}) - u^2(x_{\mathrm{A},i}, x_{\mathrm{B},i})} \tag{14}$$

$$S_2 = \sum_{\mathrm{B}\setminus\mathrm{A}} \frac{x_{\mathrm{B},i}}{u^2(x_{\mathrm{B},i})} + \sum_{\mathrm{A}\cap\mathrm{B}} \frac{u^2(x_{\mathrm{A},i})\, x_{\mathrm{B},i} - u(x_{\mathrm{A},i}, x_{\mathrm{B},i})\, x_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})\, u^2(x_{\mathrm{B},i}) - u^2(x_{\mathrm{A},i}, x_{\mathrm{B},i})} \tag{15}$$

The equations can be rewritten by substitution of the covariance by the correlation coefficient r and/or the uncertainty by the weight w:

$$r_i = \frac{u(x_{\mathrm{A},i}, x_{\mathrm{B},i})}{u(x_{\mathrm{A},i})\, u(x_{\mathrm{B},i})} \tag{16}$$

$$w_i = \frac{1}{u^2(x_i)} \tag{17}$$

It must be noted that for the calculation of the KCRV only the largest statistical consistent subset of the participant's results must be used. The determination of such subsets is exemplified in section 8.1.5.

8.1.2 Calculation of the KCRV for artefacts with significant drift

A KCRV with drift is modeled by a linear function in time t with two parameters (per loop) α and β. Here the subscript A, B for a quantity denotes either loop A or loop B, so we need to write only a single equation.

$$x_{\mathrm{ref\ (A,B)}} = \alpha_{\mathrm{A,B}} + \beta_{\mathrm{A,B}} \cdot t \tag{18}$$

The slope β and its standard uncertainty for each loop is calculated from the m stability measurements only (i.e. not including the participants data, j is running over the stability measurement results)

$$\beta_{\mathrm{A,B}} = \frac{\sum_{j=1}^{m} w_j \sum_{j=1}^{m} w_j x_j t_j - \sum_{i=1}^{m} w_j x_j \sum_{j=1}^{m} w_j t_j}{\sum_{j=1}^{m} w_j \sum_{j=1}^{m} w_j t_j^2 - \left(\sum_{j=1}^{m} w_j t_j \right)^2} \tag{19}$$

$$u(\beta_{\mathrm{A,B}}) = \sqrt{\frac{\sum_{j=1}^{m} w_j}{\sum_{j=1}^{m} w_j \sum_{j=1}^{m} w_j t_j^2 - \left(\sum_{j=1}^{m} w_j t_j \right)^2}} \tag{20}$$

Now by using the transformation of the participant's uncertainties and referencing the time of measurement to the central time (i is running over the participants results)

$$u^2\left(x_{(\mathrm{A,B}),i}\right) \rightarrow u^2\left(x_{(\mathrm{A,B}),i}\right) + u^2\left(\beta_{\mathrm{A,B}}\right)\left(t_{(\mathrm{A,B}),i} - \bar{t}_{\mathrm{A,B}}\right)^2 \tag{21}$$

$$\bar{t}_{\mathrm{A,B}} = \frac{1}{n} \sum_{i=1}^{n} t_{(\mathrm{A,B}),i} \tag{22}$$

The purpose of the time transformation is to make α independent of β. The use of the arithmetic mean (22) is only valid if all uncertainties are equal which is (almost) the case here. The equations (5-9) can formally be reused to obtain the constant parameter of (18)

$$\alpha_{\mathrm{A}} = \frac{b \cdot S_1 + c \cdot S_2}{a \cdot b - c^2} \tag{23}$$

$$\alpha_{\mathrm{B}} = \frac{c \cdot S_1 + a \cdot S_2}{a \cdot b - c^2} \tag{24}$$

$$u(\alpha_{\mathrm{A}}) = \sqrt{\frac{b}{a \cdot b - c^2}} \tag{25}$$

$$u(\alpha_{\mathrm{B}}) = \sqrt{\frac{a}{a \cdot b - c^2}}, \tag{26}$$

$$r_{\mathrm{AB}} = \frac{c}{\sqrt{a \cdot b}}, \tag{27}$$

Where a, b, c are calculated according to equations (11-13) but with S_1 and S_2 modified as follows (With t referenced to the respective mean time according to equation (22)):

$$\begin{aligned} S_1 = {} & \sum_{i \in \mathrm{A/B}} \frac{x_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})} - \sum_{i \in \mathrm{A/B}} \frac{\beta_{\mathrm{A}} t_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})} + \\ & \sum_{i \in \mathrm{B} \cap \mathrm{A}} \frac{1}{1 - r_{\mathrm{AB},i}^2} \left(\frac{x_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})} - r_{\mathrm{AB},i} \frac{x_{\mathrm{B},i}}{u(x_{\mathrm{A},i}) u(x_{\mathrm{B},i})} - \frac{\beta_{\mathrm{A}} t_{\mathrm{A},i}}{u^2(x_{\mathrm{A},i})} + r_{\mathrm{AB},i} \frac{\beta_{\mathrm{B}} t_{\mathrm{B},i}}{u(x_{\mathrm{A},i}) u(x_{\mathrm{B},i})} \right) \end{aligned} \tag{28}$$

$$\begin{aligned} S_2 = {} & \sum_{i \in \mathrm{B/A}} \frac{x_{\mathrm{B},i}}{u^2(x_{\mathrm{B},i})} - \sum_{i \in \mathrm{B/A}} \frac{\beta_{\mathrm{B}} t_{\mathrm{B},i}}{u^2(x_{\mathrm{B},i})} + \\ & \sum_{i \in \mathrm{B} \cap \mathrm{A}} \frac{1}{1 - r_{\mathrm{AB},i}^2} \left(\frac{x_{\mathrm{B},i}}{u^2(x_{\mathrm{B},i})} - r_{\mathrm{AB},i} \frac{x_{\mathrm{A},i}}{u(x_{\mathrm{A},i}) u(x_{\mathrm{B},i})} - \frac{\beta_{\mathrm{B}} t_{\mathrm{B},i}}{u^2(x_{\mathrm{B},i})} + r_{\mathrm{AB},i} \frac{\beta_{\mathrm{A}} t_{\mathrm{A},i}}{u(x_{\mathrm{A},i}) u(x_{\mathrm{B},i})} \right) \end{aligned} \tag{29}$$

8.1.3 Correlation coefficients for linking laboratories

As can be seen in the equations above it is essential to estimate the covariance or correlation coefficients of analogous measurement results (for both loops) of each linking laboratory. In past comparisons [9] this was done by combining the sample covariance according to (30) with the uncertainties stated by the laboratories.

$$u(x_{\mathrm{A},i}, x_{\mathrm{B},i}) = \left(x_{\mathrm{A},i} - \frac{1}{n} \sum_{j \in \mathrm{A} \cap \mathrm{B}} x_{\mathrm{A},j} \right) \left(x_{\mathrm{B},i} - \frac{1}{n} \sum_{j \in \mathrm{A} \cap \mathrm{B}} x_{\mathrm{B},j} \right) \tag{30}$$

Correlation coefficients must comply with $-1 \le r \le +1$. Moreover in the current context one expects them to be positive since two measurements of the same laboratory always tend to be biased in the same direction. It was found that combining the sample covariance (30) with the stated standard uncertainties (which are not obtained as sample variances) can yield implausible values. Consequently the application of equations above would not have been possible. Therefore a scientifically more warrantable technique was used to estimate the correlation coefficients.

The correlation between two measurements on different artefacts of the same laboratory may be modeled by two types of influence quantities. The first type can be considered as constant between the measurements, whilst the other type is not. Examples of the first type are traceability influences for the sensors (as long as they have not been recalibrated between the measurements), approximations for the length evaluation, and – most important – the method of correcting the roughness/phase change effect.

Provided one knows the contribution $u_C(x)$ of this influence quantity type to the overall uncertainty $u(x)$ the correlation coefficient can easily be calculated as

$$r = \frac{u_C^2(x)}{u_1(x) \cdot u_2(x)} \tag{31}$$

Often the overall uncertainties of the two measurements (of the same laboratory) are equal thus simplifying the expression even more

$$r = \frac{u_C^2(x)}{u^2(x)} \tag{32}$$

Since $u_C(x) < u(x)$ by definition the correlation coefficient is always less than 1 and because of the squares it is never negative.

The standard uncertainties $u(x)$ are reported but $u_C(x)$ are only known by the experts. At least for the pilot and linking lab (BEV) it is possible to estimate this value. For BEV the dominant constant uncertainty contribution is caused by the roughness correction. The contribution $u_C(x)$ = 6,5 nm gives r = 0,2 for gauge blocks up to 100 mm ($u(x)$ = 15 nm). The correlation coefficient decreases for longer blocks (0,1 for 150 mm and nearly 0 for 300 mm and 500 mm).

For the two remaining linking laboratories (METAS, MIKES) no explicit information is given but expert knowledge allows one to roughly estimate the correlation coefficient. For this comparison two numerical values for r are used for all three linking labs:

r = 0,2 for gauge blocks up to 100 mm

r = 0,1 for gauge blocks larger than 100 mm

Despite of the theoretical background discussed, the actual values are somewhat artificial. Therefore the influence on the reference values and the E_n-values was checked by variation of r between 0,0 and 0,9. Although the reference values can change by a few nm, the E_n-values stay virtually unaffected. Most important the pattern of $E_n > 1$ and excluded labs did not change at all. For the evaluation the correlation coefficients as discussed above are used.

8.1.4 <u>Degree of Equivalence (DoE)</u>

The deviation of each laboratory’s s result is simply

$$d_i = x_i - x_{\mathrm{ref}} \tag{33}$$

Its standard uncertainty is given by

$$u(d_i)=\sqrt{u^2(x_i)-u^2(x_{\mathrm{ref}})} \quad \text{for results contributing to the KCRV} \tag{34}$$

The minus sign under the square root originates from the correlation of laboratory's result x_i with the KCRV x_{ref} as defined in the preceding sections. In case a laboratory does not contribute to the KCRV (because its result is found to be inconsistent according to section 8.1.5) no correlation is expected and the standard uncertainty evaluates to:

$$u(d_i)=\sqrt{u^2(x_i)+u^2(x_{\mathrm{ref}})} \quad \text{for results not contributing to the KCRV} \tag{35}$$

In any case both, x_{ref} and $u(x_{\mathrm{ref}})$, might be time dependent as exemplified in 8.1.2.

For each laboratory's result the E_{n} value is calculated, where E_{n} is defined here as the absolute ratio of the deviation from the KCRV, divided by the expanded uncertainty of this deviation

$$E_{\mathrm{n}}=\left|\frac{d_i}{U(d_i)}\right| \tag{36}$$

As discussed in 5.4.1 the expanded uncertainty is obtained from the standard uncertainty by multiplication by k = 2. Prior to presentation and use the E_{n} value is rounded to one decimal place. The absolute value is used as a simplification in data presenting since the sign is anyway never used for evaluation.

8.1.5 Statistical consistency

For the determination of the key comparison reference value KCRV, statistical consistency of the results contributing to the KCRV is required. A check for statistical consistency of the results with their associated uncertainties can be made by the so-called Birge ratio R_{B} which compares the observed spread of the results with the spread expected from the individual reported uncertainties. Note: The subscript "B" here is derived from "Birge" and does not denote a loop. All equations in this section must be considered as "twofold" (one for each loop).

The application of least squares algorithms and the χ^2-test leads to the Birge ratio

$$R_{\mathrm{B}}=\frac{u_{\mathrm{ext}}(x_{\mathrm{ref}})}{u(x_{\mathrm{ref}})} \tag{37}$$

Where $u(x_{\mathrm{ref}})$ is defined above and $u_{\mathrm{ext}}(x_{\mathrm{ref}})$ is the external standard deviation

$$u_{\mathrm{ext}}(x_{\mathrm{ref}})=\sqrt{\frac{\sum_{i=1}^{N} w_i (x_i - x_{\mathrm{ref}})^2}{(N-1)\cdot\sum_{i=1}^{N} w_i}} \tag{38}$$

Here N denotes the number of laboratories. The Birge ratio has an expectation value of R_{B} = 1, when considering standard uncertainties. For a coverage factor of k = 2, the expectation value is increased and the data in a comparison are consistent provided that

$$R_B < \sqrt{1+\sqrt{\frac{8}{N-1}}} \tag{39}$$

If statistical consistency according to equation (39) is not given, the result with the largest E_n calculated according to section 8.1.3 is identified and excluded from the reference value and R_B is calculated again, now with N reduced by 1. This process of excluding the result with the largest E_n from contributing to the KCRV is iterated until statistical consistency is reached.

Because inconsistent results excluded by this technique are no longer correlated with the KCRV, when calculating their E_n value, equation (35) has to be used for determining $u(d_i)$.

8.1.6 Compilation of reference values

Table 6 sums up the reference values found by the evaluation discussed in this section. The time dependent KCRVs are tabulated for selected periods in Appendix B.

Table 6. KCRV for the gauge blocks for the two loops. Entries highlighted in red have a time dependent KCRV. The time t is expressed in units of period (see 3.2). In this case the standard uncertainty is time dependent, too. Only the minimum value is presented in the table.

Class	Nominal length / mm	Reference value (standard uncertainty) / nm	
		Loop A	Loop B
short, steel	0,5	−3,8 (3,5)	+34,8 (3,2)
	1,15	−44,5 (3,2)	+25,2 (3,1)
	3	+56,1 (3,1)	+25,5 (3,3)
	5	+21,7 (3,1)	−70,1 (3,1)
	7	−103,2 (3,2)	+34,4 (3,2)
	23,5	−99,6 (3,6)	+134,8 (3,4)
	80	−244,1 (5,3)	−332,4 (4,6)
	100	−485,3 – 5,11·t (6,0)	−675,5 – 6,05·t (5,7)
short, ceramic	0,5	+48,6 (3,3)	+64,7 (3,1)
	1,15	+135,2 (3,3)	+131,3 (3,2)
	3	+83,5 (3,3)	+49,1 (3,4)
	5	+79,0 (3,3)	+52,7 (3,2)
	7	−130,5 (3,5)	+76,4 (3,3)
	23,5	+41,8 (3,7)	+43,1 (3,3)
	80	+158,9 (5,2)	+133,7 (4,7)
	100	−10,8 (5,6)	+330,1 (5,2)
long, steel	150	−86,7 – 3,76·t (9,9)	+248,2 – 3,53·t (7,4)
	300	−7601,2 – 1,83·t (13,7)	−8306,8 – 3,55·t (10,5)
	500	+646,4 – 4,49·t (19,8)	+1364,8 – 6,18·t (14,6)

8.2 Calculation of the reference value for the auxiliary measurand d_c

The uncertainty claims for this measurand reported by the participants were quite heterogeneous and some didn't state an uncertainty at all. The reference value used here is just the arithmetic mean; its sample standard deviation is used as a measure for the reference value's uncertainty. The mean value is taken from all results as reported. This means that also results which are considered as outliers according to the evaluation for the principal measurand (section 8.1) are taken into account. Equations

(40) and (41) are considered on a per gauge block basis, the index i numerates participants. The results are summarized in Table 7.

$$d_{\mathrm{c}}^{\mathrm{ref}} = \frac{1}{n}\sum_{i}^{n} d_{\mathrm{c},i} \quad (40)$$

$$s\left(d_{\mathrm{c}}^{\mathrm{ref}}\right) = \sqrt{\frac{1}{n-1}\sum_{i}^{n}\left(d_{\mathrm{c},i} - d_{\mathrm{c}}^{\mathrm{ref}}\right)^2} \quad (41)$$

The results as presented in table 7 provide no indication for a significant asymmetry.

Table 7. Reference values for the auxiliary measurand d_{c} with standard deviation (not uncertainty).

Class	Nominal length / mm	Reference value (standard deviation) / nm	
		Loop A	Loop B
short, steel	0,5	−0,3 (5,8)	−4,1 (6,1)
	1,15	+2,2 (9,9)	−1,5 (6,2)
	3	−1,7 (7,4)	−2,8 (6,5)
	5	+1,3 (8,0)	+2,3 (7,7)
	7	−1,8 (9,5)	+0,0 (8,0)
	23,5	+2,2 (8,6)	−7,6 (11,0)
	80	+1,3 (8,6)	−6,0 (6,7)
	100	+0,2 (19,2)	+9,8 (11,4)
short, ceramic	0,5	−0,2 (3,1)	−2,6 (5,1)
	1,15	+1,0 (7,3)	−1,0 (4,2)
	3	+0,1 (7,1)	+0,0 (3,2)
	5	+5,7 (8,8)	+0,2 (6,4)
	7	−0,1 (5,7)	−0,8 (4,8)
	23,5	+3,1 (8,0)	+2,4 (4,9)
	80	+0,4 (12,0)	+0,9 (11,9)
	100	+3,7 (13,4)	−2,8 (20,8)
long, steel	150	+10,0 (17,5)	−0,8 (20,9)
	300	+7,9 (10,2)	+46,0 (88,1)
	500	+1,3 (14,6)	+7,3 (10,3)

9 Results, Reference values and degrees of Equivalence

9.1 The principal measurand e_{c}

In the following an extract of the Excel table `EURAMET.L-K1.2011-results.xls` is given for each nominal length (both loops). The sheets include the results as reported by the participants, reference values, degree of equivalence, Birge ratios, and information on the artifact drift. The graphs present the deviation from the reference value d_i together with the expanded uncertainties $U(d_i)$ (via error bars). A few results are very far off the reference value and can not be displayed in the diagram. The sequence of the laboratories as displayed is not in chronological order. Linking laboratories are in the blue shaded region.

Depending on the technique of the evaluation (8.1.1 versus 8.1.2) two different layouts are used, identified by "simple" or "linear drift" in the upper right corner. Laboratories excluded according to section 8.1.5 are marked by "excluded" in the info column. E_n-values larger than 1 are marked in red.

INRIM and MKEH were removed from all tables since they did not report results (see section 3.2).

0,5 mm steel

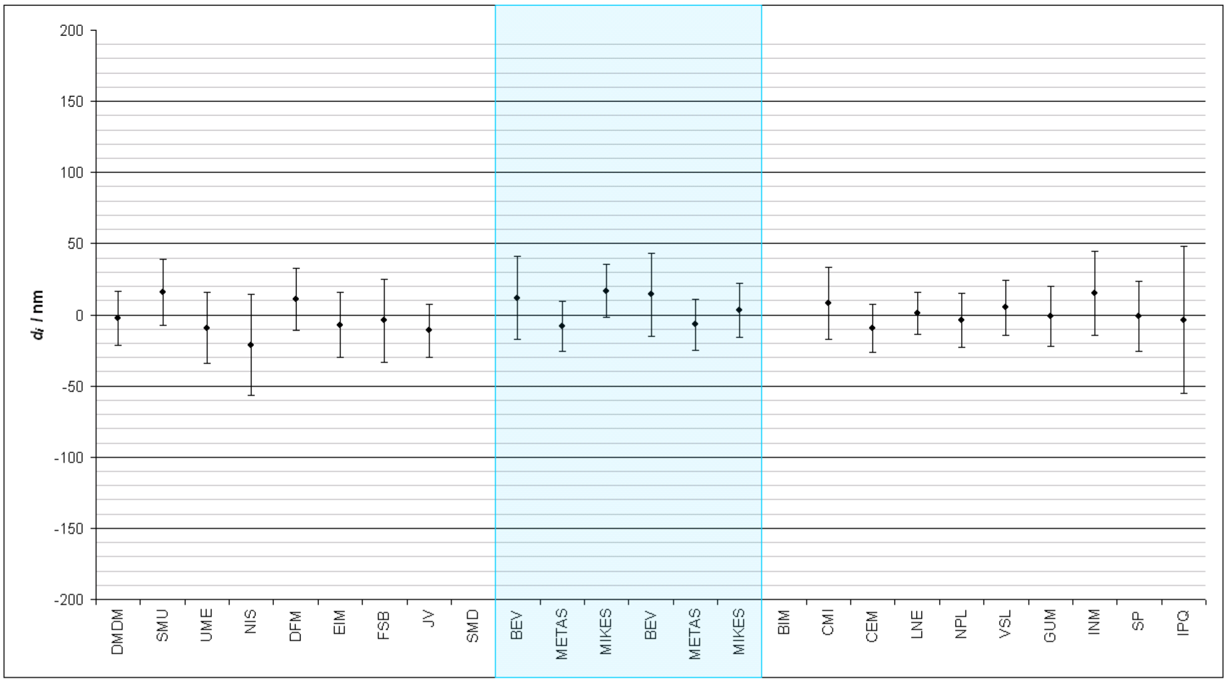
simple

Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-6,0	10,1	-2,2	9,5	18,9	0,1	
SMU	12,0	12,0	15,8	11,5	22,9	0,7	
UME	-13,0	13,0	-9,2	12,5	25,0	0,4	
NIS	-25,0	18,0	-21,2	17,7	35,3	0,6	
DFM	7,0	11,5	10,8	11,0	21,9	0,5	
EIM	-11,0	12,0	-7,2	11,5	22,9	0,3	
FSB	-8,0	15,0	-4,2	14,6	29,2	0,1	
JV	-15,0	10,0	-11,2	9,4	18,7	0,6	
SMD	-	-	-	-	-	-	not measured
BEV	8,0	15,0	11,8	14,6	29,2	0,4	
METAS	-12,0	9,5	-8,2	8,8	17,7	0,5	
MIKES	13,0	10,0	16,8	9,4	18,7	0,9	
BEV	49,0	15,0	14,2	14,7	29,3	0,5	
METAS	28,0	9,5	-6,8	9,0	17,9	0,4	
MIKES	38,0	10,0	3,2	9,5	19,0	0,2	
BIM	-	-	-	-	-	-	not measured
CMI	43,0	13,0	8,2	12,6	25,2	0,3	
CEM	25,0	9,0	-9,8	8,4	16,9	0,6	
LNE	36,0	8,0	1,2	7,3	14,7	0,1	
NPL	31,0	10,0	-3,8	9,5	19,0	0,2	
VSL	40,0	10,2	5,2	9,7	19,4	0,3	
GUM	34,0	11,0	-0,8	10,5	21,1	0,0	
INM	50,0	15,0	15,2	14,7	29,3	0,5	
SP	34,0	12,7	-0,8	12,3	24,6	0,0	
IPQ	31,1	26,0	-3,8	25,8	51,6	0,1	

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-3,8	3,5
Loop B	34,8	3,2
r_{AB}		0,06

N	11	Loop A
Birge ratio	1,02	
N	12	Loop B
Birge ratio	0,65	

Regression			
			Loop A
α	12,21	14,75	
β	-1,79	2,81	NO DRIFT
			Loop B
α	45,99	13,89	
β	0,31	2,25	NO DRIFT



1,15 mm steel

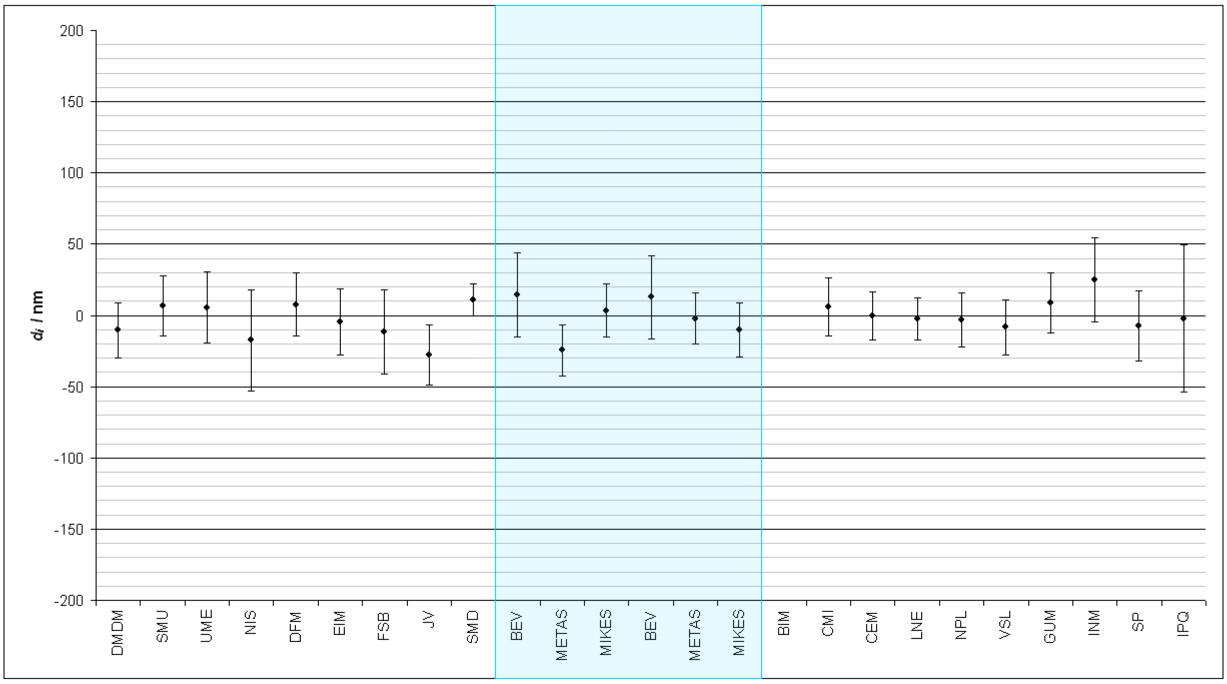
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-55,0	10,1	-10,5	9,6	19,1	0,5	
SMU	-38,0	11,0	6,5	10,5	21,0	0,3	
UME	-39,0	13,0	5,5	12,6	25,2	0,2	
NIS	-62,0	18,0	-17,5	17,7	35,4	0,5	
DFM	-37,0	11,5	7,5	11,0	22,1	0,3	
EIM	-49,0	12,0	-4,5	11,6	23,1	0,2	
FSB	-56,0	15,0	-11,5	14,6	29,3	0,4	
JV	-72,0	10,0	-27,5	10,5	21,0	1,3	excluded
SMD	-33,5	6,5	11,0	5,6	11,3	1,0	
BEV	-30,0	15,0	14,5	14,6	29,3	0,5	
METAS	-69,0	9,5	-24,5	8,9	17,9	1,4	
MIKES	-41,0	10,0	3,5	9,5	18,9	0,2	
BEV	38,0	15,0	12,8	14,7	29,3	0,4	
METAS	23,0	9,5	-2,2	9,0	17,9	0,1	
MIKES	15,0	10,0	-10,2	9,5	19,0	0,5	
BIM	-	-	-	-	-	-	not measured
CMI	31,0	10,7	5,8	10,2	20,5	0,3	
CEM	25,0	9,0	-0,2	8,4	16,9	0,0	
LNE	23,0	8,0	-2,2	7,4	14,7	0,2	
NPL	22,0	10,0	-3,2	9,5	19,0	0,2	
VSL	17,0	10,2	-8,2	9,7	19,4	0,4	
GUM	34,0	11,0	8,8	10,5	21,1	0,4	
INM	50,0	15,0	24,8	14,7	29,3	0,8	
SP	18,0	12,7	-7,2	12,3	24,6	0,3	
IPQ	23,0	26,0	-2,2	25,8	51,6	0,0	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-44,5	3,2
Loop B	25,2	3,1
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,19	
N	12	Loop B
Birge ratio	0,78	

Regression			
			Loop A
α	-13,66	14,20	
β	-1,43	2,70	NO DRIFT
			Loop B
α	36,09	13,89	
β	0,34	2,25	NO DRIFT



Note: METAS has a higher E_n-value than the excluded JV. This is a consequence of the algorithm discussed in section 8.1.5. Before exclusion JV had the highest E_n-value.

3 mm steel

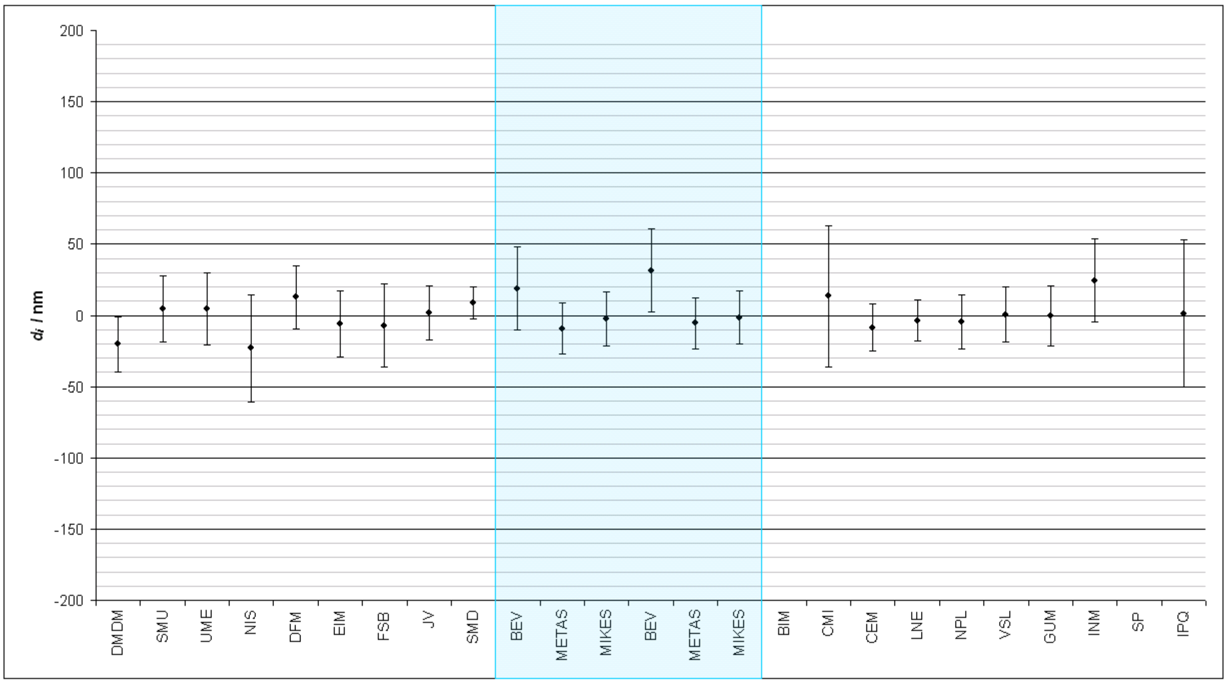
simple

Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	36,0	10,1	-20,1	9,6	19,2	1,0	
SMU	61,0	12,0	4,9	11,6	23,2	0,2	
UME	61,0	13,0	4,9	12,6	25,3	0,2	
NIS	33,0	19,0	-23,1	18,7	37,5	0,6	
DFM	69,0	11,5	12,9	11,1	22,2	0,6	
EIM	50,0	12,0	-6,1	11,6	23,2	0,3	
FSB	49,0	15,0	-7,1	14,7	29,4	0,2	
JV	58,0	10,0	1,9	9,5	19,0	0,1	
SMD	65,1	6,5	9,0	5,7	11,4	0,8	
BEV	75,0	15,0	18,9	14,7	29,4	0,6	
METAS	47,0	9,5	-9,1	9,0	18,0	0,5	
MIKES	54,0	10,0	-2,1	9,5	19,0	0,1	
BEV	57,0	15,0	31,5	14,6	29,2	1,1	
METAS	20,0	9,5	-5,5	8,9	17,8	0,3	
MIKES	24,0	10,0	-1,5	9,4	18,9	0,1	
BIM	-	-	-	-	-	-	not measured
CMI	39,0	25,1	13,5	24,9	49,8	0,3	
CEM	17,0	9,0	-8,5	8,4	16,7	0,5	
LNE	22,0	8,0	-3,5	7,3	14,5	0,2	
NPL	21,0	10,0	-4,5	9,4	18,9	0,2	
VSL	26,0	10,2	0,5	9,6	19,3	0,0	
GUM	25,0	11,0	-0,5	10,5	21,0	0,0	
INM	50,0	15,0	24,5	14,6	29,2	0,8	
SP	-	-	-	-	-	-	not measured
IPQ	26,8	26,0	1,2	25,8	51,6	0,0	

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	56,1	3,1
Loop B	25,5	3,3
r_{AB}		0,05

N	12	Loop A
Birge ratio	1,04	
N	11	Loop B
Birge ratio	0,95	

Regression			
			Loop A
α	79,11	13,89	
β	-1,09	2,05	NO DRIFT
			Loop B
α	44,93	13,89	
β	0,08	2,25	NO DRIFT



5 mm steel

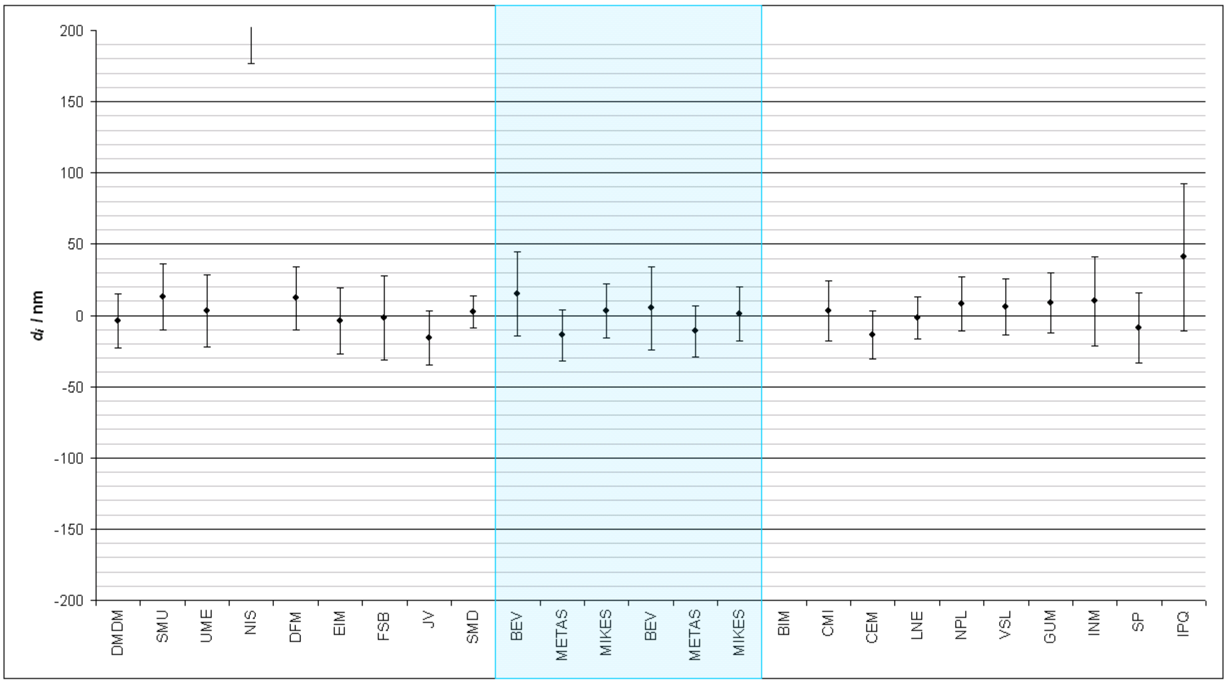
simple

Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	18,0	10,1	-3,7	9,6	19,2	0,2	
SMU	35,0	12,0	13,3	11,6	23,2	0,6	
UME	25,0	13,0	3,3	12,6	25,2	0,1	
NIS	237,0	19,0	215,3	19,3	38,5	5,6	excluded
DFM	34,0	11,5	12,3	11,1	22,1	0,6	
EIM	18,0	12,0	-3,7	11,6	23,2	0,2	
FSB	20,0	15,0	-1,7	14,7	29,3	0,1	
JV	6,0	10,1	-15,7	9,6	19,2	0,8	
SMD	24,1	6,5	2,4	5,7	11,4	0,2	
BEV	37,0	15,0	15,3	14,7	29,3	0,5	
METAS	8,0	9,5	-13,7	9,0	17,9	0,8	
MIKES	25,0	10,0	3,3	9,5	19,0	0,2	
BEV	-65,0	15,0	5,1	14,7	29,3	0,2	
METAS	-81,0	9,5	-10,9	9,0	17,9	0,6	
MIKES	-69,0	10,0	1,1	9,5	19,0	0,1	
BIM	-	-	-	-	-	-	not measured
CMI	-67,0	11,0	3,1	10,5	21,1	0,1	
CEM	-84,0	9,0	-13,9	8,4	16,9	0,8	
LNE	-72,0	8,0	-1,9	7,4	14,7	0,1	
NPL	-62,0	10,0	8,1	9,5	19,0	0,4	
VSL	-64,0	10,2	6,1	9,7	19,4	0,3	
GUM	-61,0	11,0	9,1	10,5	21,1	0,4	
INM	-60,0	16,0	10,1	15,7	31,4	0,3	
SP	-79,0	12,7	-8,9	12,3	24,6	0,4	
IPQ	-29,0	26,0	41,1	25,8	51,6	0,8	

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	21,7	3,1
Loop B	-70,1	3,1
r_{AB}		0,05

N	11	Loop A
Birge ratio	0,92	
N	12	Loop B
Birge ratio	0,91	

Regression			
			Loop A
α	37,41	14,10	
β	-0,55	2,26	NO DRIFT
			Loop B
α	-69,92	13,89	
β	0,65	2,25	NO DRIFT



7 mm steel

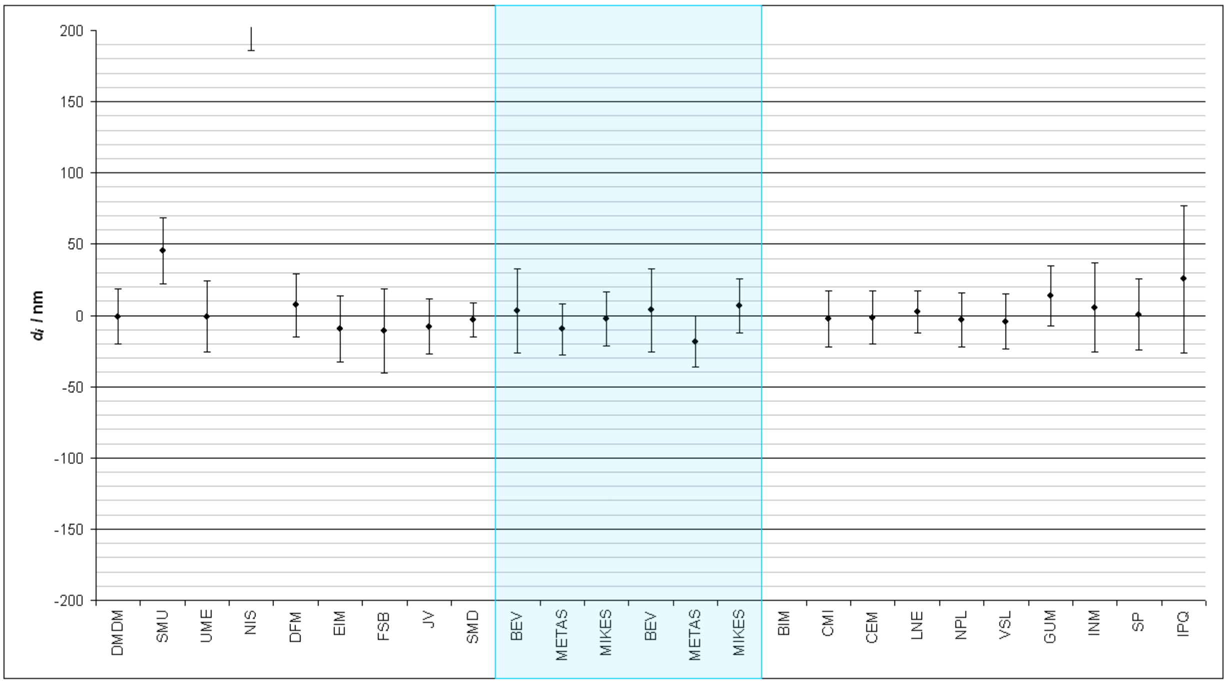
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-104,0	10,1	-0,8	9,6	19,2	0,0	
SMU	-58,0	12,0	45,2	11,6	23,1	2,0	
UME	-104,0	13,0	-0,8	12,6	25,2	0,0	
NIS	123,0	20,0	226,2	20,3	40,5	5,6	excluded
DFM	-96,0	11,5	7,2	11,1	22,1	0,3	
EIM	-113,0	12,0	-9,8	11,6	23,1	0,4	
FSB	-114,0	15,0	-10,8	14,7	29,3	0,4	
JV	-111,0	10,1	-7,8	9,6	19,2	0,4	
SMD	-106,2	6,8	-3,0	6,0	12,0	0,2	
BEV	-100,0	15,0	3,2	14,7	29,3	0,1	
METAS	-113,0	9,5	-9,8	9,0	17,9	0,5	
MIKES	-106,0	10,0	-2,8	9,5	19,0	0,1	
BEV	38,0	15,0	3,6	14,7	29,3	0,1	
METAS	16,0	9,5	-18,4	9,0	17,9	1,0	
MIKES	41,0	10,0	6,6	9,5	19,0	0,3	
BIM	-	-	-	-	-	-	not measured
CMI	32,0	10,4	-2,4	9,9	19,8	0,1	
CEM	33,0	10,0	-1,4	9,5	19,0	0,1	
LNE	37,0	8,1	2,6	7,5	14,9	0,2	
NPL	31,0	10,0	-3,4	9,5	19,0	0,2	
VSL	30,0	10,2	-4,4	9,7	19,4	0,2	
GUM	48,0	11,0	13,6	10,5	21,1	0,6	
INM	40,0	16,0	5,6	15,7	31,4	0,2	
SP	35,0	12,8	0,6	12,4	24,8	0,0	
IPQ	59,8	26,0	25,4	25,8	51,6	0,5	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-103,2	3,2
Loop B	34,4	3,2
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,33	
N	12	Loop B
Birge ratio	0,82	

Regression			
			Loop A
α	-98,11	13,89	
β	-0,39	2,05	NO DRIFT
			Loop B
α	32,47	13,89	
β	0,19	2,25	NO DRIFT



23,5 mm steel

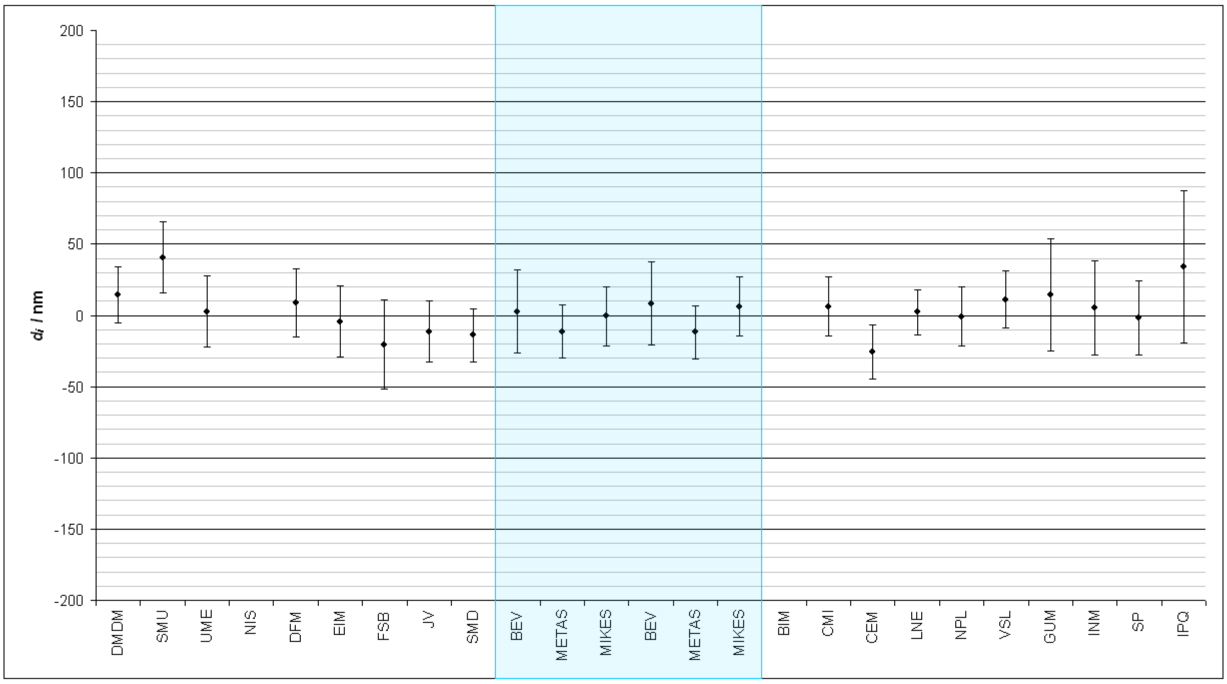
simple

Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-85,0	10,4	14,6	9,8	19,5	0,7	
SMU	-59,0	13,0	40,6	12,5	25,0	1,6	
UME	-97,0	13,0	2,6	12,5	25,0	0,1	
NIS	-542,0	24,0	-442,4	24,3	48,5	9,1	excluded
DFM	-91,0	12,5	8,6	12,0	24,0	0,4	
EIM	-104,0	13,0	-4,4	12,5	25,0	0,2	
FSB	-120,0	16,0	-20,4	15,6	31,2	0,7	
JV	-111,0	11,3	-11,4	10,7	21,4	0,5	
SMD	-113,6	9,9	-14,0	9,2	18,5	0,8	
BEV	-97,0	15,0	2,6	14,6	29,1	0,1	
METAS	-111,0	10,0	-11,4	9,3	18,7	0,6	
MIKES	-100,0	11,0	-0,4	10,4	20,8	0,0	
BEV	143,0	15,0	8,2	14,6	29,2	0,3	
METAS	123,0	10,0	-11,8	9,4	18,8	0,6	
MIKES	141,0	11,0	6,2	10,5	20,9	0,3	
BIM	-	-	-	-	-	-	not measured
CMI	141,0	10,9	6,2	10,3	20,7	0,3	
CEM	109,0	10,0	-25,8	9,4	18,8	1,4	
LNE	137,0	8,7	2,2	8,0	16,0	0,1	
NPL	134,0	11,0	-0,8	10,5	20,9	0,0	
VSL	146,0	10,5	11,2	9,9	19,9	0,6	
GUM	149,0	20,0	14,2	19,7	39,4	0,4	
INM	140,0	17,0	5,2	16,7	33,3	0,2	
SP	133,0	13,5	-1,8	13,1	26,1	0,1	
IPQ	169,1	27,0	34,3	26,8	53,6	0,6	

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-99,6	3,6
Loop B	134,8	3,4
r_{AB}		0,06

N	11	Loop A
Birge ratio	1,35	
N	12	Loop B
Birge ratio	1,06	

Regression			
			Loop A
α	-97,52	12,36	
β	-0,08	2,33	NO DRIFT
			Loop B
α	136,41	13,89	
β	-0,15	2,25	NO DRIFT



80 mm steel

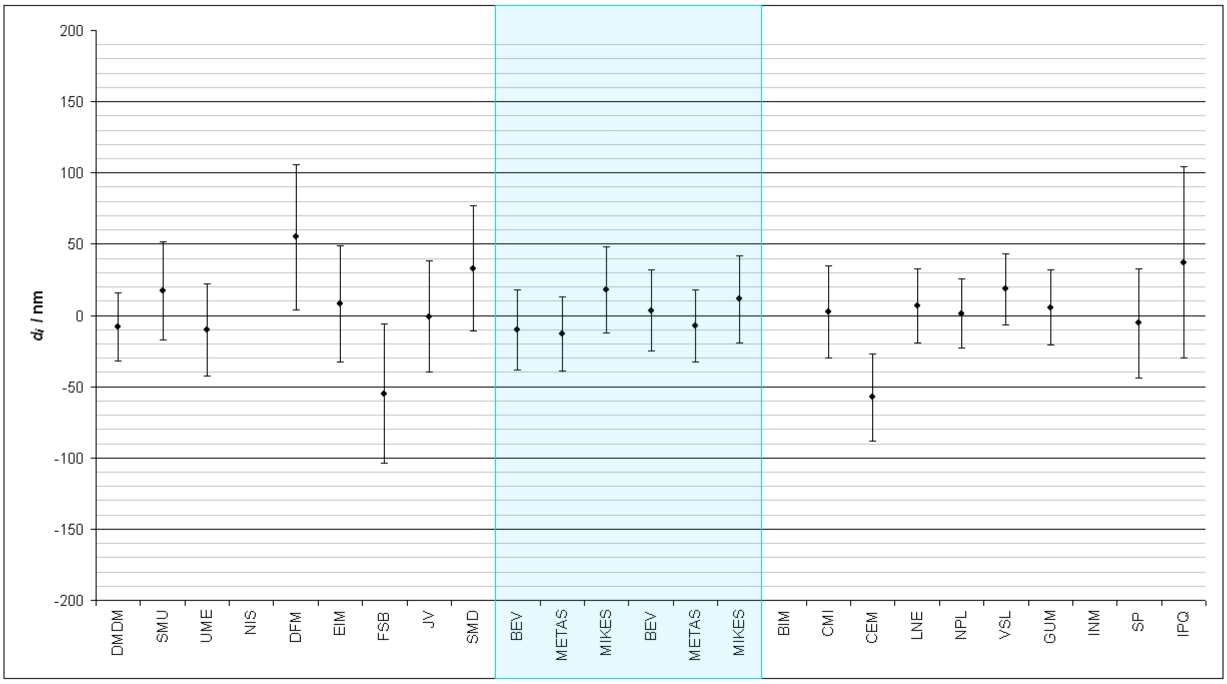
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-252,0	13,1	-7,9	12,0	24,0	0,3	
SMU	-227,0	18,0	17,1	17,2	34,4	0,5	
UME	-254,0	17,0	-9,9	16,2	32,3	0,3	
NIS	-	-	-	-	-	-	not measured
DFM	-189,0	26,0	55,1	25,5	50,9	1,0	
EIM	-236,0	21,0	8,1	20,3	40,7	0,2	
FSB	-299,0	25,0	-54,9	24,4	48,9	1,1	
JV	-245,0	20,2	-0,9	19,5	39,0	0,0	
SMD	-211,3	22,6	32,8	22,0	44,0	0,7	
BEV	-254,0	15,0	-9,9	14,0	28,1	0,3	
METAS	-257,0	14,0	-12,9	13,0	25,9	0,4	
MIKES	-226,0	16,0	18,1	15,1	30,2	0,5	
BEV	-329,0	15,0	3,4	14,3	28,5	0,1	
METAS	-340,0	13,5	-7,6	12,7	25,4	0,3	
MIKES	-321,0	16,0	11,4	15,3	30,6	0,3	
BIM	-	-	-	-	-	-	not measured
CMI	-330,0	16,9	2,4	16,3	32,5	0,1	
CEM	-390,0	16,0	-57,6	15,3	30,6	1,7	
LNE	-326,0	13,8	6,4	13,0	26,0	0,2	
NPL	-331,0	13,0	1,4	12,2	24,3	0,1	
VSL	-314,0	13,4	18,4	12,6	25,2	0,6	
GUM	-327,0	14,0	5,4	13,2	26,4	0,2	
INM	-30,0	29,0	302,4	28,6	57,3	5,1	excluded
SP	-338,0	19,8	-5,6	19,3	38,5	0,1	
IPQ	-295,2	34,0	37,2	33,7	67,4	0,5	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-244,1	5,3
Loop B	-332,4	4,6
r_{AB}		0,07

N	11	Loop A
Birge ratio	1,25	
N	11	Loop B
Birge ratio	1,32	

Regression			
			Loop A
α	-259,12	12,36	
β	0,78	2,33	NO DRIFT
			Loop B
α	-334,02	13,89	
β	0,52	2,25	NO DRIFT



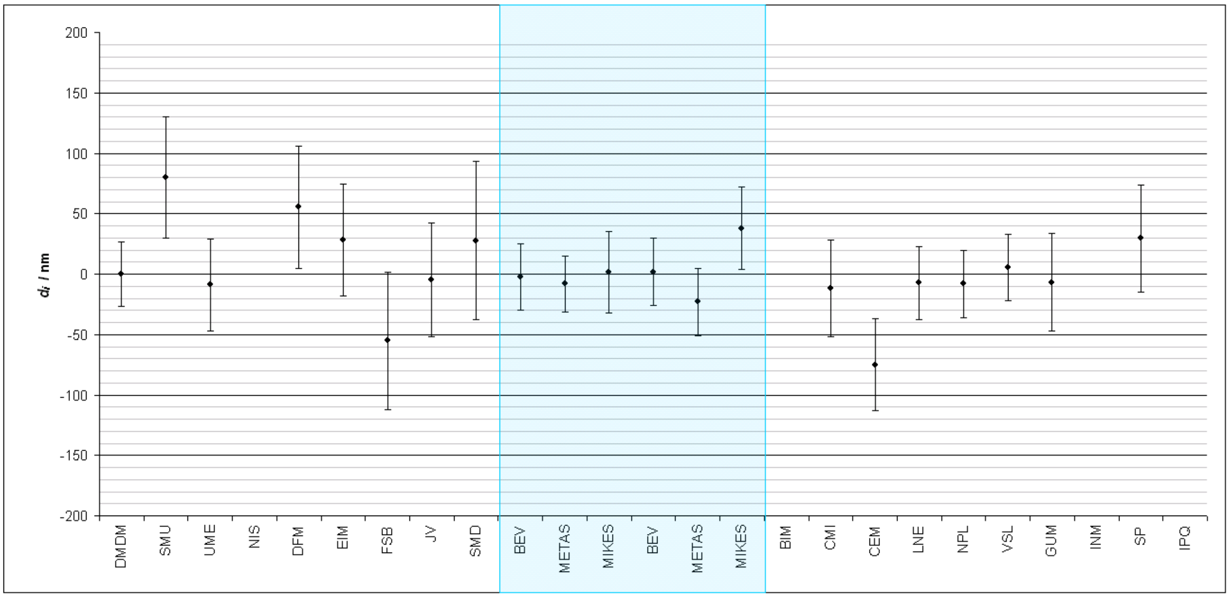
100 mm steel

linear drift

Laboratory	x_i /nm	$u(x_i)$ /nm	t_i / period	x_{ref} / nm	$u(x_{ref})$ / nm	d_i / nm	$u(d_i)$ /nm	$U(d_i)$ /nm	E_n	Info
DMDM	-544,0	14,6	11,5	-544,0	6,04	0,0	13,30	26,59	0,0	
SMU	-423,0	23,0	3,5	-503,2	8,44	80,2	25,20	50,40	1,6	excluded
UME	-558,0	20,0	12,5	-549,2	6,04	-8,8	19,07	38,14	0,2	
NIS	460,0	42,0	17,5	-574,7	7,11	1034,7	42,77	85,53	12,1	excluded
DFM	-527,0	26,0	19,0	-582,4	7,72	55,4	25,29	50,58	1,1	
EIM	-485,0	24,0	5,5	-513,4	7,54	28,4	23,23	46,46	0,6	
FSB	-594,0	29,0	10,5	-538,9	6,12	-55,1	28,37	56,73	1,0	
JV	-559,0	24,2	13,5	-554,3	6,11	-4,7	23,44	46,87	0,1	
SMD	-552,0	33,4	18,5	-579,8	7,50	27,8	32,85	65,70	0,4	
BEV	-526,0	15,0	7,5	-523,6	6,80	-2,4	13,73	27,47	0,1	
METAS	-542,0	13,0	9,5	-533,8	6,28	-8,2	11,52	23,03	0,4	
MIKES	-563,0	18,0	15,5	-564,5	6,49	1,5	16,96	33,92	0,0	
BEV	-719,0	15,0	7,5	-720,9	5,86	1,9	13,88	27,75	0,1	
METAS	-750,0	15,0	8,5	-726,9	5,73	-23,1	13,88	27,75	0,8	
MIKES	-659,0	18,0	3,5	-696,7	7,19	37,7	17,07	34,15	1,1	
BIM	-	-	-	-	-	-	-	-	-	not measured
CMI	-763,0	20,9	12,5	-751,2	6,17	-11,8	20,11	40,22	0,3	
CEM	-814,0	18,0	10,5	-739,0	5,77	-75,0	18,92	37,84	2,0	excluded
LNE	-722,0	16,1	6,5	-714,8	6,08	-7,2	15,06	30,12	0,2	
NPL	-741,0	15,0	9,5	-733,0	5,70	-8,0	13,88	27,75	0,3	
VSL	-697,0	14,9	4,5	-702,7	6,75	5,7	13,77	27,53	0,2	
GUM	-764,0	21,0	13,5	-757,2	6,50	-6,8	20,21	40,42	0,2	
INM	-390,0	33,0	14,5	-763,3	6,89	373,3	33,93	67,87	5,5	excluded
SP	-661,0	22,9	2,5	-690,6	7,67	29,6	22,18	44,36	0,7	
IPQ	-228,2	38,0	18,5	-787,5	8,93	559,3	39,64	79,27	7,2	excluded

N	10	Loop A
Birge ratio	1,09	
N	9	Loop B
Birge ratio	1,07	

	$\alpha_{A,B}$ / $\beta_{A,B}$	$u(\alpha_{A,B}$ / $\beta_{A,B})$
α_A	-485,30	6,03
β_A	-5,11	6,92E-01
α_B	-675,50	5,70
β_B	-6,05	7,50E-01



0,5 mm ceramic

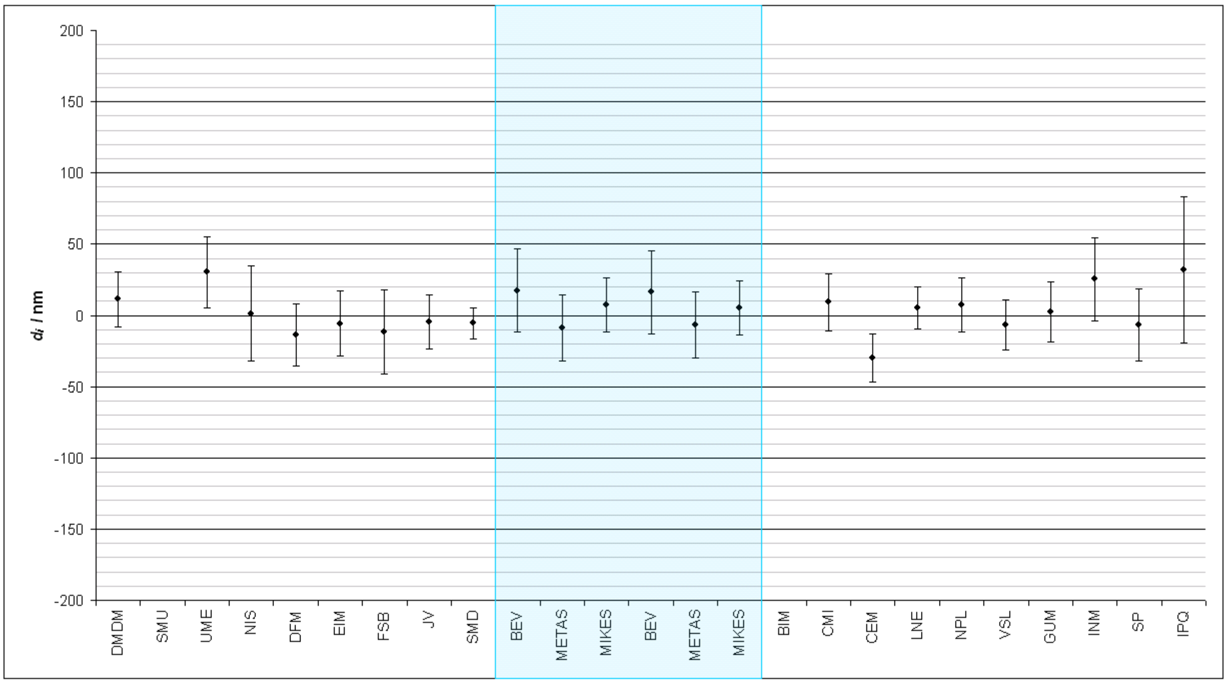
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	60,0	10,1	11,4	9,6	19,1	0,6	
SMU	-	-	-	-	-	-	not measured
UME	79,0	13,0	30,4	12,6	25,2	1,2	
NIS	50,0	17,0	1,4	16,7	33,4	0,0	
DFM	35,0	11,5	-13,6	11,0	22,1	0,6	
EIM	43,0	12,0	-5,6	11,6	23,1	0,2	
FSB	37,0	15,0	-11,6	14,6	29,3	0,4	
JV	44,0	10,0	-4,6	9,5	18,9	0,2	
SMD	43,2	6,4	-5,4	5,5	11,0	0,5	
BEV	66,0	15,0	17,4	14,6	29,3	0,6	
METAS	40,0	12,0	-8,6	11,6	23,1	0,4	
MIKES	56,0	10,0	7,4	9,5	18,9	0,4	
BEV	81,0	15,0	16,3	14,7	29,3	0,6	
METAS	58,0	12,0	-6,7	11,6	23,2	0,3	
MIKES	70,0	10,0	5,3	9,5	19,0	0,3	
BIM	-	-	-	-	-	-	not measured
CMI	74,0	10,5	9,3	10,0	20,0	0,5	
CEM	35,0	9,0	-29,7	8,4	16,9	1,8	
LNE	70,0	8,0	5,3	7,4	14,7	0,4	
NPL	72,0	10,0	7,3	9,5	19,0	0,4	
VSL	58,0	9,2	-6,7	8,6	17,3	0,4	
GUM	67,0	11,0	2,3	10,5	21,1	0,1	
INM	90,0	15,0	25,3	14,7	29,3	0,9	
SP	58,0	13,2	-6,7	12,8	25,6	0,3	
IPQ	96,7	26,0	32,0	25,8	51,6	0,6	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	48,6	3,3
Loop B	64,7	3,1
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,11	
N	12	Loop B
Birge ratio	1,34	

Regression			
			Loop A
α	71,06	12,99	
β	-0,26	1,54	NO DRIFT
			Loop B
α	91,72	12,99	
β	-0,60	1,54	NO DRIFT



1,15 mm ceramic

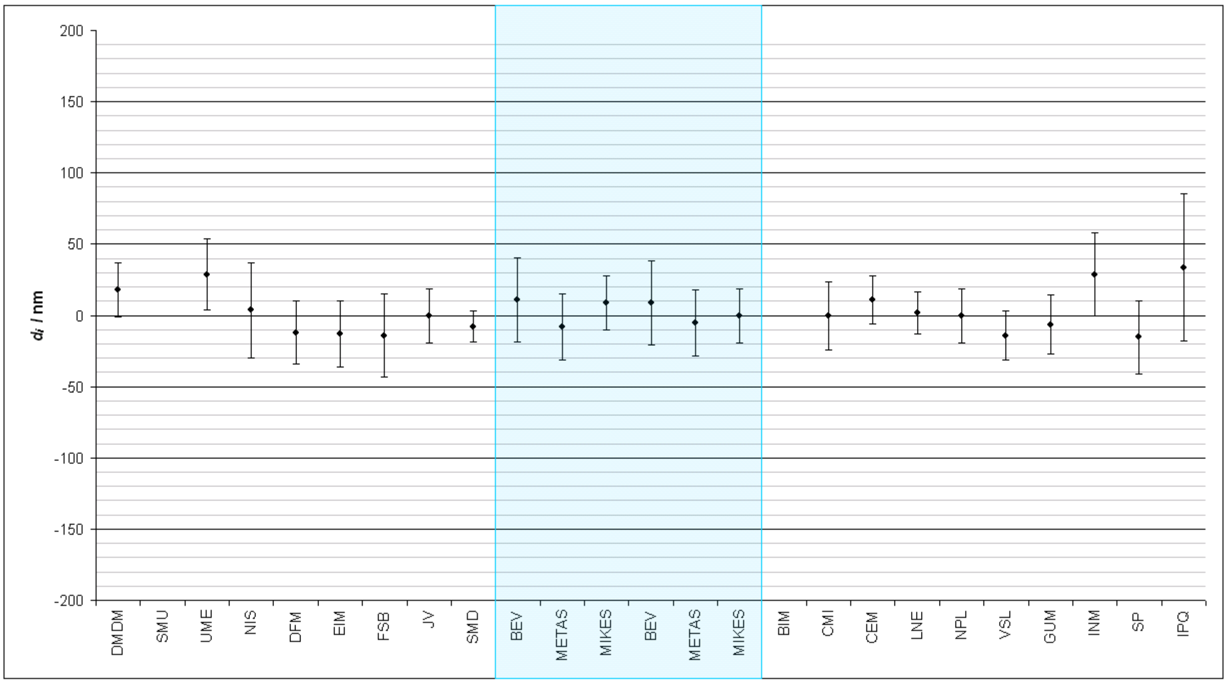
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	153,0	10,1	17,8	9,6	19,1	0,9	
SMU	-	-	-	-	-	-	not measured
UME	164,0	13,0	28,8	12,6	25,2	1,1	
NIS	139,0	17,0	3,8	16,7	33,4	0,1	
DFM	123,0	11,5	-12,2	11,0	22,1	0,6	
EIM	122,0	12,0	-13,2	11,6	23,1	0,6	
FSB	121,0	15,0	-14,2	14,6	29,3	0,5	
JV	135,0	10,0	-0,2	9,5	18,9	0,0	
SMD	127,3	6,4	-7,9	5,5	11,0	0,7	
BEV	146,0	15,0	10,8	14,6	29,3	0,4	
METAS	127,0	12,0	-8,2	11,6	23,1	0,4	
MIKES	144,0	10,0	8,8	9,5	18,9	0,5	
BEV	140,0	15,0	8,7	14,7	29,3	0,3	
METAS	126,0	12,0	-5,3	11,6	23,1	0,2	
MIKES	131,0	10,0	-0,3	9,5	19,0	0,0	
BIM	-	-	-	-	-	-	not measured
CMI	131,0	12,4	-0,3	12,0	24,0	0,0	
CEM	142,0	9,0	10,7	8,4	16,8	0,6	
LNE	133,0	8,0	1,7	7,3	14,7	0,1	
NPL	131,0	10,0	-0,3	9,5	19,0	0,0	
VSL	117,0	9,2	-14,3	8,6	17,3	0,8	
GUM	125,0	11,0	-6,3	10,5	21,1	0,3	
INM	160,0	15,0	28,7	14,7	29,3	1,0	
SP	116,0	13,2	-15,3	12,8	25,6	0,6	
IPQ	165,0	26,0	33,6	25,8	51,6	0,7	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	135,2	3,3
Loop B	131,3	3,2
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,21	
N	12	Loop B
Birge ratio	1,02	

Regression			
			Loop A
α	144,68	12,99	
β	0,11	1,54	NO DRIFT
			Loop B
α	144,82	12,99	
β	-0,41	1,54	NO DRIFT



3 mm ceramic

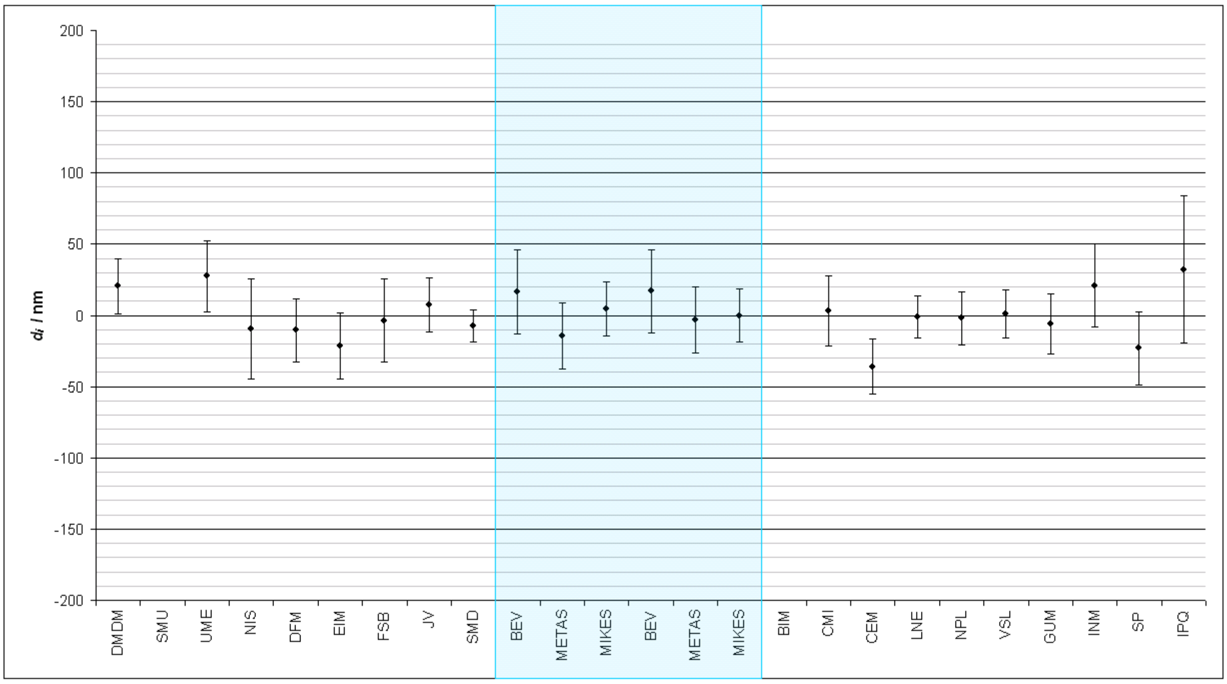
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	104,0	10,1	20,5	9,6	19,1	1,1	
SMU	-	-	-	-	-	-	not measured
UME	111,0	13,0	27,5	12,6	25,2	1,1	
NIS	74,0	18,0	-9,5	17,7	35,4	0,3	
DFM	73,0	11,5	-10,5	11,0	22,1	0,5	
EIM	62,0	12,0	-21,5	11,5	23,1	0,9	
FSB	80,0	15,0	-3,5	14,6	29,3	0,1	
JV	91,0	10,0	7,5	9,4	18,9	0,4	
SMD	76,3	6,5	-7,2	5,6	11,2	0,6	
BEV	100,0	15,0	16,5	14,6	29,3	0,6	
METAS	69,0	12,0	-14,5	11,5	23,1	0,6	
MIKES	88,0	10,0	4,5	9,4	18,9	0,2	
BEV	66,0	15,0	16,9	14,6	29,2	0,6	
METAS	46,0	12,0	-3,1	11,5	23,0	0,1	
MIKES	49,0	10,0	-0,1	9,4	18,8	0,0	
BIM	-	-	-	-	-	-	not measured
CMI	52,0	12,8	2,9	12,3	24,7	0,1	
CEM	13,0	9,0	-36,1	9,6	19,3	1,9	excluded
LNE	48,0	8,0	-1,1	7,2	14,5	0,1	
NPL	47,0	10,0	-2,1	9,4	18,8	0,1	
VSL	50,0	9,2	0,9	8,5	17,1	0,1	
GUM	43,0	11,0	-6,1	10,5	20,9	0,3	
INM	70,0	15,0	20,9	14,6	29,2	0,7	
SP	26,0	13,2	-23,1	12,7	25,5	0,9	
IPQ	81,2	26,0	32,1	25,8	51,5	0,6	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	83,5	3,3
Loop B	49,1	3,4
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,33	
N	11	Loop B
Birge ratio	0,91	

Regression			
			Loop A
α	100,73	12,99	
β	-0,31	1,54	NO DRIFT
			Loop B
α	70,09	12,99	
β	0,05	1,54	NO DRIFT



5 mm ceramic

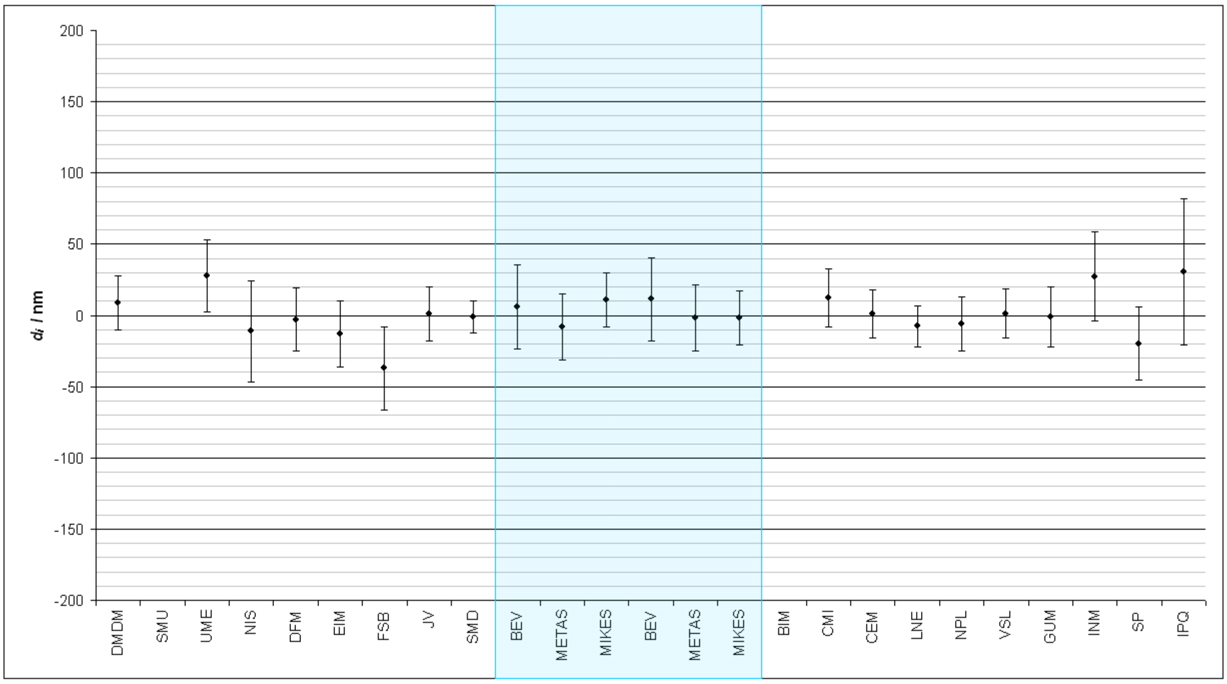
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	88,0	10,1	9,0	9,6	19,1	0,5	
SMU	-	-	-	-	-	-	not measured
UME	107,0	13,0	28,0	12,6	25,2	1,1	
NIS	68,0	18,0	-11,0	17,7	35,4	0,3	
DFM	76,0	11,5	-3,0	11,0	22,0	0,1	
EIM	66,0	12,0	-13,0	11,5	23,1	0,6	
FSB	42,0	15,0	-37,0	14,6	29,3	1,3	
JV	80,0	10,1	1,0	9,6	19,1	0,1	
SMD	77,8	6,5	-1,2	5,6	11,2	0,1	
BEV	85,0	15,0	6,0	14,6	29,3	0,2	
METAS	71,0	12,0	-8,0	11,5	23,1	0,3	
MIKES	90,0	10,0	11,0	9,4	18,9	0,6	
BEV	64,0	15,0	11,3	14,7	29,3	0,4	
METAS	51,0	12,0	-1,7	11,6	23,2	0,1	
MIKES	51,0	10,0	-1,7	9,5	19,0	0,1	
BIM	-	-	-	-	-	-	not measured
CMI	65,0	10,6	12,3	10,1	20,2	0,6	
CEM	54,0	9,0	1,3	8,4	16,9	0,1	
LNE	45,0	8,0	-7,7	7,3	14,7	0,5	
NPL	47,0	10,0	-5,7	9,5	19,0	0,3	
VSL	54,0	9,2	1,3	8,6	17,3	0,1	
GUM	52,0	11,0	-0,7	10,5	21,1	0,0	
INM	80,0	16,0	27,3	15,7	31,4	0,9	
SP	33,0	13,2	-19,7	12,8	25,6	0,8	
IPQ	83,3	26,0	30,5	25,8	51,6	0,6	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	79,0	3,3
Loop B	52,7	3,2
r_{AB}		0,05

N	11	Loop A
Birge ratio	1,22	
N	12	Loop B
Birge ratio	0,94	

Regression			
		Loop A	
α	88,55	12,99	
β	0,05	1,54	NO DRIFT
		Loop B	
α	67,88	12,99	
β	0,12	1,54	NO DRIFT



7 mm ceramic

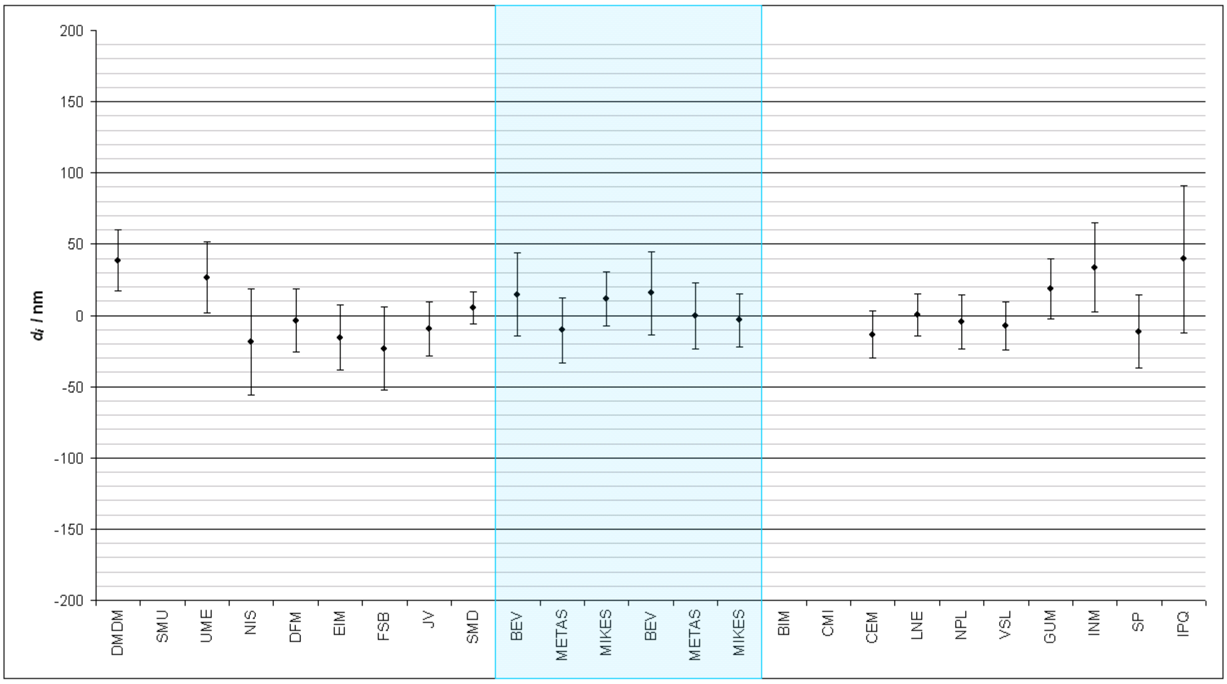
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-92,0	10,1	38,5	10,7	21,4	1,8	excluded
SMU	-	-	-	-	-	-	not measured
UME	-104,0	13,0	26,5	12,5	25,1	1,1	
NIS	-149,0	19,0	-18,5	18,7	37,4	0,5	
DFM	-134,0	11,5	-3,5	11,0	21,9	0,2	
EIM	-146,0	12,0	-15,5	11,5	23,0	0,7	
FSB	-154,0	15,0	-23,5	14,6	29,2	0,8	
JV	-140,0	10,1	-9,5	9,5	19,0	0,5	
SMD	-125,3	6,5	5,2	5,5	11,0	0,5	
BEV	-116,0	15,0	14,5	14,6	29,2	0,5	
METAS	-141,0	12,0	-10,5	11,5	23,0	0,5	
MIKES	-119,0	10,0	11,5	9,4	18,8	0,6	
BEV	92,0	15,0	15,6	14,6	29,3	0,5	
METAS	76,0	12,0	-0,4	11,5	23,1	0,0	
MIKES	73,0	10,0	-3,4	9,4	18,9	0,2	
BIM	-	-	-	-	-	-	not measured
CMI	-	-	-	-	-	-	not measured
CEM	63,0	9,0	-13,4	8,4	16,7	0,8	
LNE	77,0	8,1	0,6	7,4	14,8	0,0	
NPL	72,0	10,0	-4,4	9,4	18,9	0,2	
VSL	69,0	9,2	-7,4	8,6	17,2	0,4	
GUM	95,0	11,0	18,6	10,5	21,0	0,9	
INM	110,0	16,0	33,6	15,7	31,3	1,1	
SP	65,0	13,3	-11,4	12,9	25,8	0,4	
IPQ	115,8	26,0	39,4	25,8	51,6	0,8	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-130,5	3,5
Loop B	76,4	3,3
r_{AB}		0,05

N	10	Loop A
Birge ratio	1,24	
N	11	Loop B
Birge ratio	1,21	

Regression			
		Loop A	
α	-109,28	12,99	
β	-0,31	1,54	NO DRIFT
		Loop B	
α	93,83	13,00	
β	0,53	1,66	NO DRIFT



23,5 mm ceramic

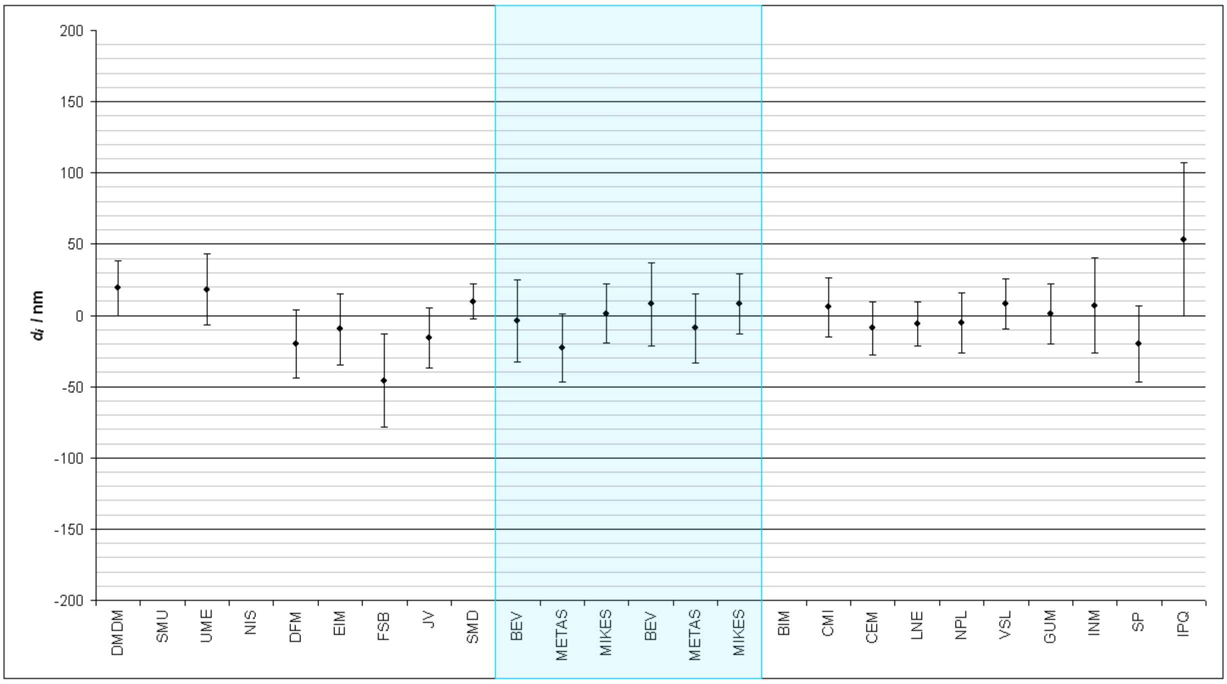
simple

Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	61,0	10,3	19,2	9,6	19,3	1,0	
SMU	-	-	-	-	-	-	not measured
UME	60,0	13,0	18,2	12,5	24,9	0,7	
NIS	-350,0	22,0	-391,8	22,3	44,6	8,8	excluded
DFM	22,0	12,5	-19,8	12,0	23,9	0,8	
EIM	32,0	13,0	-9,8	12,5	24,9	0,4	
FSB	-4,0	16,0	-45,8	16,4	32,8	1,4	excluded
JV	26,0	11,3	-15,8	10,7	21,4	0,7	
SMD	51,6	7,2	9,8	6,2	12,4	0,8	
BEV	38,0	15,0	-3,8	14,5	29,1	0,1	
METAS	19,0	12,5	-22,8	12,0	23,9	1,0	
MIKES	43,0	11,0	1,2	10,4	20,7	0,1	
BEV	51,0	15,0	7,9	14,6	29,2	0,3	
METAS	34,0	12,5	-9,1	12,0	24,1	0,4	
MIKES	51,0	11,0	7,9	10,5	21,0	0,4	
BIM	-	-	-	-	-	-	not measured
CMI	49,0	10,9	5,9	10,4	20,8	0,3	
CEM	34,0	10,0	-9,1	9,4	18,9	0,5	
LNE	37,0	8,5	-6,1	7,8	15,6	0,4	
NPL	38,0	11,0	-5,1	10,5	21,0	0,2	
VSL	51,0	9,4	7,9	8,8	17,6	0,5	
GUM	44,0	11,0	0,9	10,5	21,0	0,0	
INM	50,0	17,0	6,9	16,7	33,3	0,2	
SP	23,0	13,9	-20,1	13,5	27,0	0,7	
IPQ	96,5	27,0	53,4	26,8	53,6	1,0	

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	41,8	3,7
Loop B	43,1	3,3
r_{AB}		0,05

N	9	Loop A
Birge ratio	1,40	
N	12	Loop B
Birge ratio	0,96	

Regression			
			Loop A
α	37,26	12,71	
β	0,08	1,58	NO DRIFT
			Loop B
α	49,11	13,03	
β	0,11	1,58	NO DRIFT



80 mm ceramic

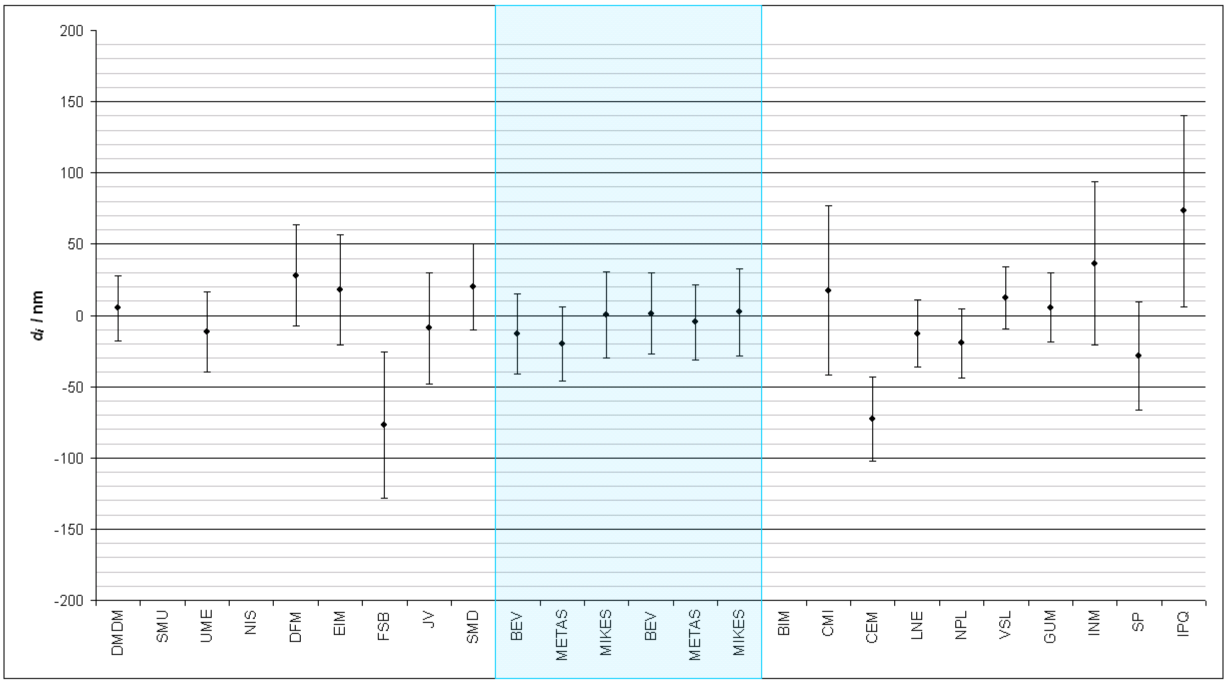
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	164,0	12,6	5,1	11,5	22,9	0,2	
SMU	-	-	-	-	-	-	not measured
UME	147,0	15,0	-11,9	14,1	28,1	0,4	
NIS	-490,0	35,0	-648,9	35,4	70,8	9,2	excluded
DFM	187,0	18,5	28,1	17,7	35,5	0,8	
EIM	177,0	20,0	18,1	19,3	38,6	0,5	
FSB	82,0	25,0	-76,9	25,5	51,1	1,5	excluded
JV	150,0	20,2	-8,9	19,5	39,0	0,2	
SMD	178,9	16,0	20,0	15,1	30,2	0,7	
BEV	146,0	15,0	-12,9	14,1	28,1	0,5	
METAS	139,0	14,0	-19,9	13,0	26,0	0,8	
MIKES	159,0	16,0	0,1	15,1	30,2	0,0	
BEV	135,0	15,0	1,3	14,2	28,5	0,0	
METAS	129,0	14,0	-4,7	13,2	26,3	0,2	
MIKES	136,0	16,0	2,3	15,3	30,6	0,1	
BIM	-	-	-	-	-	-	not measured
CMI	151,0	30,1	17,3	29,7	59,4	0,3	
CEM	61,0	14,0	-72,7	14,8	29,6	2,5	excluded
LNE	121,0	12,8	-12,7	11,9	23,8	0,5	
NPL	114,0	13,0	-19,7	12,1	24,2	0,8	
VSL	146,0	11,9	12,3	10,9	21,8	0,6	
GUM	139,0	13,0	5,3	12,1	24,2	0,2	
INM	170,0	29,0	36,3	28,6	57,2	0,6	
SP	105,0	19,6	-28,7	19,0	38,0	0,8	
IPQ	206,8	34,0	73,1	33,7	67,3	1,1	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	158,9	5,2
Loop B	133,7	4,7
r_{AB}		0,07

N	9	Loop A
Birge ratio	1,03	
N	11	Loop B
Birge ratio	1,15	

Regression			
			Loop A
α	156,67	12,78	
β	0,00	1,62	NO DRIFT
			Loop B
α	130,76	13,07	
β	0,58	1,62	NO DRIFT



100 mm ceramic

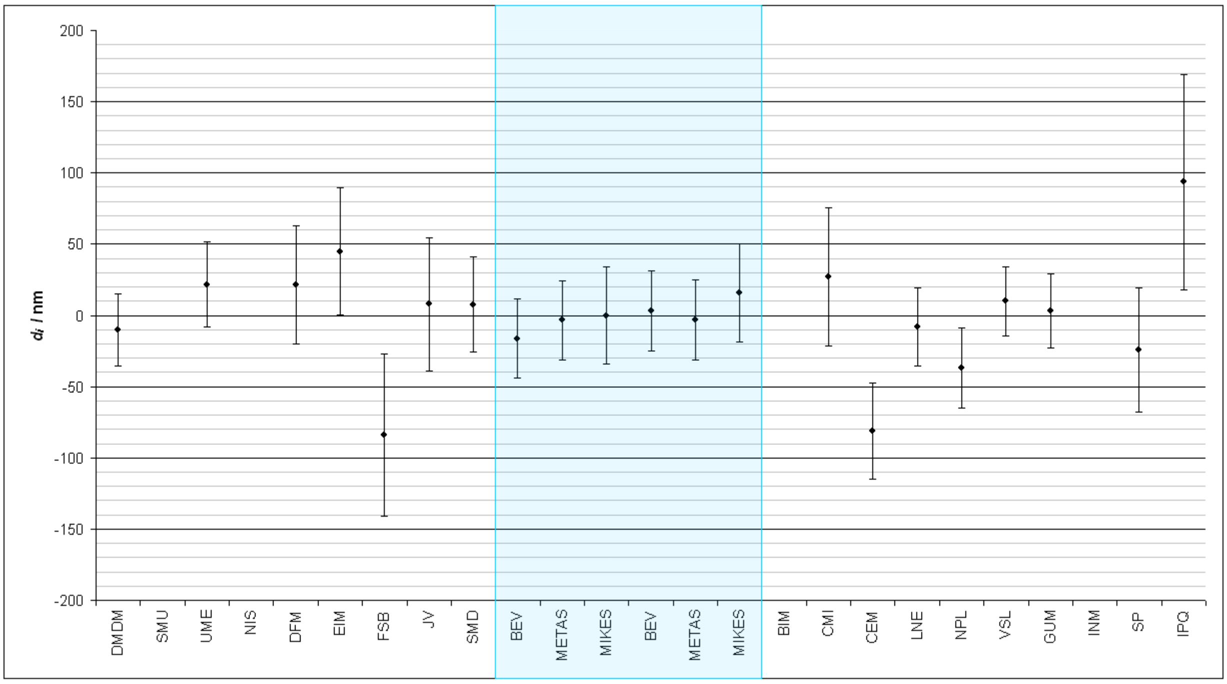
Laboratory	x_i / nm	$u(x_i)$ / nm	d_i / nm	$u(d_i)$ / nm	$U(d_i)$ / nm	E_n	Info
DMDM	-21,0	13,9	-10,2	12,7	25,4	0,4	
SMU	-	-	-	-	-	-	not measured
UME	11,0	16,0	21,8	15,0	30,0	0,7	
NIS	-516,0	39,0	-505,2	39,4	78,8	6,4	excluded
DFM	11,0	21,5	21,8	20,7	41,5	0,5	
EIM	34,0	23,0	44,8	22,3	44,6	1,0	
FSB	-95,0	29,0	-84,2	28,4	56,9	1,5	
JV	-3,0	24,2	7,8	23,5	47,1	0,2	
SMD	-3,1	17,7	7,7	16,8	33,6	0,2	
BEV	-27,0	15,0	-16,2	13,9	27,8	0,6	
METAS	-14,0	15,0	-3,2	13,9	27,8	0,1	
MIKES	-11,0	18,0	-0,2	17,1	34,2	0,0	
BEV	333,0	15,0	2,9	14,1	28,1	0,1	
METAS	327,0	15,0	-3,1	14,1	28,1	0,1	
MIKES	346,0	18,0	15,9	17,2	34,4	0,5	
BIM	-	-	-	-	-	-	not measured
CMI	357,0	24,9	26,9	24,3	48,7	0,6	
CEM	249,0	16,0	-81,1	16,8	33,7	2,4	excluded
LNE	322,0	14,8	-8,1	13,8	27,7	0,3	
NPL	293,0	15,0	-37,1	14,1	28,1	1,3	
VSL	340,0	13,2	9,9	12,1	24,2	0,4	
GUM	333,0	14,0	2,9	13,0	26,0	0,1	
INM	-170,0	33,0	-500,1	33,4	66,8	7,5	excluded
SP	306,0	22,4	-24,1	21,8	43,6	0,6	
IPQ	423,6	38,0	93,5	37,6	75,3	1,2	

simple

	x_{ref} / nm	$u(x_{ref})$ / nm
Loop A	-10,8	5,6
Loop B	330,1	5,2
r_{AB}		0,07

N	10	Loop A
Birge ratio	1,38	
N	10	Loop B
Birge ratio	1,34	

Regression			
			Loop A
α	-6,12	12,84	
β	-0,39	1,65	NO DRIFT
			Loop B
α	329,16	13,11	
β	0,30	1,65	NO DRIFT



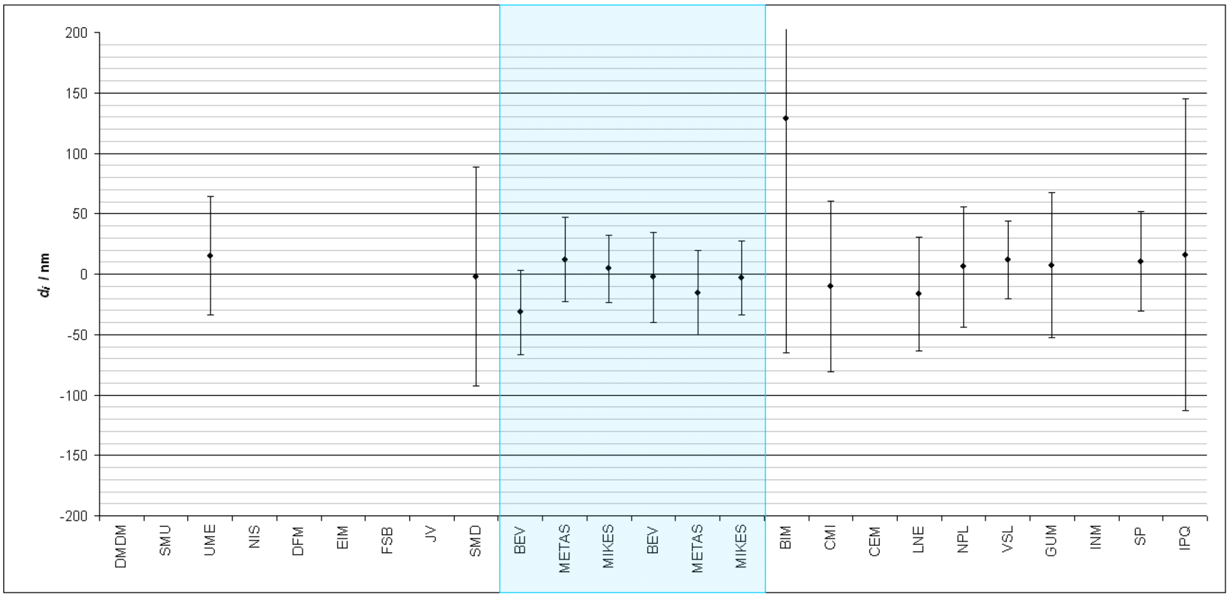
150 mm steel

Laboratory	x_i /nm	$u(x_i)$ /nm	t_i / period	x_{ref} / nm	$u(x_{ref})$ / nm	d_i / nm	$u(d_i)$ /nm	$U(d_i)$ /nm	E_n	Info
DMDM	-	-	-	-	-	-	-	-	-	not measured
SMU	-	-	-	-	-	-	-	-	-	not measured
UME	-118,0	26,5	12,5	-133,2	9,86	15,2	24,60	49,20	0,3	
NIS	-	-	-	-	-	-	-	-	-	not measured
DFM	-	-	-	-	-	-	-	-	-	not measured
EIM	-	-	-	-	-	-	-	-	-	not measured
FSB	-	-	-	-	-	-	-	-	-	not measured
JV	-	-	-	-	-	-	-	-	-	not measured
SMD	-157,7	46,5	18,5	-155,7	11,07	-2,0	45,44	90,89	0,0	
BEV	-146,0	20,0	7,5	-114,4	10,84	-31,6	17,40	34,80	0,9	
METAS	-110,0	20,0	9,5	-121,9	10,24	11,9	17,40	34,80	0,3	
MIKES	-140,0	17,0	15,5	-144,4	10,15	4,4	13,85	27,70	0,2	
BEV	191,0	20,0	15,5	193,6	8,78	-2,6	18,58	37,17	0,1	
METAS	203,0	19,0	8,5	218,3	7,55	-15,3	17,50	35,01	0,4	
MIKES	233,0	17,0	3,5	236,0	9,55	-3,0	15,31	30,62	0,1	
BIM	315,0	97,0	17,5	186,5	9,87	128,5	96,72	193,44	0,7	
CMI	194,0	36,0	12,5	204,2	7,67	-10,2	35,23	70,47	0,1	
CEM	-	-	-	-	-	-	-	-	-	not measured
LNE	209,0	24,7	6,5	225,4	8,12	-16,4	23,57	47,14	0,4	
NPL	221,0	26,0	9,5	214,8	7,42	6,2	24,93	49,85	0,1	
VSL	244,0	17,7	4,5	232,4	9,01	11,6	16,08	32,17	0,4	
GUM	208,0	31,0	13,5	200,7	7,96	7,3	30,11	60,21	0,1	
INM	-	-	-	-	-	-	-	-	-	not measured
SP	250,0	22,0	2,5	239,5	10,14	10,5	20,72	41,44	0,3	
IPQ	199,0	65,0	18,5	183,0	10,49	16,0	64,58	129,16	0,1	

linear drift

N	5	Loop A
Birge ratio	0,88	
N	11	Loop B
Birge ratio	0,61	

	$\alpha_{A,B}$ / $\beta_{A,B}$	$u(\alpha_{A,B}$ / $\beta_{A,B})$
α_A	-86,19	9,86
β_A	-3,76	8,67E-01
α_B	248,34	7,39
β_B	-3,53	8,99E-01



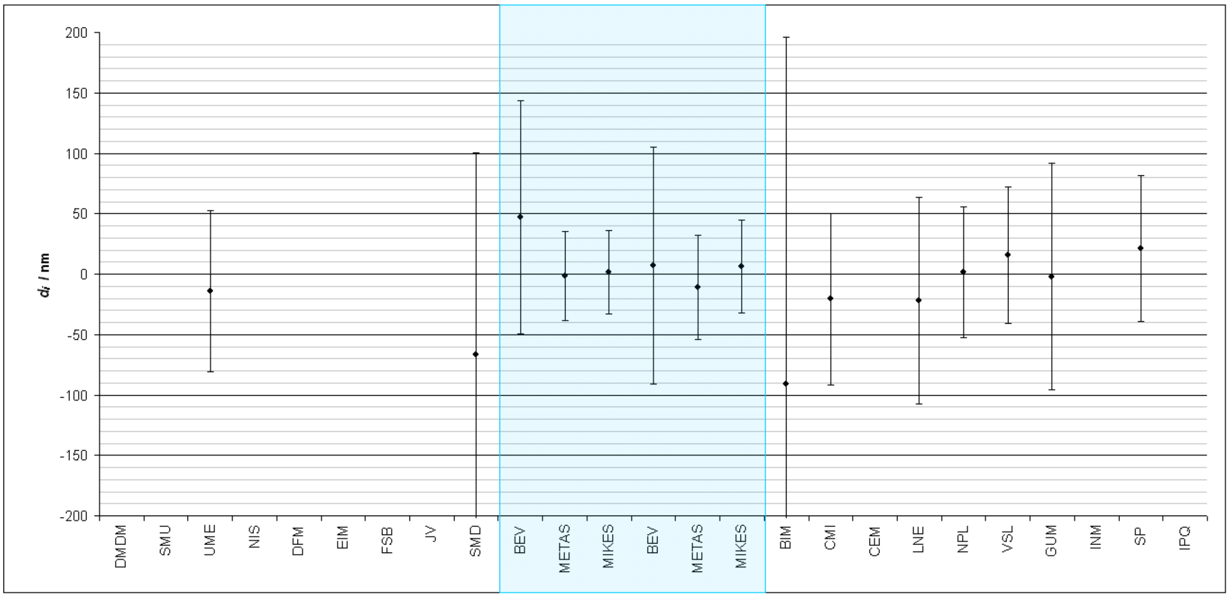
300 mm steel

Laboratory	x_i /nm	$u(x_i)$ /nm	t_i / period	x_{ref} / nm	$u(x_{ref})$ / nm	d_i / nm	$u(d_i)$ /nm	$U(d_i)$ /nm	E_n	Info
DMDM	-	-	-	-	-	-	-	-	-	not measured
SMU	-	-	-	-	-	-	-	-	-	not measured
UME	-7638,0	36,0	12,5	-7623,9	13,85	-14,1	33,28	66,55	0,2	
NIS	-	-	-	-	-	-	-	-	-	not measured
DFM	-	-	-	-	-	-	-	-	-	not measured
EIM	-	-	-	-	-	-	-	-	-	not measured
FSB	-	-	-	-	-	-	-	-	-	not measured
JV	-	-	-	-	-	-	-	-	-	not measured
SMD	-7701,6	84,5	18,5	-7634,9	14,08	-66,7	83,38	166,75	0,4	
BEV	-7586,0	50,0	17,5	-7633,0	13,92	47,0	48,08	96,15	0,5	
METAS	-7620,0	23,0	9,5	-7618,4	14,37	-1,6	18,45	36,89	0,0	
MIKES	-7628,0	22,0	15,5	-7629,4	13,75	1,4	17,18	34,37	0,0	
BEV	-8355,0	50,0	15,5	-8362,1	11,35	7,1	48,88	97,76	0,1	
METAS	-8348,0	24,0	8,5	-8337,2	10,61	-10,8	21,57	43,14	0,3	
MIKES	-8313,0	22,0	3,5	-8319,4	11,85	6,4	19,32	38,64	0,2	
BIM	-8460,0	144,0	17,5	-8369,2	12,05	-90,8	143,62	287,23	0,3	
CMI	-8372,0	37,0	12,5	-8351,4	10,68	-20,6	35,47	70,95	0,3	
CEM	-	-	-	-	-	-	-	-	-	not measured
LNE	-8352,0	44,0	6,5	-8330,1	10,94	-21,9	42,72	85,45	0,3	
NPL	-8339,0	29,0	9,5	-8340,7	10,54	1,7	27,02	54,05	0,0	
VSL	-8307,0	30,1	4,5	-8323,0	11,50	16,0	28,20	56,40	0,3	
GUM	-8357,0	48,0	13,5	-8355,0	10,85	-2,0	46,83	93,67	0,0	
INM	-	-	-	-	-	-	-	-	-	not measured
SP	-8295,0	32,0	2,5	-8315,9	12,24	20,9	30,22	60,44	0,4	
IPQ	1065,1	123,0	18,5	-8372,7	12,47	9437,8	123,81	247,62	38,2	excluded

linear drift

N	5	Loop A
Birge ratio	0,65	
N	10	Loop B
Birge ratio	0,46	

	$\alpha_{A,B}$ / $\beta_{A,B}$	$u(\alpha_{A,B}$ / $\beta_{A,B})$
α_A	-7600,98	13,74
β_A	-1,83	8,09E-01
α_B	-8306,98	10,52
β_B	-3,55	8,09E-01



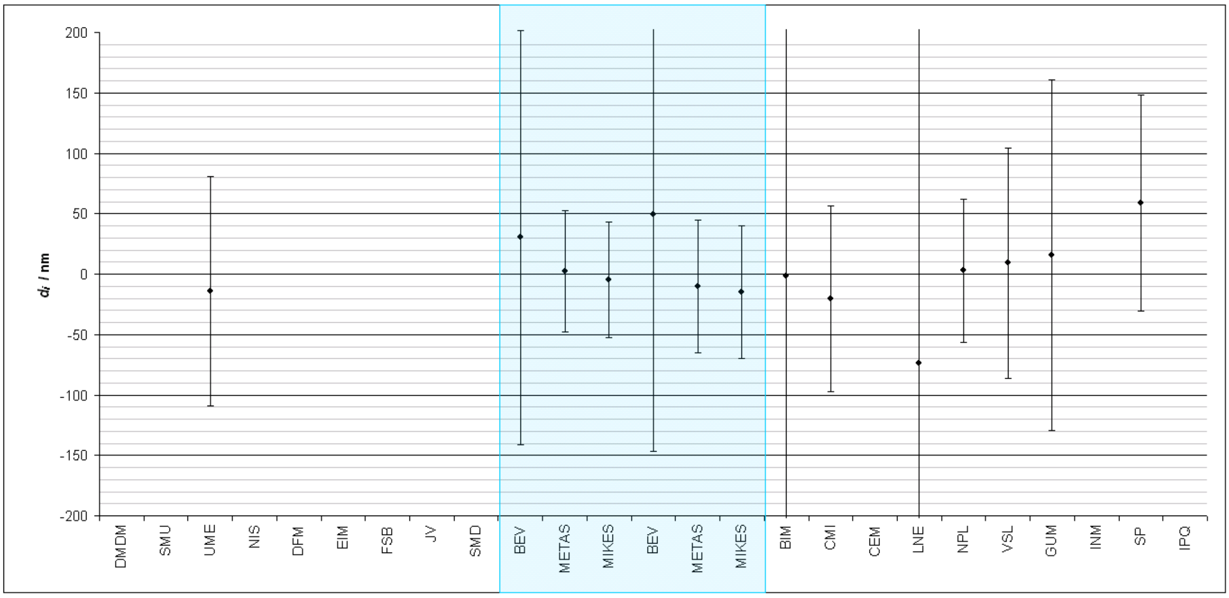
500 mm steel

linear drift

Laboratory	x_i /nm	$u(x_i)$ /nm	t_i / period	x_{ref} / nm	$u(x_{ref})$ / nm	d_i / nm	$u(d_i)$ /nm	$U(d_i)$ /nm	E_n	Info
DMDM	-	-	-	-	-	-	-	-	-	not measured
SMU	-	-	-	-	-	-	-	-	-	not measured
UME	577,0	51,5	12,5	591,2	19,86	-14,2	47,54	95,07	0,1	
NIS	-	-	-	-	-	-	-	-	-	not measured
DFM	-	-	-	-	-	-	-	-	-	not measured
EIM	-	-	-	-	-	-	-	-	-	not measured
FSB	-	-	-	-	-	-	-	-	-	not measured
JV	-	-	-	-	-	-	-	-	-	not measured
SMD	-	-	-	-	-	-	-	-	-	not measured
BEV	599,0	88,0	17,5	568,8	20,22	30,2	85,74	171,48	0,2	
METAS	607,0	32,0	9,5	604,7	20,34	2,3	25,13	50,25	0,0	
MIKES	573,0	31,0	15,5	577,8	19,91	-4,8	23,84	47,68	0,1	
BEV	1300,0	99,0	15,5	1250,9	16,11	49,1	97,92	195,85	0,3	
METAS	1284,0	31,0	8,5	1294,2	14,59	-10,2	27,37	54,74	0,2	
MIKES	1310,0	31,0	3,5	1325,1	16,02	-15,1	27,37	54,74	0,3	
BIM	1237,0	218,0	17,5	1238,5	17,20	-1,5	217,51	435,03	0,0	
CMI	1249,0	41,0	12,5	1269,4	14,97	-20,4	38,33	76,66	0,3	
CEM	-	-	-	-	-	-	-	-	-	not measured
LNE	1233,0	226,7	6,5	1306,5	14,92	-73,5	226,23	452,46	0,2	
NPL	1291,0	33,0	9,5	1288,0	14,56	3,0	29,62	59,23	0,1	
VSL	1328,0	49,8	4,5	1318,9	15,58	9,1	47,62	95,25	0,1	
GUM	1279,0	74,0	13,5	1263,2	15,28	15,8	72,55	145,11	0,1	
INM	-	-	-	-	-	-	-	-	-	not measured
SP	1390,0	47,0	2,5	1331,3	16,52	58,7	44,69	89,38	0,7	
IPQ	-	-	-	-	-	-	-	-	-	not measured

N	4	Loop A
Birge ratio	0,27	
N	10	Loop B
Birge ratio	0,53	

	$\alpha_{A,B}$ / $\beta_{A,B}$	$u(\alpha_{A,B}$ / $\beta_{A,B})$
α_A	647,29	19,82
β_A	-4,49	1,08E+00
α_B	1346,72	14,56
β_B	-6,18	1,13E+00



9.2 The auxiliary measurand d_c

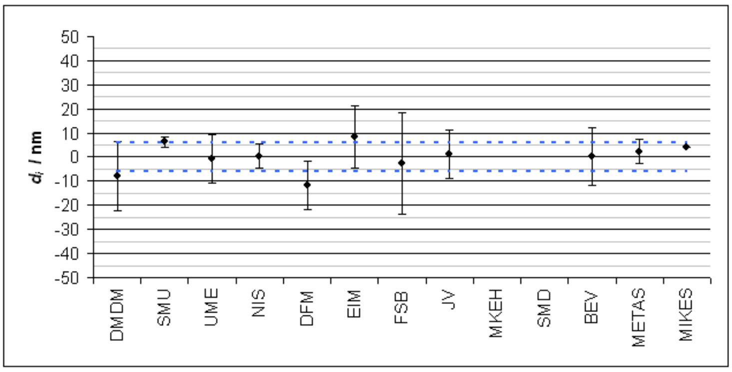
In the following an extract of the Excel table `EURAMET.L-K1.2011-diff.xls` is given for each nominal length (both loops). The tables include the results as reported by the participants and the reference values. Two graphs per nominal length are shown since there is no linking between the two loops. They present the d_{Ci} together with the standard uncertainties $u(d_{Ci})$, if reported. The highlighting of the linking laboratories has no significance in this context. The blue dashed lines represent the standard deviation of the results.

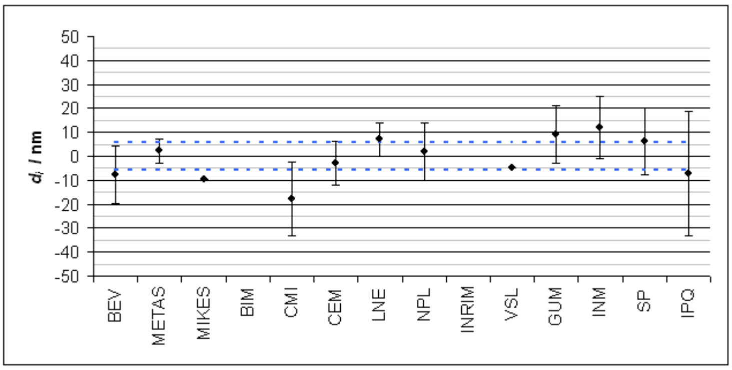
INRIM and MKEH were removed from all tables since they did not report results (see section 3.2).

0,5 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-8,0	14,3	-7,7
SMU	6,0	2,0	6,3
UME	-1,0	10,0	-0,7
NIS	0,0	5,0	0,3
DFM	-12,0	10,0	-11,7
EIM	8,0	13,0	8,3
FSB	-3,0	21,0	-2,7
JV	1,0	10,0	1,3
MKEH	-	-	-
SMD	-	-	-
BEV	0,0	12,0	0,3
METAS	2,0	5,0	2,3
MIKES	4,0	-	4,3
BEV	-8,0	12,0	-7,7
METAS	2,0	5,0	2,3
MIKES	-10,0	-	-9,7
BIM	-	-	-
CMI	-22,0	15,3	-17,9
CEM	-7,0	9,0	-2,9
LNE	3,0	7,0	7,1
NPL	-2,0	12,0	2,1
INRIM	-	-	-
VSL	-9,0	-	-4,9
GUM	5,0	12,0	9,1
INM	8,0	13,0	12,1
SP	2,0	13,9	6,1
IPQ	-11,5	26,0	-7,4

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	-0,3	5,8
Loop B	-4,1	6,1

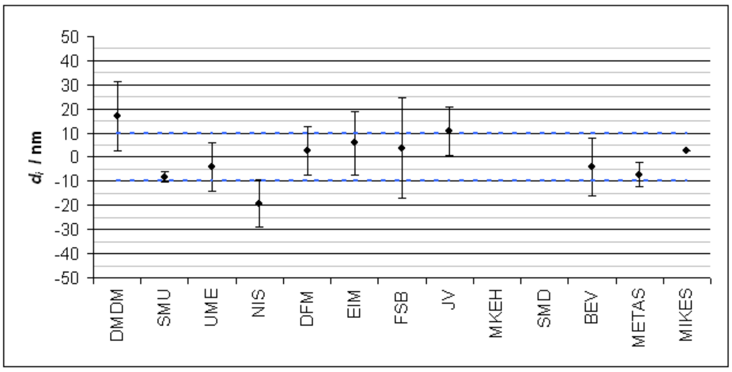


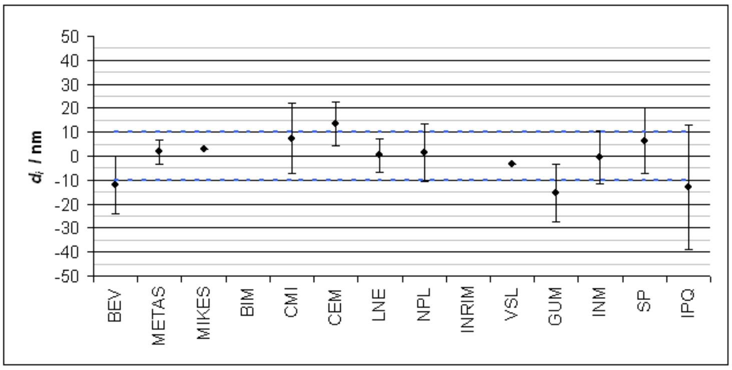


1,15 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	19,0	14,3	16,8
SMU	-6,0	2,0	-8,2
UME	-2,0	10,0	-4,2
NIS	-17,0	10,0	-19,2
DFM	5,0	10,0	2,8
EIM	8,0	13,0	5,8
FSB	6,0	21,0	3,8
JV	13,0	10,0	10,8
MKEH	-	-	-
SMD	-	-	-
BEV	-2,0	12,0	-4,2
METAS	-5,0	5,0	-7,2
MIKES	5,0	-	2,8
BEV	-10,0	12,0	-12,2
METAS	4,0	5,0	1,8
MIKES	5,0	-	2,8
BIM	-	-	-
CMI	6,0	14,7	7,5
CEM	12,0	9,0	13,5
LNE	-1,0	7,0	0,5
NPL	0,0	12,0	1,5
INRIM	-	-	-
VSL	-5,0	-	-3,6
GUM	-17,0	12,0	-15,6
INM	-2,0	11,0	-0,6
SP	5,0	13,9	6,5
IPQ	-14,4	26,0	-13,0

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	2,2	9,9
Loop B	-1,5	6,2

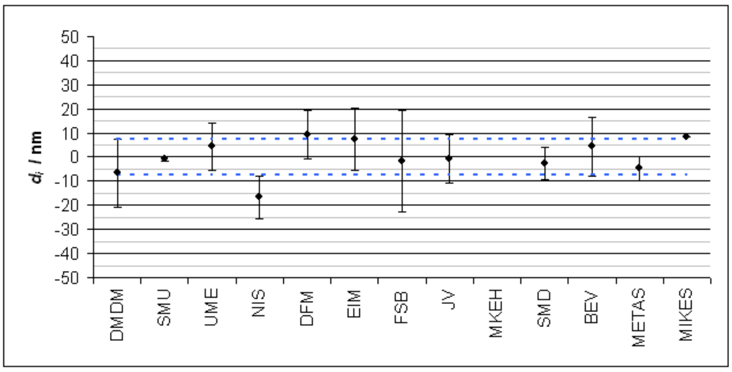


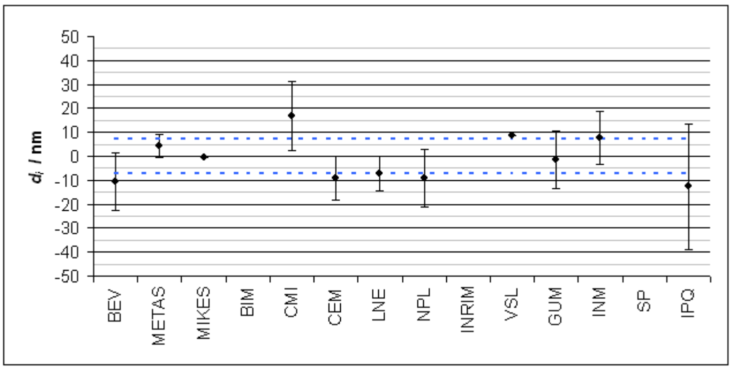


3 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-5,0	14,3	-6,7
SMU	1,0	1,0	-0,7
UME	6,0	10,0	4,3
NIS	-15,0	9,0	-16,7
DFM	11,0	10,0	9,3
EIM	9,0	13,0	7,3
FSB	0,0	21,0	-1,7
JV	1,0	10,1	-0,7
MKEH	-	-	-
SMD	-0,9	6,8	-2,6
BEV	6,0	12,0	4,3
METAS	-3,0	5,0	-4,7
MIKES	10,0	-	8,3
BEV	-9,0	12,0	-10,7
METAS	6,0	5,0	4,3
MIKES	1,0	-	-0,7
BIM	-	-	-
CMI	14,0	14,5	16,8
CEM	-12,0	9,0	-9,2
LNE	-10,0	7,0	-7,2
NPL	-12,0	12,0	-9,2
INRIM	-	-	-
VSL	6,0	-	8,8
GUM	-4,0	12,0	-1,2
INM	5,0	11,0	7,8
SP	-	-	-
IPQ	-15,5	26,0	-12,7

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	1,7	7,4
Loop B	-2,8	6,5

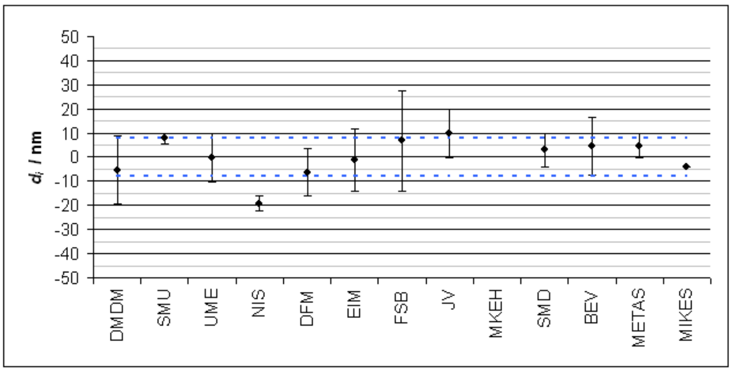


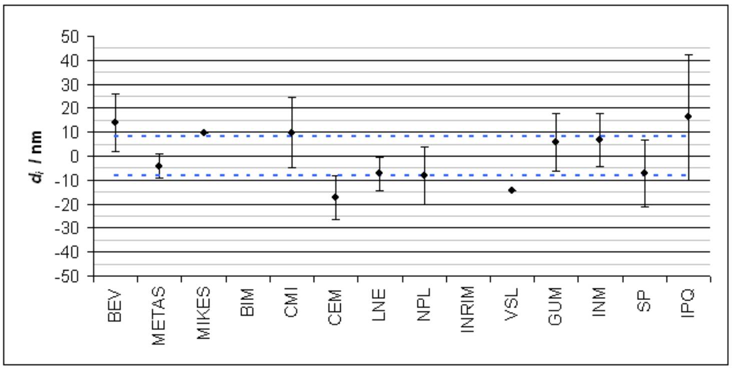


5 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-4,0	14,3	-5,3
SMU	9,0	2,0	7,7
UME	1,0	10,0	-0,3
NIS	-18,0	3,0	-19,3
DFM	-5,0	10,0	-6,3
EIM	0,0	13,0	-1,3
FSB	8,0	21,0	6,7
JV	11,0	10,1	9,7
MKEH	-	-	-
SMD	4,2	6,8	2,9
BEV	6,0	12,0	4,7
METAS	6,0	5,0	4,7
MIKES	-3,0	-	-4,3
BEV	15,0	12,0	13,7
METAS	-3,0	5,0	-4,3
MIKES	11,0	-	9,7
BIM	-	-	-
CMI	12,0	14,6	9,7
CEM	-15,0	9,0	-17,3
LNE	-5,0	7,0	-7,3
NPL	-6,0	12,0	-8,3
INRIM	-	-	-
VSL	-12,0	-	-14,3
GUM	8,0	12,0	5,7
INM	9,0	11,0	6,7
SP	-5,0	13,9	-7,3
IPQ	18,4	26,0	16,1

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	1,3	8,0
Loop B	2,3	7,7

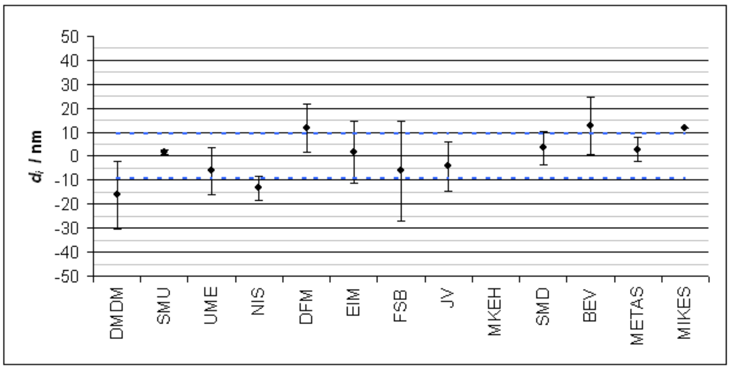


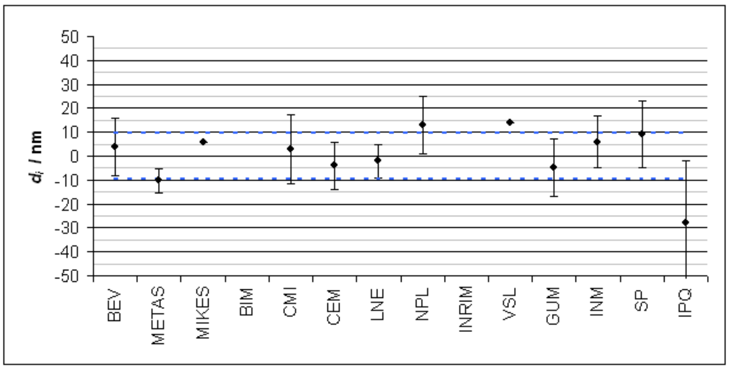


7 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-18,0	14,3	-16,2
SMU	0,0	1,0	1,8
UME	-8,0	10,0	-6,2
NIS	-15,0	5,0	-13,2
DFM	10,0	10,0	11,8
EIM	0,0	13,0	1,8
FSB	-8,0	21,0	-6,2
JV	-6,0	10,3	-4,2
MKEH	-	-	-
SMD	1,6	6,8	3,4
BEV	11,0	12,0	12,8
METAS	1,0	5,0	2,8
MIKES	10,0	-	11,8
BEV	2,0	12,0	3,8
METAS	-12,0	5,0	-10,2
MIKES	4,0	-	5,8
BIM	-	-	-
CMI	3,0	14,5	3,0
CEM	-4,0	10,0	-4,0
LNE	-2,0	7,0	-2,0
NPL	13,0	12,0	13,0
INRIM	-	-	-
VSL	14,0	-	14,0
GUM	-5,0	12,0	-5,0
INM	6,0	11,0	6,0
SP	9,0	14,0	9,0
IPQ	-27,8	26,0	-27,8

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	-1,8	9,5
Loop B	0,0	8,0

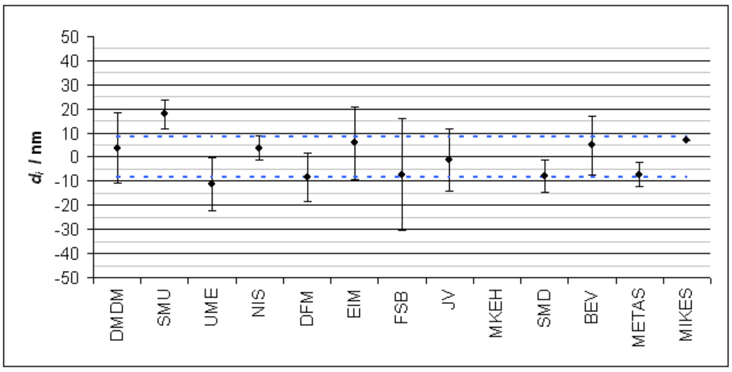


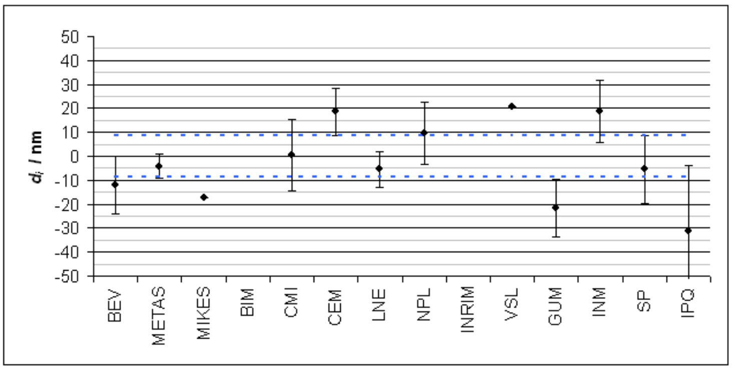


23,5 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	6,0	14,7	3,8
SMU	20,0	6,0	17,8
UME	-9,0	11,0	-11,2
NIS	6,0	5,0	3,8
DFM	-6,0	10,0	-8,2
EIM	8,0	15,0	5,8
FSB	-5,0	23,0	-7,2
JV	1,0	12,8	-1,2
MKEH	-	-	-
SMD	-5,7	6,8	-7,9
BEV	7,0	12,0	4,8
METAS	-5,0	5,0	-7,2
MIKES	9,0	-	6,8
BEV	-10,0	12,0	-12,2
METAS	-2,0	5,0	-4,2
MIKES	-15,0	-	-17,2
BIM	-	-	-
CMI	-7,0	15,0	0,6
CEM	11,0	10,0	18,6
LNE	-13,0	7,4	-5,5
NPL	2,0	13,0	9,6
INRIM	-	-	-
VSL	13,0	-	20,6
GUM	-29,0	12,0	-21,5
INM	11,0	13,0	18,6
SP	-13,0	14,3	-5,5
IPQ	-38,6	27,0	-31,1

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	2,2	8,6
Loop B	-7,6	11,0

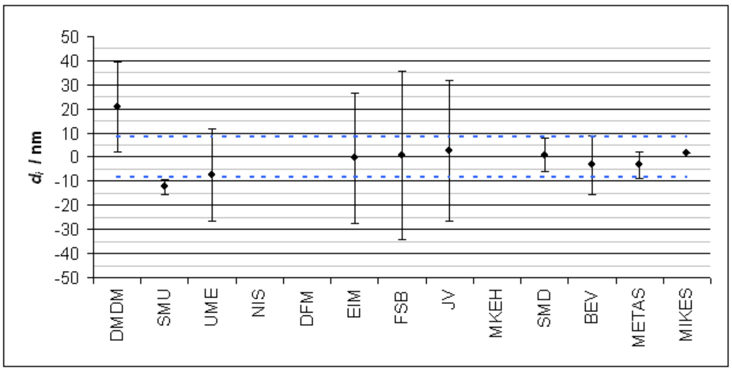


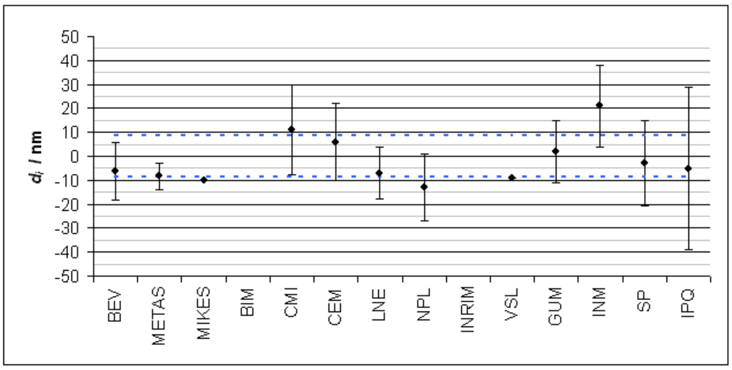


80 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	22,0	18,6	20,7
SMU	-11,0	3,0	-12,3
UME	-6,0	19,0	-7,3
NIS	-	-	-
DFM	-	-	-
EIM	1,0	27,0	-0,3
FSB	2,0	35,0	0,7
JV	4,0	29,0	2,7
MKEH	-	-	-
SMD	2,2	6,8	0,9
BEV	-2,0	12,0	-3,3
METAS	-2,0	5,5	-3,3
MIKES	3,0	-	1,7
BEV	-5,0	12,0	-6,3
METAS	-7,0	5,5	-8,3
MIKES	-9,0	-	-10,3
BIM	-	-	-
CMI	5,0	18,8	11,0
CEM	0,0	16,0	6,0
LNE	-13,0	10,6	-7,0
NPL	-19,0	14,0	-13,0
INRIM	-	-	-
VSL	-15,0	-	-9,0
GUM	-4,0	13,0	2,0
INM	15,0	17,0	21,0
SP	-9,0	17,9	-3,0
IPQ	-11,1	34,0	-5,1

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	1,3	8,6
Loop B	-6,0	6,7

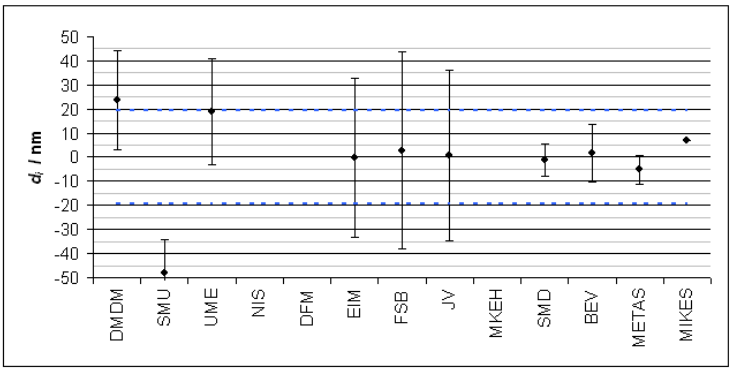


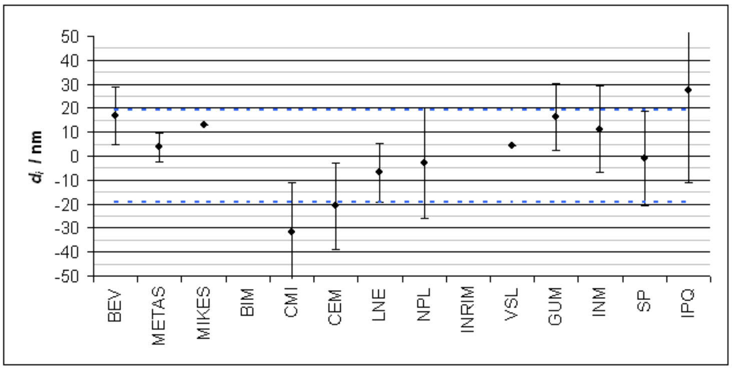


100 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	24,0	20,6	23,8
SMU	-48,0	14,0	-48,2
UME	19,0	22,0	18,8
NIS	-	-	-
DFM	-	-	-
EIM	0,0	33,0	-0,2
FSB	3,0	41,0	2,8
JV	1,0	35,4	0,8
MKEH	-	-	-
SMD	-1,0	6,8	-1,2
BEV	2,0	12,0	1,8
METAS	-5,0	6,0	-5,2
MIKES	7,0	-	6,8
BEV	17,0	12,0	16,8
METAS	4,0	6,0	3,8
MIKES	13,0	-	12,8
BIM	-	-	-
CMI	-22,0	20,7	-31,8
CEM	-11,0	18,0	-20,8
LNE	3,0	12,2	-6,8
NPL	7,0	23,0	-2,8
INRIM	-	-	-
VSL	14,0	-	4,2
GUM	26,0	14,0	16,2
INM	21,0	18,0	11,2
SP	9,0	19,8	-0,8
IPQ	37,0	38,0	27,2

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	0,2	19,2
Loop B	9,8	11,4

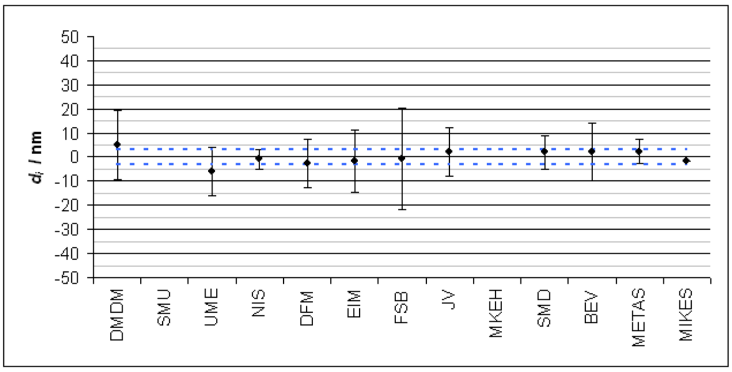


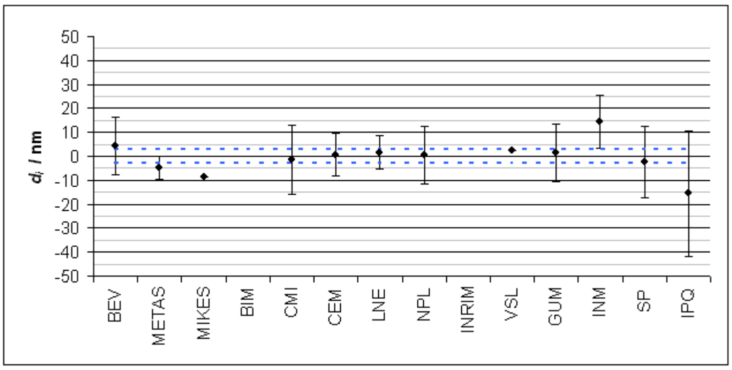


0,5 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	5,0	14,3	5,2
SMU	-	-	-
UME	-6,0	10,0	-5,8
NIS	-1,0	4,0	-0,8
DFM	-3,0	10,0	-2,8
EIM	-2,0	13,0	-1,8
FSB	-1,0	21,0	-0,8
JV	2,0	10,0	2,2
MKEH	-	-	-
SMD	1,8	6,8	2,0
BEV	2,0	12,0	2,2
METAS	2,0	5,0	2,2
MIKES	-2,0	-	-1,8
BEV	4,0	12,0	4,2
METAS	-5,0	5,0	-4,8
MIKES	-9,0	-	-8,8
BIM	-	-	-
CMI	-4,0	14,6	-1,4
CEM	-2,0	9,0	0,6
LNE	-1,0	7,0	1,6
NPL	-2,0	12,0	0,6
INRIM	-	-	-
VSL	0,0	-	2,6
GUM	-1,0	12,0	1,6
INM	12,0	11,0	14,6
SP	-5,0	14,8	-2,4
IPQ	-18,2	26,0	-15,6

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	-0,2	3,1
Loop B	-2,6	5,1

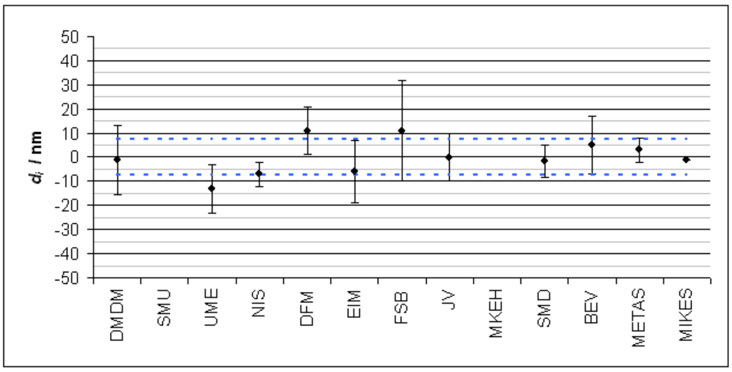


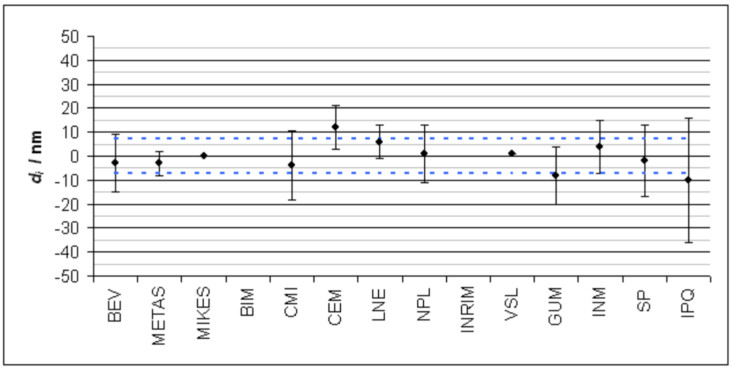


1,15 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	0,0	14,3	-1,0
SMU	-	-	-
UME	-12,0	10,0	-13,0
NIS	-6,0	5,0	-7,0
DFM	12,0	10,0	11,0
EIM	-5,0	13,0	-6,0
FSB	12,0	21,0	11,0
JV	1,0	10,0	0,0
MKEH	-	-	-
SMD	-0,7	6,8	-1,7
BEV	6,0	12,0	5,0
METAS	4,0	5,0	3,0
MIKES	0,0	-	-1,0
BEV	-2,0	12,0	-3,0
METAS	-2,0	5,0	-3,0
MIKES	1,0	-	0,0
BIM	-	-	-
CMI	-5,0	14,4	-4,0
CEM	11,0	9,0	12,0
LNE	5,0	7,0	6,0
NPL	0,0	12,0	1,0
INRIM	-	-	-
VSL	0,0	-	1,0
GUM	-9,0	12,0	-8,0
INM	3,0	11,0	4,0
SP	-3,0	14,8	-2,0
IPQ	-10,9	26,0	-9,9

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	1,0	7,3
Loop B	-1,0	4,2

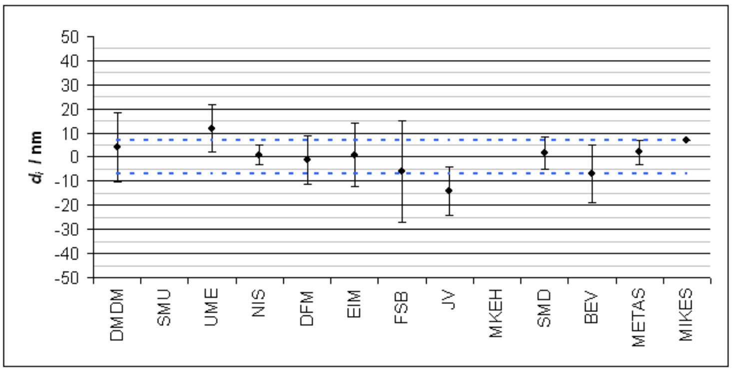


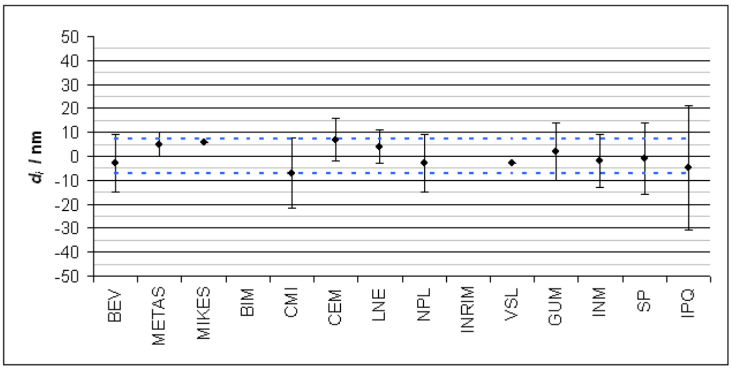


3 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	4,0	14,3	3,9
SMU	-	-	-
UME	12,0	10,0	11,9
NIS	1,0	4,0	0,9
DFM	-1,0	10,0	-1,1
EIM	1,0	13,0	0,9
FSB	-6,0	21,0	-6,1
JV	-14,0	10,1	-14,1
MKEH	-	-	-
SMD	1,8	6,8	1,7
BEV	-7,0	12,0	-7,1
METAS	2,0	5,0	1,9
MIKES	7,0	-	6,9
BEV	-3,0	12,0	-3,1
METAS	5,0	5,0	4,9
MIKES	6,0	-	5,9
BIM	-	-	-
CMI	-7,0	14,8	-7,0
CEM	7,0	9,0	7,0
LNE	4,0	7,0	4,0
NPL	-3,0	12,0	-3,0
INRIM	-	-	-
VSL	-3,0	-	-3,0
GUM	2,0	12,0	2,0
INM	-2,0	11,0	-2,0
SP	-1,0	14,8	-1,0
IPQ	-4,6	26,0	-4,6

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	0,1	7,1
Loop B	0,0	3,2

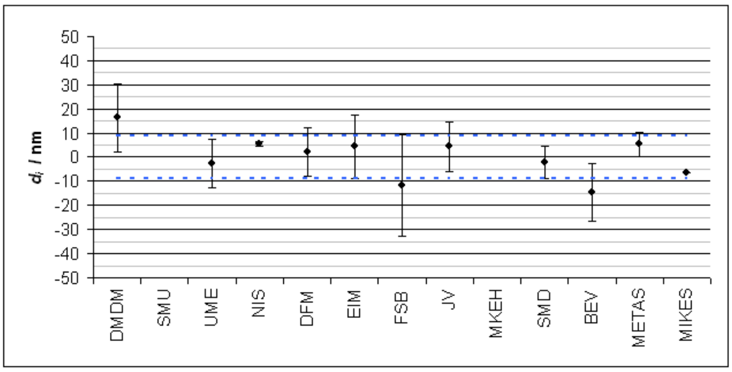


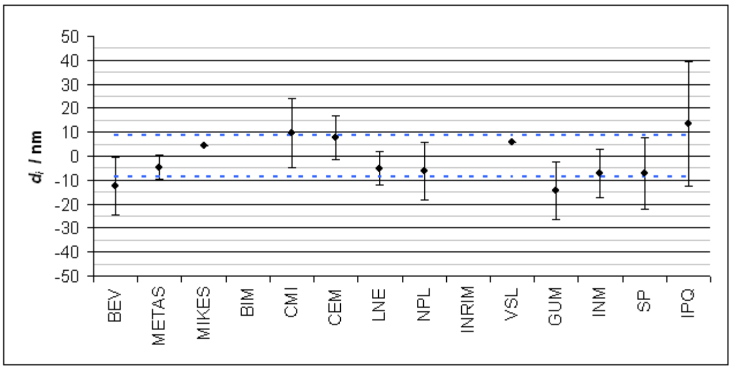


5 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	22,0	14,3	16,3
SMU	-	-	-
UME	3,0	10,0	-2,7
NIS	11,0	1,0	5,3
DFM	8,0	10,0	2,3
EIM	10,0	13,0	4,3
FSB	-6,0	21,0	-11,7
JV	10,0	10,1	4,3
MKEH	-	-	-
SMD	3,5	6,8	-2,2
BEV	-9,0	12,0	-14,7
METAS	11,0	5,0	5,3
MIKES	-1,0	-	-6,7
BEV	-7,0	12,0	-12,7
METAS	1,0	5,0	-4,7
MIKES	10,0	-	4,3
BIM	-	-	-
CMI	10,0	14,5	9,8
CEM	8,0	9,0	7,8
LNE	-5,0	7,0	-5,2
NPL	-6,0	12,0	-6,2
INRIM	-	-	-
VSL	6,0	-	5,8
GUM	-14,0	12,0	-14,2
INM	-7,0	10,0	-7,2
SP	-7,0	14,8	-7,2
IPQ	13,9	26,0	13,7

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	5,7	8,8
Loop B	0,2	6,4

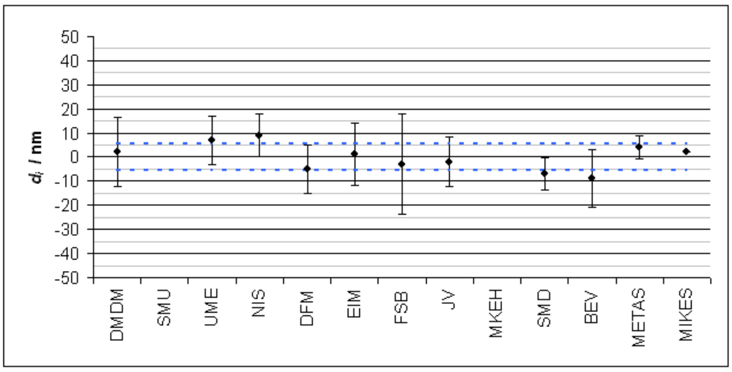


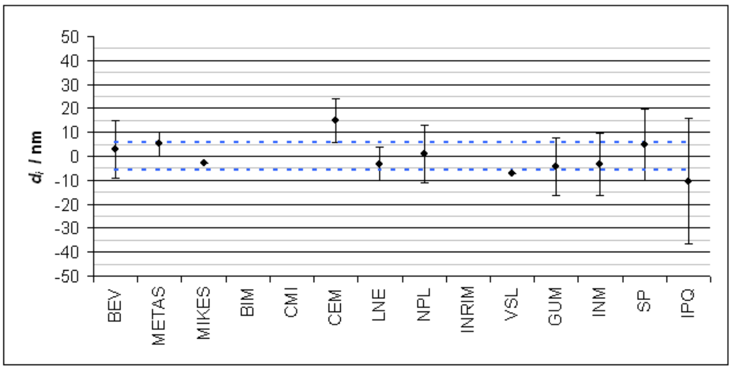


7 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	2,0	14,3	2,1
SMU	-	-	-
UME	7,0	10,0	7,1
NIS	9,0	9,0	9,1
DFM	-5,0	10,0	-4,9
EIM	1,0	13,0	1,1
FSB	-3,0	21,0	-2,9
JV	-2,0	10,3	-1,9
MKEH	-	-	-
SMD	-6,9	6,8	-6,8
BEV	-9,0	12,0	-8,9
METAS	4,0	5,0	4,1
MIKES	2,0	-	2,1
BEV	3,0	12,0	3,1
METAS	5,0	5,0	5,1
MIKES	-3,0	-	-2,9
BIM	-	-	-
CMI	-	-	-
CEM	14,0	9,0	14,8
LNE	-4,0	7,0	-3,2
NPL	0,0	12,0	0,8
INRIM	-	-	-
VSL	-8,0	-	-7,2
GUM	-5,0	12,0	-4,2
INM	-4,0	13,0	-3,2
SP	4,0	14,9	4,8
IPQ	-11,2	26,0	-10,4

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	-0,1	5,7
Loop B	-0,8	4,8

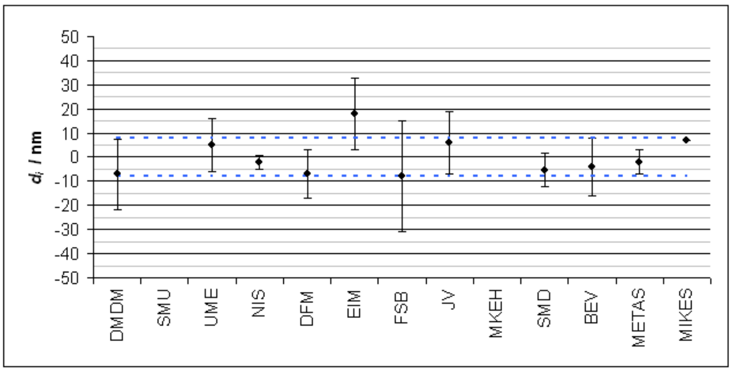


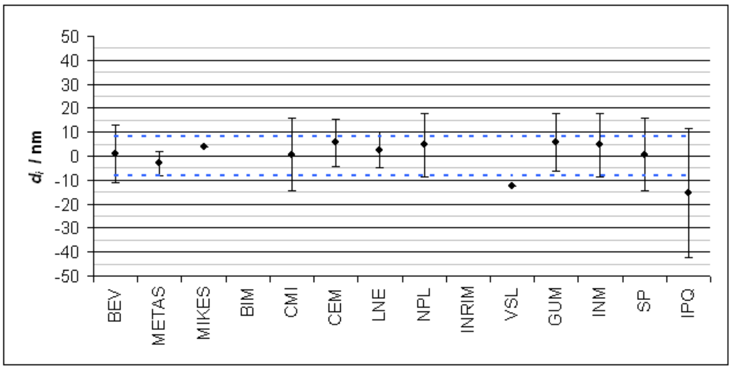


23,5 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-4,0	14,6	-7,1
SMU	-	-	-
UME	8,0	11,0	4,9
NIS	1,0	3,0	-2,1
DFM	-4,0	10,0	-7,1
EIM	21,0	15,0	17,9
FSB	-5,0	23,0	-8,1
JV	9,0	12,8	5,9
MKEH	-	-	-
SMD	-2,2	6,8	-5,3
BEV	-1,0	12,0	-4,1
METAS	1,0	5,0	-2,1
MIKES	10,0	-	6,9
BEV	4,0	12,0	0,9
METAS	0,0	5,0	-3,1
MIKES	7,0	-	3,9
BIM	-	-	-
CMI	3,0	15,2	0,6
CEM	8,0	10,0	5,6
LNE	5,0	7,3	2,6
NPL	7,0	13,0	4,6
INRIM	-	-	-
VSL	-10,0	-	-12,4
GUM	8,0	12,0	5,6
INM	7,0	13,0	4,6
SP	3,0	15,1	0,6
IPQ	-13,0	27,0	-15,4

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	3,1	8,0
Loop B	2,4	4,9

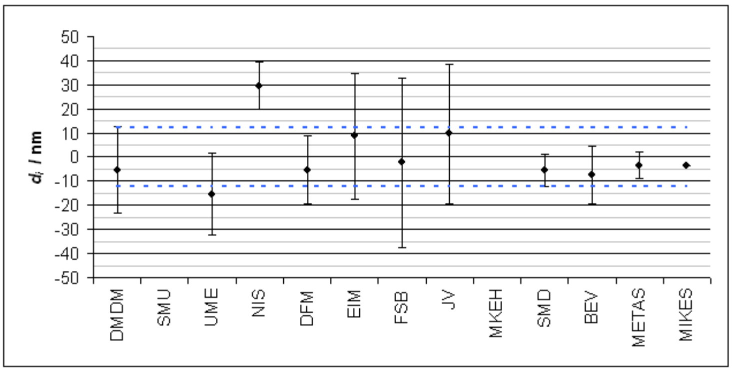


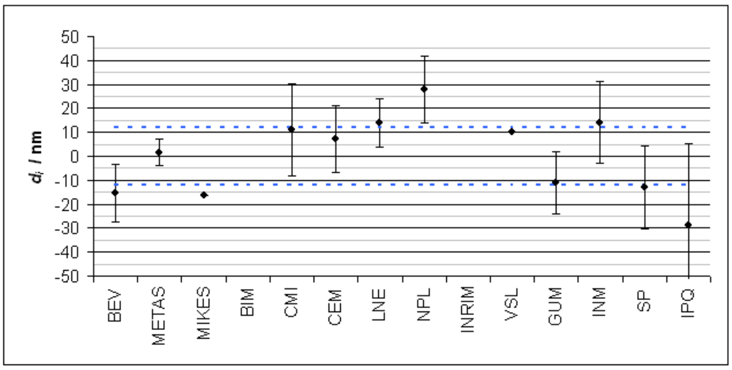


80 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-5,0	17,9	-5,4
SMU	-	-	-
UME	-15,0	17,0	-15,4
NIS	30,0	10,0	29,6
DFM	-5,0	14,0	-5,4
EIM	9,0	26,0	8,6
FSB	-2,0	35,0	-2,4
JV	10,0	29,0	9,6
MKEH	-	-	-
SMD	-5,1	6,8	-5,5
BEV	-7,0	12,0	-7,4
METAS	-3,0	5,5	-3,4
MIKES	-3,0	-	-3,4
BEV	-15,0	12,0	-15,4
METAS	2,0	5,5	1,6
MIKES	-16,0	-	-16,4
BIM	-	-	-
CMI	12,0	19,0	11,1
CEM	8,0	14,0	7,1
LNE	15,0	10,0	14,1
NPL	29,0	14,0	28,1
INRIM	-	-	-
VSL	11,0	-	10,1
GUM	-10,0	13,0	-10,9
INM	15,0	17,0	14,1
SP	-12,0	17,4	-12,9
IPQ	-27,8	34,0	-28,7

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	0,4	12,0
Loop B	0,9	11,9

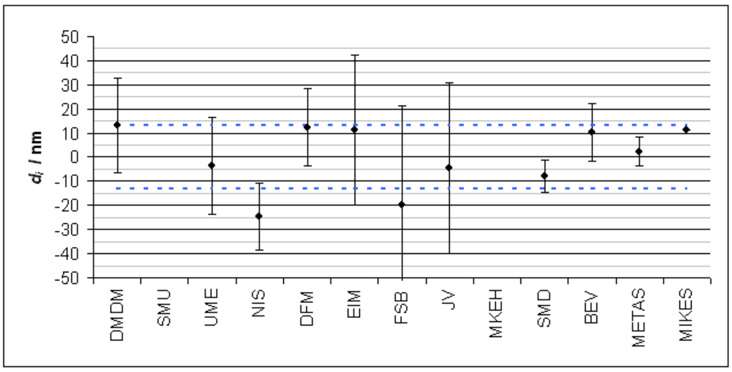


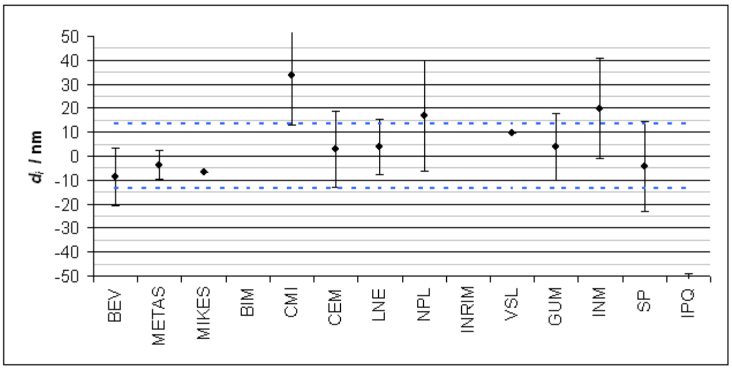


100 mm ceramic

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	17,0	19,6	13,3
SMU	-	-	-
UME	0,0	20,0	-3,7
NIS	-21,0	14,0	-24,7
DFM	16,0	16,0	12,3
EIM	15,0	31,0	11,3
FSB	-16,0	41,0	-19,7
JV	-1,0	35,4	-4,7
MKEH	-	-	-
SMD	-4,2	6,8	-7,9
BEV	14,0	12,0	10,3
METAS	6,0	6,0	2,3
MIKES	15,0	-	11,3
BEV	-5,0	12,0	-8,7
METAS	0,0	6,0	-3,7
MIKES	-3,0	-	-6,7
BIM	-	-	-
CMI	31,0	20,9	33,8
CEM	0,0	16,0	2,8
LNE	1,0	11,4	3,8
NPL	14,0	23,0	16,8
INRIM	-	-	-
VSL	7,0	-	9,8
GUM	1,0	14,0	3,8
INM	17,0	21,0	19,8
SP	-7,0	18,7	-4,2
IPQ	-89,6	38,0	-86,8

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	3,7	13,4
Loop B	-2,8	20,8

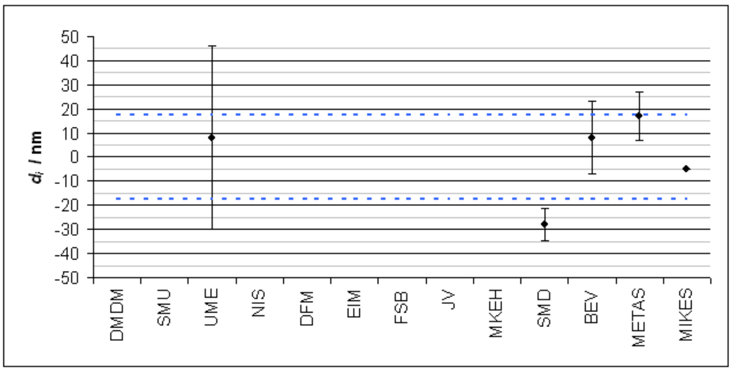


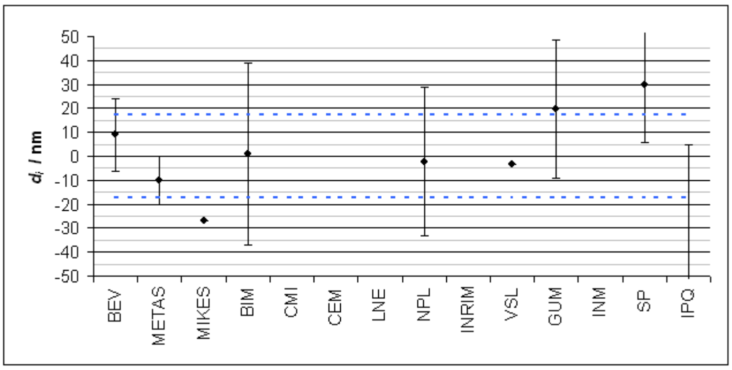


150 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-	-	-
SMU	-	-	-
UME	18,0	38,0	8,0
NIS	-	-	-
DFM	-	-	-
EIM	-	-	-
FSB	-	-	-
JV	-	-	-
MKEH	-	-	-
SMD	-17,9	6,8	-27,9
BEV	18,0	15,0	8,0
METAS	27,0	10,0	17,0
MIKES	5,0	-	-5,0
BEV	19,0	15,0	9,0
METAS	0,0	10,0	-10,0
MIKES	-17,0	-	-27,0
BIM	11,0	38,0	1,0
CMI	-	-	-
CEM	-	-	-
LNE	-	-	-
NPL	-3,0	31,0	-2,2
INRIM	-	-	-
VSL	-4,0	-	-3,2
GUM	19,0	29,0	19,8
INM	-	-	-
SP	29,0	24,0	29,8
IPQ	-60,8	65,0	-60,0

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	10,0	17,5
Loop B	-0,8	20,9

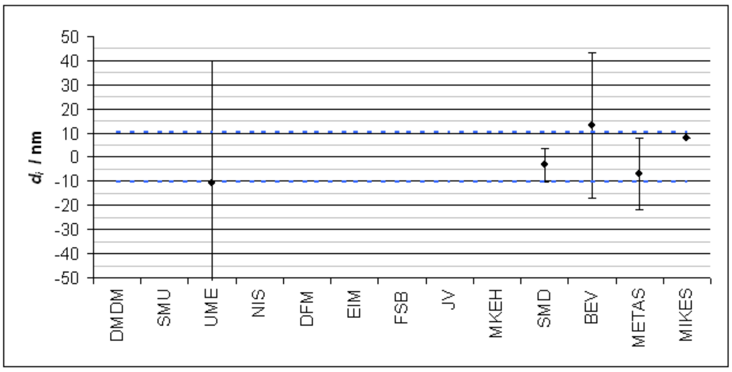


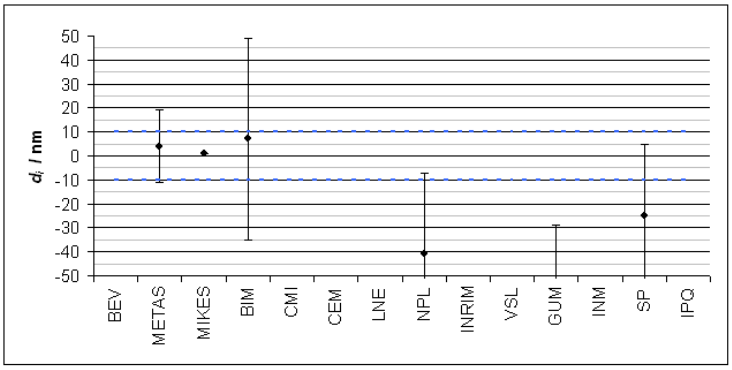


300 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-	-	-
SMU	-	-	-
UME	-3,0	51,0	-10,9
NIS	-	-	-
DFM	-	-	-
EIM	-	-	-
FSB	-	-	-
JV	-	-	-
MKEH	-	-	-
SMD	4,6	7,0	-3,3
BEV	21,0	30,0	13,1
METAS	1,0	15,0	-6,9
MIKES	16,0	-	8,1
BEV	-	-	-
METAS	12,0	15,0	4,1
MIKES	9,0	-	1,1
BIM	15,0	42,0	7,1
CMI	-	-	-
CEM	-	-	-
LNE	-	-	-
NPL	5,0	34,0	-41,0
INRIM	-	-	-
VSL	-9,0	-	-55,0
GUM	-15,0	32,0	-61,0
INM	-	-	-
SP	21,0	30,0	-25,0
IPQ	329,8	123,0	283,8

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	7,9	10,2
Loop B	46,0	88,1

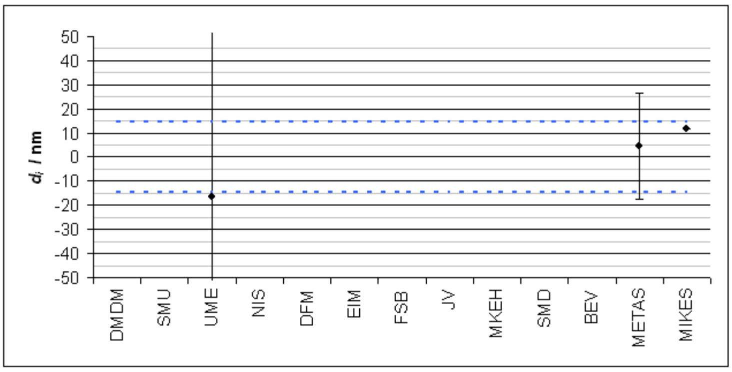


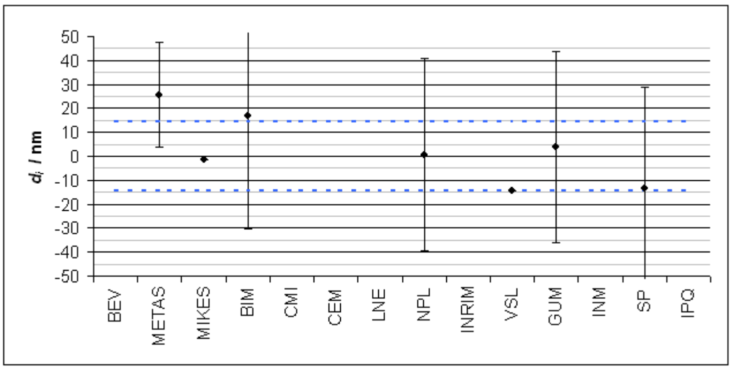


500 mm steel

Laboratory	d_C^i /nm	$u(d_C^i)$ /nm	d_i /nm
DMDM	-	-	-
SMU	-	-	-
UME	-15,0	73,0	-16,3
NIS	-	-	-
DFM	-	-	-
EIM	-	-	-
FSB	-	-	-
JV	-	-	-
MKEH	-	-	-
SMD	-	-	-
BEV	-	-	-
METAS	6,0	22,0	4,7
MIKES	13,0	-	11,7
BEV	-	-	-
METAS	27,0	22,0	25,7
MIKES	0,0	-	-1,3
BIM	18,0	47,0	16,7
CMI	-	-	-
CEM	-	-	-
LNE	-	-	-
NPL	8,0	40,0	0,7
INRIM	-	-	-
VSL	-7,0	-	-14,3
GUM	11,0	40,0	3,7
INM	-	-	-
SP	-6,0	42,0	-13,3
IPQ	-	-	-

	d_C^{ref} / nm	$s(d_C^{ref})$ / nm
Loop A	1,3	14,6
Loop B	7,3	10,3





9.3 Discussion of results

The following table is a compilation of all E_n values of this comparison. Data presented in the table is not in chronological order. Meanings of non numerical entries in the table are as follows:

—	Participant did not intend to measure the specific artifact
*	Artifact could not be measured (bad wringing etc.)
‡	Participant did not report result or could not perform measurements in allocated time
†	Different artifact (see Appendix C)
(pink)	$1 < E_n \leq 1{,}5$ (questionable result)
(red)	$1{,}5 < E_n$ (unsatisfactory result)

The classification of the E_n values is inspired from the PT-community and has no CIPM-MRA relevance. It may be considered as a visual aid only.

Table 8. E_n values for all measurement results.

Loop	Laboratory	0,5 mm Steel	1,15 mm Steel	3 mm Steel	5 mm Steel	7 mm Steel	23,5 mm Steel	80 mm Steel	100 mm Steel	0,5 mm Cer.	1,15 mm Cer.	3 mm Cer.	5 mm Cer.	7 mm Cer.	23,5 mm Cer.	80 mm Cer.	100 mm Cer.	150 mm Steel	300 mm Steel	500 mm Steel
Loop A	DMDM	0,1	0,5	1,0	0,2	0,0	0,7	0,3	0,0	0,6	0,9	1,1	0,5	1,8	1,0	0,2	0,4	—	—	—
	SMU	0,7	0,3	0,2	0,6	2,0	1,6	0,5	1,6	—	—	—	—	—	—	—	—	—	—	—
	UME	0,4	0,2	0,2	0,1	0,0	0,1	0,3	0,2	1,2	1,1	1,1	1,1	1,1	0,7	0,4	0,7	0,3	0,2	0,1
	NIS	0,6	0,5	0,6	5,6	5,6	9,1	*	12	0,0	0,1	0,3	0,3	0,5	8,8	9,2	6,4	—	—	—
	DFM	0,5	0,3	0,6	0,6	0,3	0,4	1,1	1,1	0,6	0,6	0,5	0,1	0,2	0,8	0,8	0,5	—	—	—
	EIM	0,3	0,2	0,3	0,2	0,4	0,2	0,2	0,6	0,2	0,6	0,9	0,6	0,7	0,4	0,5	1,0	—	—	—
	FSB	0,1	0,4	0,2	0,1	0,4	0,7	1,1	1,0	0,4	0,5	0,1	1,3	0,8	1,4	1,5	1,5	—	—	—
	JV	0,6	1,3	0,1	0,8	0,4	0,5	0,0	0,1	0,2	0,0	0,4	0,1	0,5	0,7	0,2	0,2	—	—	—
	MKEH	‡	‡	‡	‡	‡	‡	‡	‡	—	—	—	—	—	—	—	—	—	—	—
	SMD	*	1,0	0,8	0,2	0,2	0,8	0,7	0,4	0,5	0,7	0,6	0,1	0,5	0,8	0,7	0,2	0,0	0,4	—
	BEV	0,4	0,5	0,6	0,5	0,1	0,1	0,4	0,1	0,6	0,4	0,6	0,2	0,5	0,1	0,5	0,6	0,9	0,5	0,2
	METAS	0,5	1,4	0,5	0,8	0,5	0,6	0,5	0,4	0,4	0,4	0,6	0,3	0,5	1,0	0,8	0,1	0,3	0,0	0,0
	MIKES	0,9	0,2	0,1	0,2	0,1	0,0	0,6	0,0	0,4	0,5	0,2	0,6	0,6	0,1	0,0	0,0	0,2	0,0	0,1
Loop B	BEV	0,5	0,4	1,1	0,2	0,1	0,3	0,1	0,1	0,6	0,3	0,6	0,4	0,5	0,3	0,0	0,1	0,1	0,1	0,3
	METAS	0,4	0,1	0,3	0,6	1,0	0,6	0,3	0,8	0,3	0,2	0,1	0,1	0,0	0,4	0,2	0,1	0,4	0,3	0,2
	MIKES	0,2	0,5	0,1	0,1	0,3	0,3	0,4	1,1	0,3	0,0	0,0	0,1	0,2	0,4	0,1	0,5	0,1	0,2	0,3
	BIM	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0,7	0,3	0,0
	CMI	0,3	0,3	0,3	0,1	0,1	0,3	0,1	0,3	0,5	0,0	0,1	0,6	*	0,3	0,3	0,6	0,1	0,3	0,3
	CEM	0,6	0,0	0,5	0,8	0,1	1,4	1,9	2,0	1,8	0,6	1,9	0,1	0,8	0,5	2,5	2,4	—	—	—
	LNE	0,1	0,2	0,2	0,1	0,2	0,1	0,2	0,2	0,4	0,1	0,1	0,5	0,0	0,4	0,5	0,3	0,4	0,3	0,2
	NPL	0,2	0,2	0,2	0,4	0,2	0,0	0,1	0,3	0,4	0,0	0,1	0,3	0,2	0,2	0,8	1,3	0,1	0,0	0,1
	INRIM	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
	VSL	0,3	0,4	0,0	0,3	0,2	0,6	0,7	0,2	0,4	0,8	0,1	0,1	0,4	0,5	0,6	0,4	0,4	0,3	0,1
	GUM	0,0	0,4	0,0	0,4	0,6	0,4	0,2	0,2	0,1	0,3	0,3	0,0	0,9	0,0	0,2	0,1	0,1	0,0	0,1
	INM	0,5	0,8	0,8	0,3	0,2	0,2	5,1	5,5	0,9	1,0	0,7	0,9	1,1	0,2	0,6	7,5	—	—	—
	SP	0,0	0,3	†	0,4	0,0	0,1	0,1	0,7	0,3	0,6	0,9	0,8	0,4	0,7	0,8	0,6	0,3	0,4	0,7
	IPQ	0,1	0,0	0,0	0,8	0,5	0,6	0,6	7,2	0,6	0,7	0,6	0,6	0,8	1,0	1,1	1,2	0,1	38	—

9.4 Changes to results after Draft A.1 report

After sending draft A1 report, the pilot received no requests to change values or uncertainties (other than errors introduced by the transfer of values from the report sheets).

9.5 Comments received after Draft B.1 report

After sending draft B.1 report, the pilot received the following comments:

9.5.1 NPL comment from 29.07.2015

NPL commented mainly on the single result with E_n value larger than 1:

Regarding the single 'borderline' result for NPL on the 100 mm ceramic gauge, examining the measurement records reveals the following. We used 9.3 ppm/K for the expansion, as stated in the protocol.

B wring (NPL first wring)
Temperature = 20.018 °C, deviation = +334 nm [started at +373 nm whilst cooling from 20.078 °C]

A wring (NPL second wring)
Temperature = 20.023 °C, deviation = +348 nm [started at +393 nm before being re-wrung]

Phase correction
Determined using stack technique = −48 nm.

Mean phase corrected result, deviation = (+334 +348)/2 − 48 = +293 nm.
Result from mechanical comparator, deviation = +286 nm.

Our result is 37 nm below the KCRV but if we had used the longer results obtained during 'cooling' we would be 7 nm above the KCRV with $E_n < 1$. I do note that our 80 mm ceramic result is showing the same trend as the 100 mm ceramic, i.e. shorter than the KCRV, but is still within $E_n < 1$.

1. *The long steel gauges were measured OK so there is no alignment problem and other length dependent issues (refractive index, thermal measurement & compensation) are OK.*
2. *A bad wring would make the gauge measure longer, but we measured shorter.*
3. *A wrong CTE value would only affect the result if the temperature is far from 20 °C. On average, we measured the gauge when 20 mK 'hot', leading to a correction of only 19 nm.*
4. *All other gauges measure very well (very low E_n values), so there is nothing fundamentally wrong with our process.*
5. *There is no mention in our records of poor surface geometry and none given in the report, so it is unlikely a flatness or variation issue has caused the problem.*
6. *The trend observed for the 80 mm ceramic and 100 mm ceramic gauges suggest a possible length dependent issue for ceramic gauges only, which may suggest a thermal effect due to the poor thermal conductivity of ceramic material. This may be also affected because we wrung the ceramic gauges to steel platens.*
7. *We had some difficulty wringing the phase stack with the ceramic gauges but eventually good phase stacks were obtained in both wrings and the results for the other ceramic gauges are good, suggesting the phase correction is OK.*
8. *The mechanical comparator results for the gauges agree well with the interferometer results for all gauges in the comparison.*

Pilot: The comment has no influence on the outcome of this key comparison (no change in values or evaluation) and is reproduced here as such.

9.5.2 METAS comment from 30.07.2015

Beside some typos METAS also send suggestions for improvement. Specifically an argument on the validity of the linking process was asked for (especially since some of the linking laboratory results have E_n-values larger than one)

Pilot: Most recommendations have been included in the draft B.2 report. Also an (hand waving) argument was added in section 10.

9.5.3 GUM comment from 31.08.2015

Beside of some typos, GUM spotted severe errors in the graphs of section 9.2 (mixing up standard and expanded uncertainties, using wrong reference value). Moreover the two measurement loops were not consistently designated in the document.

Pilot: All recommendations have been included in the draft B.2 report.

9.5.4 DFM comment from 04.09.2015

DFM provided valuable suggestions on the boundary conditions for the formulas developed in section 8.1. Also some inaccurateness was pointed out regarding the time transformation for drifting artefacts.

Pilot: All recommendations have been included in the draft B.2 report.

9.5.5 DFM comment from 14.09.2015

This was a post-deadline comment. It gives additional information on artefact stability and the influence on the evaluation schema. Since this topics are of general interest this comment is reproduced here. All files mentioned in the following can be found on Google Drive, see 6.1.

Harald Bosse visited DFM last week as one of the technical assessor for the renewal of DFM's accreditation.

As part of his assessment, we discussed DFM's results in the EURAMET.L-K1.2011 comparison. As you know, we have two E_n values slightly above one for the 80 mm and 100 mm steel gauge blocks. My colleague Lars Nielsen, our local expert in data analysis and key comparisons, has performed an alternative analysis of the EURAMET.L-K1.2011 results using methods developed some time ago (see attached pdf files for details). Harald suggested that I informed you about this analysis, giving you the possibility to comment in the report (in case you find it relevant) that an alternative analysis for the 80 mm and 100 mm steel gauges gives slightly different results.

I have attached Lars' analyses in the two Excel work books.

Note that the equivalent of the E_n value is in Lars' analysis the 'normalised deviations d'. A value of $E_n = 1$ is equivalent to a value of $d = 2$; thus, $d \leq 2$ is in general fine.

For both gauge blocks, Lars' analysis reduces the number of 'questionable results' by one – in both cases DFM is affected (going from an E_n value of 1.1 to what compares to a value of 0.9 (i.e. d=1.8) in Lars' analysis).

One major difference between Lars' analysis and yours is that Lars include all consistent results in the drift estimation. There are possibly arguments for and against this method.

In any case, this additional analysis is not in any way criticism of your work, merely a supplement. Taking the uncertainties of the E_n values into account, I think both analyses give consistent results.

Pilot: The proposed analysis technique has advantages regarding the determination of a more robust KCRV with lower uncertainty. However it is not in line with the decided evaluation technique as laid down in the technical protocol.

Essentially the proposal differs in two aspects from the technique actually taken in this report.

1. It takes into account any available information for the determination of the KCRV.
2. All artefacts are modelled as having a linear time drift right from the beginning.

By taking all available data for the fit of a linear drift the respective coefficient (drift rate) can be determined with smaller uncertainty.

For example, for the 80 mm steel block, loop A, one obtains +0,94 ± 0,68 as compared to +0,78 ± 2,33 in this work (all values in nm·period^{-1}). Whilst the actual drift rate does not change significantly, the respective uncertainty is much smaller. The same holds for the constant parameter α (equ. 18), simply because the number of input data is larger. Since the uncertainty of the KCRV is smaller and the drift is now accounted for, the E_n-values tend to be smaller, too.

Unfortunately this procedure gives the laboratory performing the stability measurements a weight 5 to 7 times larger than the remaining participants. Even worse, this laboratory might not even be a participant (PTB for long blocks).

In summary this technique might be an alternative approach to evaluate future key (provided to make clear how to give equal weights to all participants). Also for an in-depth analysis of specific participants results this might be useful.

9.6 Linking of result to other comparisons

The comparison followed the protocol of the former comparison CCL-K1.2011 as closely as possible. To what extent the two comparisons can be linked to each other, and whether this brings any added value, needs to be investigated by the CCL Task Group on comparison linking (TG-L) once the final reports of the comparisons are available.

10 Conclusion

In total there were 44 E_n values larger than 1. This represents 10 % of the full set of 420 results which is a considerable high number. At least 12 of them are clearly outlier where the participants have been informed by the pilot as soon as possible. With a single exception (see discussion in section 7.2) the discrepancies have not been solved.

The comparison was conducted in two loops with two sets of artifacts. Like in similar comparisons a statistical technique for linking the reference values was applied [8, 9]. As a consequence the reference value of one loop is influenced by the measurements of the other loop although they did not even see the artifacts of the others. This influence comes solely from the “linking laboratories” which measure both sets of artifacts. This influence depends among others on the correlation of the two measurements of each linking laboratory. Taking the sample variance as an estimate yields sometimes implausible values (negative correlation) therefore a GUM type B evaluation was used (see section 8.1.3). The numerical value of the respective correlation coefficients includes some arbitrariness. Its impact was checked by variation of this parameter within a practical range. The reference values are influenced in the nm-range but the pattern of E_n values did not change at all.

For each of the three linking labs there was a single result (out of 38 each) with E_n-value slightly larger than one. The validity of the linking process is not at risk since this number is smaller the 5 % which could be expected on a statistical basis.

All artifacts were newly acquired and were monitored for stability during the comparison. The length of the 8 longest steel gauge blocks proved to decrease in time with different rates. These drift rates were included in the evaluation of the KCRV in a straightforward way by modeling the length as a linear function in time (see section 8.1.2). Care was taken to determine this drift rate with a self contained technique thus preventing any influence of the stability measurements on the KCRV as far as possible. The stability measurements of the short gauge blocks were performed by BEV (a participant), for the long blocks by PTB (not a participant). In both cases only the slope of the linear function is used for the evaluation leading to a very small additional weight of the BEV stability measurements to the KCRV of the 100 mm steel blocks. For the remaining 30 blocks with no significant drift, the KCRV is not at all influenced by the multiple stability measurements. The consideration of the drift improves the number of consistent results considerable, especially for the 100 mm gauge blocks.

The results for the supplementary measurand d_c (equation (2)) were inconclusive. This quantity is of some importance for the uncertainty estimation but is never communicated per se to clients. For this use an uncertainty value and even the sign is unimportant. For future comparison on gauge blocks this measurand should probably be no longer considered to save time in reporting.

Appendix A Equipment and measuring processes of the participants

The participants were asked to supply this information in a format ready for inclusion. Since not all participants provided an electronic version, this information has been collated in a separate PDF file `EURAMET.L-K1.2011_AppendixA.pdf`. This file includes the participant’s reports “Appendix B – Condition of Measuring Faces (short GB)”, “Appendix C – Condition of Measuring Faces (long GB)”, and “Appendix E – Description of the measurement instrument”. The same order as in section 9.1 was utilized for the laboratories. Not each participant provided all reports.

Appendix B Time dependent KCRVs

The numerical values for the KCRV together with its standard uncertainty are presented in the following table for convenience.

Table 9. KCRV of the eight unstable gauge blocks for different times. Values in parenthesis are the respective standard uncertainties. Time *t* is given in periods; all other values are given in nm.

t	100 mm loop A	100 mm loop B	150 mm loop A	150 mm loop B	300 mm loop A	300 mm loop B	500 mm loop A	500 mm loop B
0	-485,3 (10,3)	-675,5 (9,0)	-86,7 (14,8)	+248,2 (11,7)	-7601,2 (18,2)	-8306,8 (13,4)	+646,4 (24,8)	+1364,8 (18,0)
1	-490,4 (9,7)	-681,6 (8,4)	-90,5 (14,1)	+244,7 (11,0)	-7603,0 (17,7)	-8310,4 (12,9)	+641,9 (24,1)	+1358,6 (17,4)
2	-495,5 (9,2)	-687,6 (7,9)	-94,2 (13,5)	+241,1 (10,4)	-7604,9 (17,2)	-8313,9 (12,4)	+637,4 (23,5)	+1352,4 (16,8)
3	-500,6 (8,7)	-693,7 (7,4)	-98,0 (13,0)	+237,6 (9,8)	-7606,7 (16,7)	-8317,5 (12,0)	+632,9 (23,0)	+1346,3 (16,3)
4	-505,7 (8,2)	-699,7 (6,9)	-101,7 (12,4)	+234,1 (9,2)	-7608,5 (16,2)	-8321,0 (11,7)	+628,4 (22,4)	+1340,1 (15,8)
5	-510,9 (7,8)	-705,8 (6,5)	-105,5 (11,9)	+230,6 (8,7)	-7610,4 (15,8)	-8324,6 (11,3)	+624,0 (22,0)	+1333,9 (15,4)
6	-516,0 (7,3)	-711,8 (6,2)	-109,3 (11,4)	+227,0 (8,3)	-7612,2 (15,4)	-8328,1 (11,1)	+619,5 (21,5)	+1327,7 (15,1)
7	-521,1 (7,0)	-717,9 (6,0)	-113,0 (11,0)	+223,5 (7,9)	-7614,0 (15,1)	-8331,7 (10,8)	+615,0 (21,1)	+1321,5 (14,8)
8	-526,2 (6,6)	-723,9 (5,8)	-116,8 (10,7)	+220,0 (7,6)	-7615,8 (14,8)	-8335,2 (10,7)	+610,5 (20,8)	+1315,4 (14,6)
9	-531,3 (6,4)	-730,0 (5,7)	-120,5 (10,4)	+216,4 (7,5)	-7617,7 (14,5)	-8338,8 (10,6)	+606,0 (20,5)	+1309,2 (14,6)
10	-536,4 (6,2)	-736,0 (5,7)	-124,3 (10,1)	+212,9 (7,4)	-7619,5 (14,3)	-8342,3 (10,5)	+601,5 (20,2)	+1303,0 (14,6)
11	-541,5 (6,1)	-742,1 (5,8)	-128,1 (10,0)	+209,4 (7,4)	-7621,3 (14,1)	-8345,9 (10,5)	+597,0 (20,0)	+1296,8 (14,7)
12	-546,6 (6,0)	-748,1 (6,0)	-131,8 (9,9)	+205,8 (7,6)	-7623,2 (13,9)	-8349,4 (10,6)	+592,5 (19,9)	+1290,6 (14,9)
13	-551,7 (6,1)	-754,2 (6,3)	-135,6 (9,9)	+202,3 (7,8)	-7625,0 (13,8)	-8353,0 (10,8)	+588,0 (19,8)	+1284,5 (15,1)
14	-556,8 (6,2)	-760,2 (6,7)	-139,3 (9,9)	+198,8 (8,1)	-7626,8 (13,8)	-8356,5 (11,0)	+583,5 (19,8)	+1278,3 (15,5)
15	-562,0 (6,4)	-766,3 (7,1)	-143,1 (10,1)	+195,3 (8,5)	-7628,7 (13,7)	-8360,1 (11,2)	+579,1 (19,9)	+1272,1 (15,9)
16	-567,1 (6,6)	-772,3 (7,6)	-146,9 (10,3)	+191,7 (9,0)	-7630,5 (13,8)	-8363,6 (11,5)	+574,6 (20,0)	+1265,9 (16,4)
17	-572,2 (6,9)	-778,4 (8,1)	-150,6 (10,5)	+188,2 (9,6)	-7632,3 (13,9)	-8367,2 (11,9)	+570,1 (20,1)	+1259,7 (16,9)
18	-577,3 (7,3)	-784,4 (8,7)	-154,4 (10,9)	+184,7 (10,1)	-7634,1 (14,0)	-8370,7 (12,3)	+565,6 (20,3)	+1253,6 (17,5)
19	-582,4 (7,7)	-790,5 (9,2)	-158,1 (11,3)	+181,1 (10,8)	-7636,0 (14,2)	-8374,3 (12,7)	+561,1 (20,6)	+1247,4 (18,2)
20	-587,5 (8,2)	-796,5 (9,8)	-161,9 (11,7)	+177,6 (11,4)	-7637,8 (14,4)	-8377,8 (13,2)	+556,6 (20,9)	+1241,2 (18,9)
21	-592,6 (8,6)	-802,6 (10,5)	-165,7 (12,2)	+174,1 (12,1)	-7639,6 (14,7)	-8381,4 (13,7)	+552,1 (21,3)	+1235,0 (19,6)
22	-597,7 (9,2)	-808,6 (11,1)	-169,4 (12,7)	+170,5 (12,8)	-7641,5 (15,0)	-8384,9 (14,2)	+547,6 (21,7)	+1228,8 (20,4)
23	-602,8 (9,7)	-814,7 (11,8)	-173,2 (13,3)	+167,0 (13,6)	-7643,3 (15,3)	-8388,5 (14,8)	+543,1 (22,2)	+1222,7 (21,2)
24	-607,9 (10,2)	-820,7 (12,4)	-176,9 (13,9)	+163,5 (14,3)	-7645,1 (15,7)	-8392,0 (15,3)	+538,6 (22,7)	+1216,5 (22,0)
25	-613,1 (10,8)	-826,8 (13,1)	-180,7 (14,5)	+160,0 (15,1)	-7647,0 (16,1)	-8395,6 (15,9)	+534,2 (23,2)	+1210,3 (22,9)
26	-618,2 (11,4)	-832,8 (13,8)	-184,5 (15,2)	+156,4 (15,9)	-7648,8 (16,5)	-8399,1 (16,6)	+529,7 (23,8)	+1204,1 (23,7)
27	-623,3 (12,0)	-838,9 (14,4)	-188,2 (15,8)	+152,9 (16,7)	-7650,6 (17,0)	-8402,7 (17,2)	+525,2 (24,4)	+1197,9 (24,6)
28	-628,4 (12,6)	-844,9 (15,1)	-192,0 (16,5)	+149,4 (17,5)	-7652,4 (17,5)	-8406,2 (17,8)	+520,7 (25,1)	+1191,8 (25,6)
29	-633,5 (13,2)	-851,0 (15,8)	-195,7 (17,2)	+145,8 (18,3)	-7654,3 (18,0)	-8409,8 (18,5)	+516,2 (25,8)	+1185,6 (26,5)
30	-638,6 (13,8)	-857,0 (16,5)	-199,5 (17,9)	+142,3 (19,1)	-7656,1 (18,5)	-8413,3 (19,2)	+511,7 (26,5)	+1179,4 (27,5)

Appendix C Additional measurements not contributing to the KCRV

A number of additional measurement results accumulated during the run of the comparison which could not be included for different reasons. However they provide additional evidence for the results so they should be documented here.

- CMI sent two set of results, one obtained with a standard gauge block interferometer (where the blocks have to be wrung on a platen) and one set obtained with a double ended interferometer. Both are primary techniques. Taking both into account would give this lab a higher weight for the KCDB. CMI decided to use the former set which is relevant for CIPM-MRA matters. The results for the double ended interferometer are presented below.

- SMD calibrated the 150 mm, 300 mm and 500 mm gauge blocks of loop B by mechanical comparison. Since this is no primary technique the respective values must not contribute to the KCRV.

- UME calibrated the 150 mm, 300 mm and 500 mm gauge blocks of loop A by mechanical comparison. Since this is no primary technique the respective values must not contribute to the KCRV.

- PTB calibrated (beside the two sets of long gauge blocks) also the short blocks of both loops at various times. Being not a participant these values must not contribute to the KCRV.

- SP calibrated the 3 mm steel gauge block of loop B. After the measurements this very block (# 88287) was destroyed by an accident and this artefact was measured by the pilot only. This result could understandably not contribute to the KCRV. A bilateral E_n value (BEV – SP) was calculated for this measurement without trying to link it numerically to the KCRV.

The measurement results as reported by the different parties (with the exception of SP) are presented in table 10. The E_n values in table 11 were calculated using the KCRV as defined in section 8.1.

Table 10. Results e_c with standard uncertainties (in parenthesis) for the additional measurements. All values are given in nm.

Loop	Laboratory period	0,5 mm Steel	1,15 mm Steel	3 mm Steel	5 mm Steel	7 mm Steel	23,5 mm Steel	80 mm Steel	100 mm Steel	0,5 mm Cer.	1,15 mm Cer.	3 mm Cer.	5 mm Cer.	7 mm Cer.	23,5 mm Cer.	80 mm Cer.	100 mm Cer.	150 mm Steel	300 mm Steel	500 mm Steel
B	CMI 12,5	+41 (15)	+24 (15)	−4 (26)	−66 (15)	+28 (15)	+131 (16)	−349 (19)	−783 (21)	+72 (15)	+148 (17)	+67 (17)	+74 (16)	+97 (30)	+49 (15)	+72 (43)	+302 (33)	+163 (42)	−8360 (34)	+1241 (52)
B	SMD 5,5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+266 (76)	−8363 (84)	+1356 (103)
A	UME 12,5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	−127 (37)	−7570 (35)	+592 (46,5)
A	PTB 16,5	−21 (10)	−64 (10)	+44 (10)	+18 (10)	−117 (10)	−101 (11)	−249 (13)	−564 (14)	–	–	–	–	–	–	–	–	–	–	–
A	PTB 26	–	–	–	–	–	–	–	−594 (14)	+65 (15)	+146 (15)	+89 (15)	+89 (15)	−118 (15)	+40 (16)	+160 (17)	−17 (18)	−155 (17)	−7624 (15)	+583 (20)
B	PTB 26	–	–	–	–	–	–	–	−818 (14)	+73 (15)	+133 (15)	+77 (15)	+67 (15)	+109 (15)	+50 (16)	+147 (17)	+339 (18)	+155 (17)	−8367 (15)	+1210 (22)

Table 11. E_n values for the additional measurement results.

Loop	Laboratory	0,5 mm Steel	1,15 mm Steel	3 mm Steel	5 mm Steel	7 mm Steel	23,5 mm Steel	80 mm Steel	100 mm Steel	0,5 mm Cer.	1,15 mm Cer.	3 mm Cer.	5 mm Cer.	7 mm Cer.	23,5 mm Cer.	80 mm Cer.	100 mm Cer.	150 mm Steel	300 mm Steel	500 mm Steel
B	CMI	0,2	0,0	1,0	0,1	0,2	0,1	0,4	0,7	0,2	0,5	0,5	0,7	0,3	0,2	0,7	0,4	0,5	0,1	0,4
B	SMD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,2	0,2	0,1
A	UME	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,1	0,7	0,0
A	PTB	0,8	0,9	0,6	0,2	0,7	0,1	0,2	0,2	–	–	–	–	–	–	–	–	–	–	–
A	PTB	–	–	–	–	–	–	–	0,7	0,5	0,4	0,2	0,3	0,4	0,1	0,0	0,2	0,6	0,6	0,9
B	PTB	–	–	–	–	–	–	–	0,4	0,3	0,1	0,9	0,5	1,1	0,2	0,4	0,2	0,0	0,7	0,1

SP measurement on 3 mm steel block

The 3 mm steel gauge block # 88287 had been measured only by SP and the pilot BEV. The block was destroyed by an accident afterwards. These two measurements can be treated like a bilateral comparison without a numerical link to the actual key comparison. The results are shown below.

Laboratory	e_c	$u(e_c)$	E_n
BEV	+103 nm	15 nm	0,3
SP	+91 nm	12,7 nm	

Expansion coefficient – Complementary Measurements by CMI

CMI as a participant reported the linear thermal expansion coefficient for the three long gauge blocks of loop B. The values and expanded uncertainties are presented in table 12. The values are in good agreement with the data provided by PTB (table 4).

Table 12. Coefficients of linear thermal expansion as measured by CMI. The number following the symbol ± is the numerical value of the expanded (*k*=2) uncertainty.

Identification	Nominal length / mm	α / 10^{-6} K^{-1}
Loop B Nr. 110147	150	11,607 ± 0,132
	300	11,610 ± 0,066
	500	11,596 ± 0,040

Appendix D Measurement faces – Compilation of images

This appendix presents a number of assorted micrographic images of measurement faces. Different features emerging during the comparison are selected.

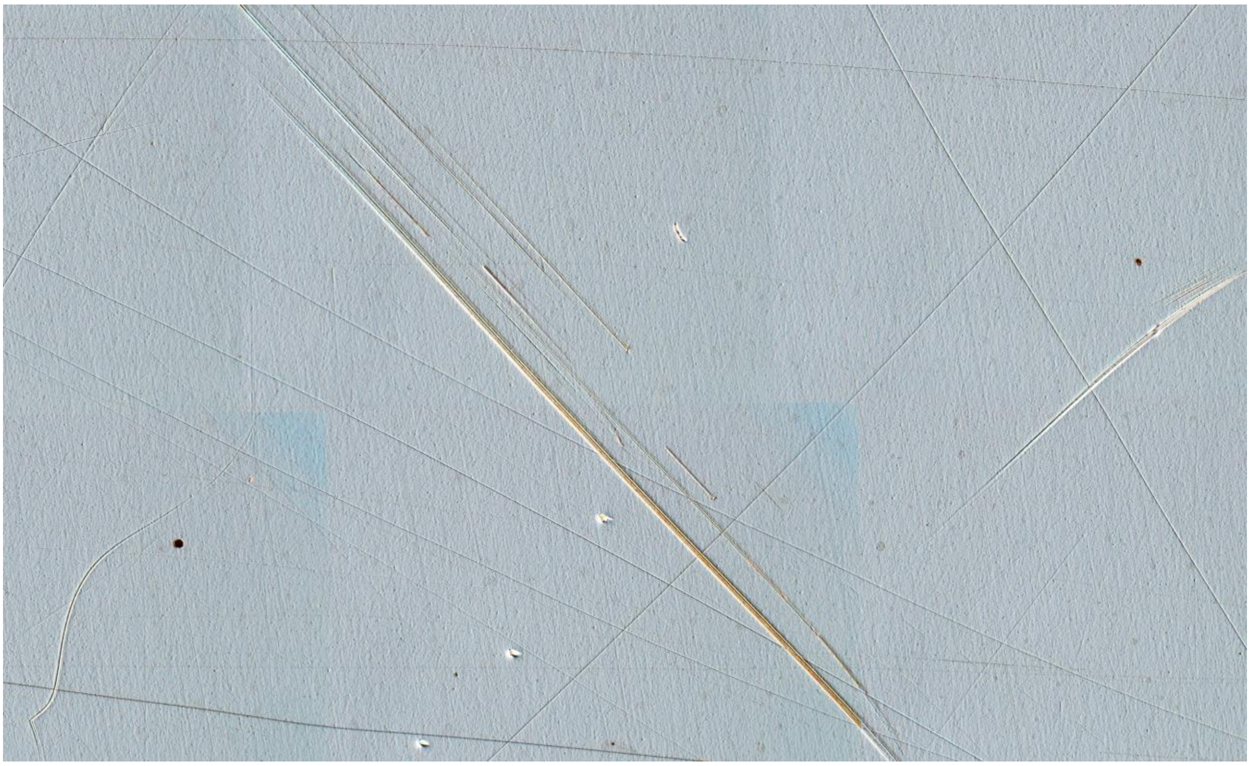


Figure D.1 – Face A of 7 mm ceramic gauge block 10710, (loop B) at period 20. This side is not wringeable any more. Differential interference contrast.

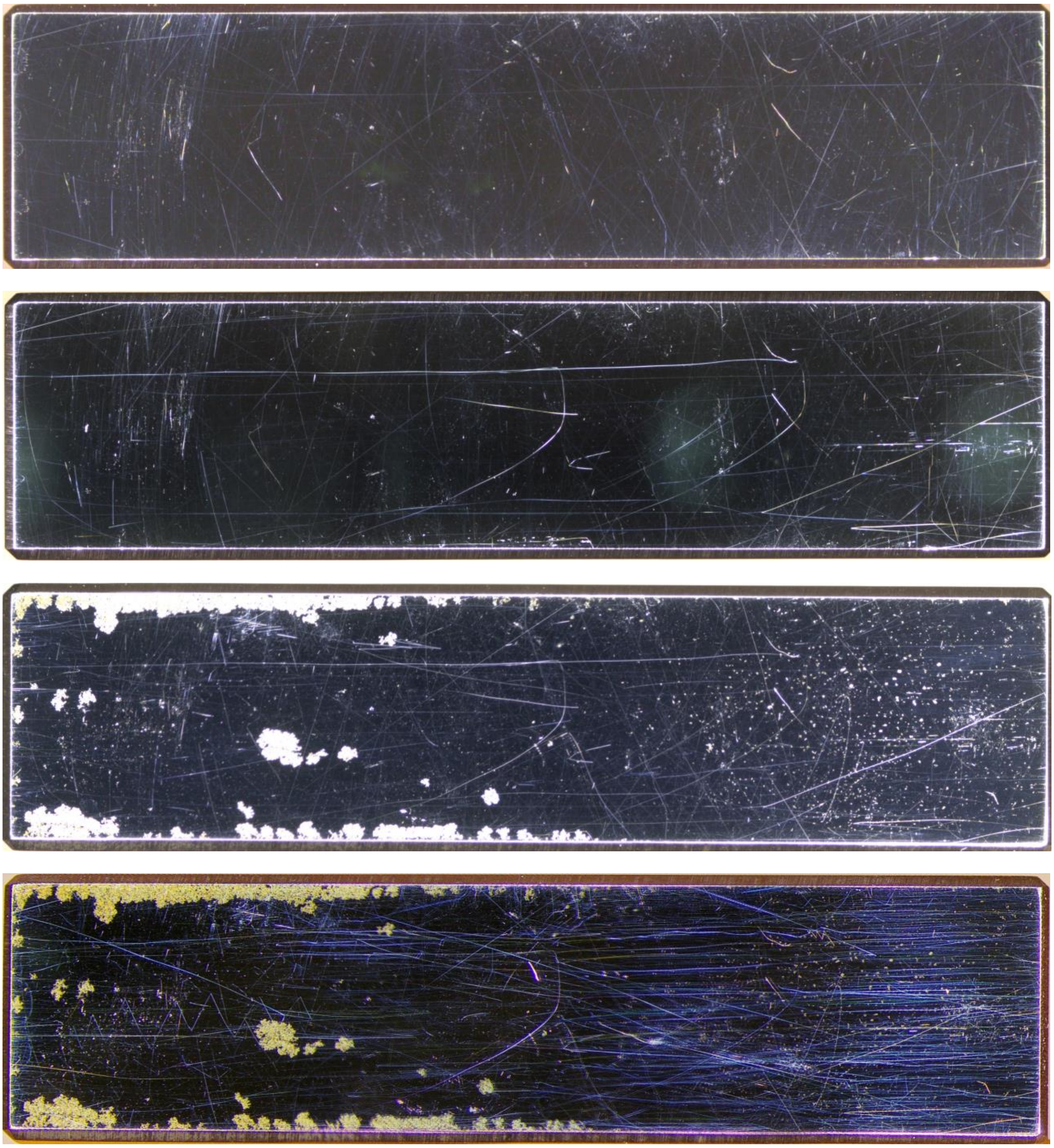


Figure D.2 – Face B of 100 mm steel gauge block 88286, (loop A). Images were taken at periods 4, 7, 17, and 20, respectively. The prominent patches and tiny dots in the last two photographs are corrosion products (rust). Dark field

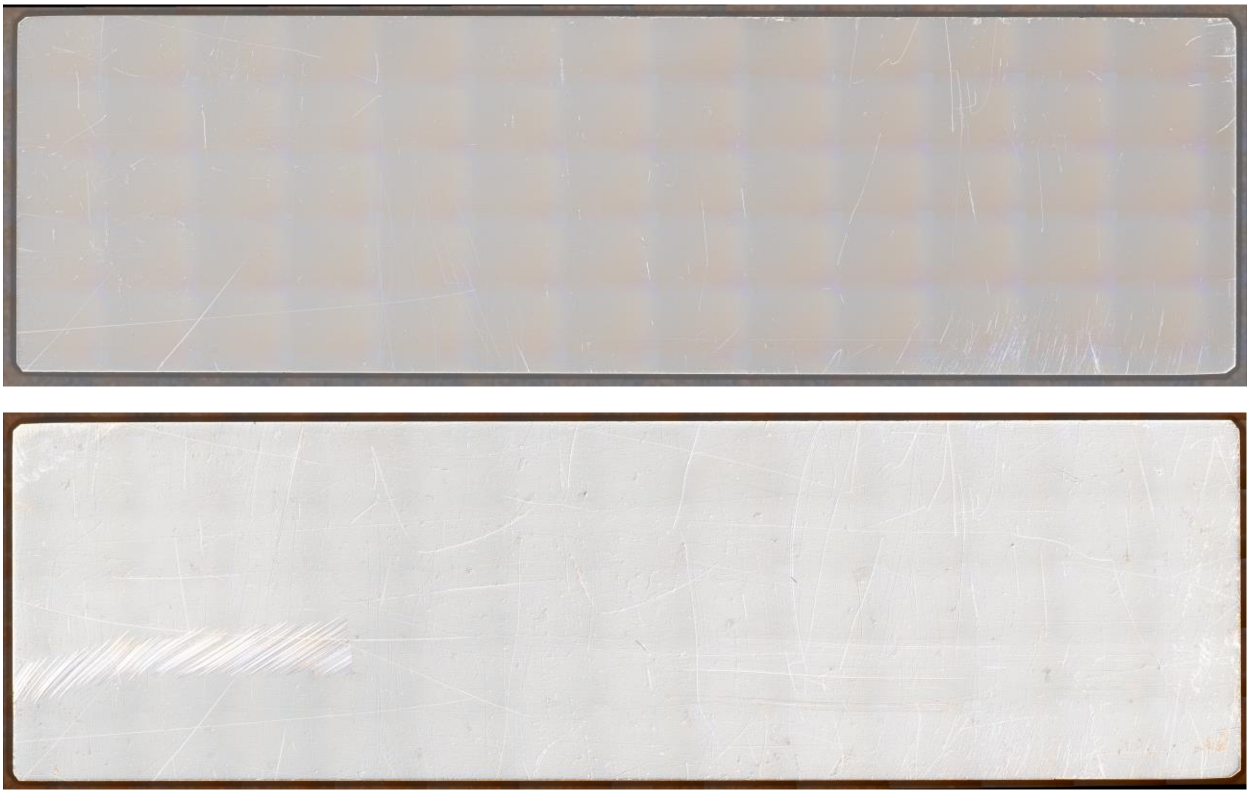


Figure D.3 – Face B of 0,5 mm steel gauge block 88286, (loop A). Images were taken at periods 7 and 17, respectively. Note the severe scratches on the left side. Differential interference contrast.

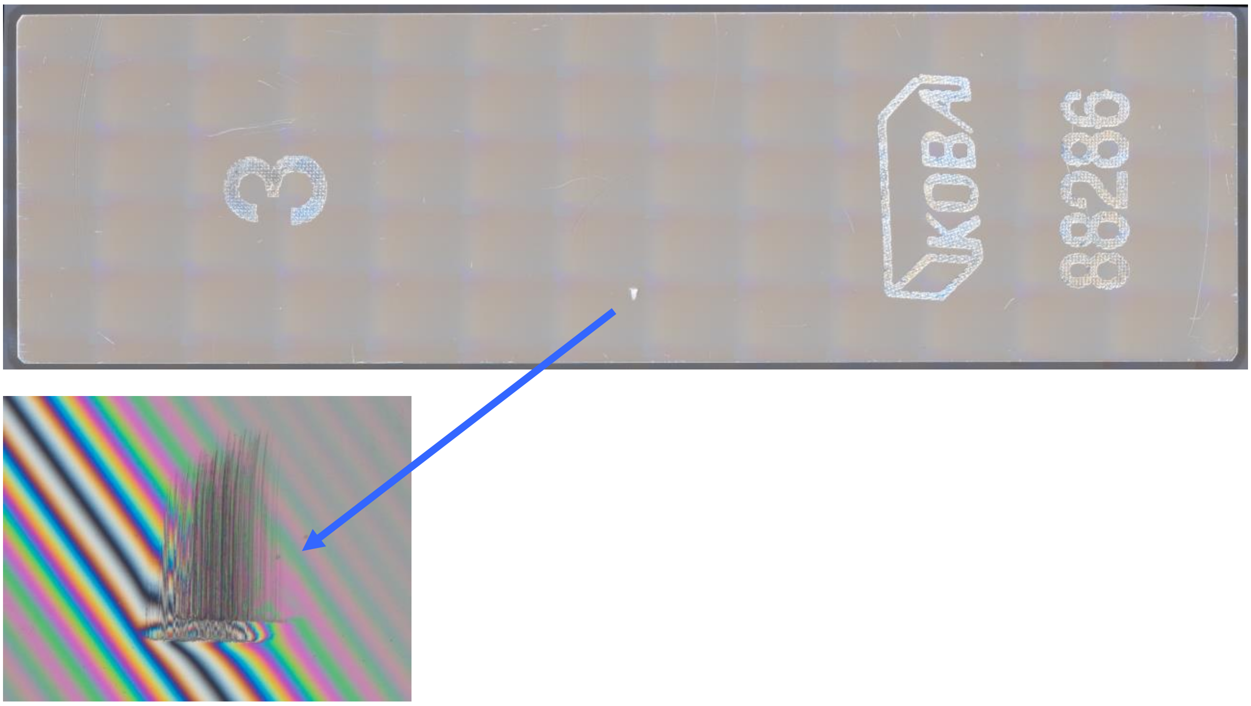


Figure D.4 – Face A of 3 mm steel gauge block 88286, (loop A). Images were taken at period 4. Differential interference contrast and total interference contrast

Appendix E CMCs as declared by the laboratories in the CIPM-MRA

The table summarizes the uncertainty claims as published in the KCDB and those given by the participants of this comparison. The published expanded uncertainties are recalculated to standard uncertainties by dividing the values by 2. The parameters a and b are according to the functional form as defined in equation (3) which were asked for in the technical protocol.

The measurement units for a and b as requested in the protocol (nm and 1, respectively) caused some confusion. Frequently b was given in 10^{-6} (instead of 1) or even in 10^{6}. To avoid this kind of confusion all length dependent contributions stated by the participants are normalized to 10^{-6} for presentation in the table 13.

The CMCs as published in the KCDB do not differentiate between gauge block materials. For this compilation steel is assumed.

Table 13. Parameters for the length dependent standard uncertainty claims as stated by the participants for this key comparison and as published in the KCDB (CMC).

NMI	End standard type	this KC a / nm	this KC b / $1{\cdot}10^{-6}$	CMC a / nm	CMC b / $1{\cdot}10^{-6}$	Comments
DMDM	Short, steel	10,1	0,105	10	0,10	
	Short, ceramic	10,1	0,095			
	Long, steel	—	—	—	—	
SMU	Short, steel	11,5	0,182	10	0,10	
	Short, ceramic	—	—			
	Long, steel	—	—	—	—	
UME	Short, steel	12,5	0,15	12,5	0,20	CMC 100mm to 300mm (a=17,5 b=0,2)
	Short, ceramic	12,5	0,096			
	Long, steel	22,5	0,093			See above
NIS	Short, steel	18	0,24	—	—	
	Short, ceramic	17	0,22	—	—	
	Long, steel	—	—	—	—	
DFM	Short, steel	11,5	0,18	11,5	0,18	For 80 mm and 100 mm could be measured on one side only.
	Short, ceramic	11,5	0,18			For those gauge blocks the assigned uncertainties are larger
	Long, steel	—	—	—	—	than calculated by a and b.
EIM	Short, steel	12,3	0,21	12,5	0,205	
	Short, ceramic	12,3	0,20			
	Long, steel	—	—	—	—	
FSB	Short, steel	15	0,25	15	0,25	
	Short, ceramic	15	0,25			
	Long, steel	—	—	—	—	
JV	Short, steel	10	0,22	13,5	0,25	
	Short, ceramic	10	0,22			
	Long, steel	—	—	—	—	
SMD	Short, steel	—	—	9,5	0,11	0,1 mm to 300 mm
	Short, ceramic	—	—			
	Long, steel	—	—	9,5	0,11	0,1 mm to 300 mm
BEV	Short, steel	15	0	12,5	0,15	
	Short, ceramic	15	0	?	?	
	Long, steel	—	—	150	0,40	Individual uncertainties for this KC
METAS	Short, steel	9,5	0,1	9,5	0,095	expanded uncertainty was stated in report, recalculated by pilot
	Short, ceramic	12	0,09			
	Long, steel	—	—	15	0,085	Individual uncertainties for this KC
MIKES	Short, steel	10	0,150	10	0,15	
	Short, ceramic	10	0,150			
	Long, steel	15	0,055	15	0,055	
BIM	Short, steel	—	—	10	0,15	
	Short, ceramic	—	—			
	Long, steel	75	0,41			(greyed out)
CMI	Short, steel	10	0,10	10	0,10	CMC range overlapping
	Short, ceramic	10	0,10			
	Long, steel	10	0,043	35	0,045	CMC range overlapping
CEM	Short, steel	9	0,16	8,5	0,15	

	Short, ceramic	9	0,14			
	Long, steel	—	—	35	0,2	
LNE	Short, steel	8	0,140	8,5	0,115	
	Short, ceramic	8	0,125			
	Long, steel	13	0,14	150	0,4	For 500 mm: *a*=131 *b*=0,37
NPL	Short, steel	9,4	0,11	9,5	0,105	
	Short, ceramic	9,4	0,11			
	Long, steel	25	0,0423	24,5	0,0415	
VSL	Short, steel	9,2	0,11	10	0,11	k = 2,03
	Short, ceramic	9,2	0,10			k = 2,03
	Long, steel	9,9	0,10	10	0,10	
GUM	Short, steel	10,5	0,10	10,5	0,10	CMC up to 305 mm
	Short, ceramic	10,5	0,09			
	Long, steel	22,4	0,14	—	—	See above
INM	Short, steel	15	0,2	15	0,1	
	Short, ceramic	—	—			
	Long, steel	—	—	—	—	
SP	Short, steel	12,7	0,190	12,5	0,25	
	Short, ceramic	13,2	0,181			
	Long, steel	18,2	0,086	10	0,10	
IPQ	Short, steel	26	0,28	13	0,14	It is striking, that stated uncertainties are twice the CMC values?
	Short, ceramic	26	0,28			
	Long, steel	26	0,40	—	—	

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