REPORT ON EURAMET Key Comparison

Measurements of Surface texture - roughness

EURAMET L-K8

(EURAMET PROJECT n° 1003)

Final Report

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CONTENT

1 VERSION CONTROL

Version Draft A.1 : issued on 05 October 2012
Version Draft B.1 : issued on 29 July 2013
Version Draft B.2 : issued on 07 October 2016
Version Draft B.3 : issued on 23 January 2017
Final report: issued on 14 February 2017
Final report: issued on 03 May 2017, taking into account comments from CCL WG-MRA reviewers

2 INTRODUCTION

At the EURAMET meeting in October 2007 it was proposed to initiate a comparison on surface roughness, this project was accepted as project n° 1003. The Pilot for the Euramet comparison is LNE – France.

The last SIM.L-S2 comparison was published in 2004. At a SIM meeting in October 30-31 2006 it was decided to initiate the next regular surface roughness comparison for the SIM region, the SIM.L-K8 with NRC – Canada being the pilot. Taking into account the limited number of participants for both regions it was decided to merge the two planned comparisons into one. The protocol was approved by all participants from both regions.

3 ORGANIZATION

3.1 Participants

Country (code)	Laboratory	Name of contact	Address	
EURAMET Labs				
1 - Croatia (HR)	DZM/LSFB - HMI	Vedran Mudronja	DZM/LSFB Ivana Lučića 5 HR-1000 Zagreb	Tel : 385 1 616 8327 Fax : 385 1 616 8599 e-mail : vedran.mudronja@fsb.hr
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3 – Estonia (EE)	AS Metrosert / TTU	Mats-Maidu Nanits	Tallinn Technical University (TTU) Laboratory of Mechanical Testing and Metrology	Tel : 202 372 620 3471 Fax : ? mnanits@staff.ttu.ee
4 – Egypt (EG)	NIS	Mohamed A. Amer	National Institute of Standards Tersa Street – El Haram EG-12211 Giza	Tel : 372 620 3471 Fax : 372 620 3196 amer@nis.sci.eg
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6 – France (FR)	LNE	José Salgado	LNE Laboratoire National de métrologie et d'Essais 1, rue Gaston Boissier F-75015 Paris	Tel : 33 1 40 43 39 57 Fax :33 1 30 16 28 31 e-mail : jose.salgado@lne.fr
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8 - United Kingdom (GB)	NPL	Andrew Lewis	National Physical Laboratory Dimensional Metrology Hampton Road TW11 OLW Teddington, Middlesex	Tel : 44 20 8943 6074 Fax :44 20 8614 0533 e-mail : andrew.lewis@npl.co.uk
SIM Labs				
9-Argentina (AR)	INTI	Fernando Kornblit	INTI, Instituto Nacional de Tecnología Industrial, Centro de Investigación y Desarrollo en Física Av. Gral Paz 5445 (1650) Prov. De Buenos Aires Argentina	Tel. +(05411) 4 755 5402 Fax +(05411) 4 713 4140 e-mail: ferk@inti.gov.ar
10-Brazil (BR)	INMETRO	Marcos Motta de Souza	INMETRO Instituto Nacional de Metrologia, Normalização e Qualidade Industrial DIMCI/DIMEC/LAMED Laboratório de Metrologia Dimensional Xerém, Duque de Caxias, R.J. Brazil	Tel. +55-21-2679-9726 Fax +55-21-26791505 e-mail: mmsouza@inmetro.gov.br
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Table 1 : Participating Laboratories

3.2 Time schedule

Each laboratory had one month for measurements, including transportation. An ATA carnet was sent with the standard, but since some participating country are not members of the ATA convention then they had to take care of customs procedures.

Country	Laboratory	Original schedule	Date of measurements	Results received
France	LNE	May 2009	May 2009	18/05/2009
Canada	NRC	June 2009	June - July 2009[1]	Withdraw
Brazil	INMETRO	July 2009	Oct. – Nov. 2009	27/12/2010
Mexico	CENAM	August 2009	August 2009	19/02/2010
Argentina	INTI	September 2009	Dec. 09 – Jan. 10	20/04/2011
USA	NIST	October 2009	Feb. – Mar. 2010	08/11/2011
Canada	NRC	November 2009	Apr. 2010[2]	Withdraw
France	LNE	December 2009	May 2010	20/05/2010
Czech Republic	CMI	January 2010	July 2010	16/09/2010
Estonia	AS Metrosert / TTU	February 2010	August 2010	16/10/2010
Croatia	DZM/LSFB - HMI	March 2010	September 2010[3]	26/11/2010
United Kingdom	NPL	April 2010	Nov. 10 – Jan.11	26/09/2011
Italy	INRIM	May 2010	Feb. – Mar. 2011	10/08/2011
Romania	INM	June 2010	June 2010	27/08/2010[4]
France	LNE	June - July 2010	Apr. - May 2011	Technical transit
Egypt	NIS	July 2010	June 2011	14/09/2011
France	LNE	August 2010	July 2011	11/10/2011
Canada	NRC	September 2010	Cancelled	/

Table 2 : Time schedule

In the SIM region a delay occurred because of customs. Therefore the time schedule had to be rearranged several times.

In April 2010 NRC could not perform the measurements and decided to withdraw from the comparison and resigned to be the pilot for the SIM region. The standards were sent to LNE. The total delay in the SIM region was 5 months.

In the EURAMET region everything went fine until NPL received the standards one month late because of customs problems between Croatia and Estonia, therefore they could not perform measurements because of insufficient environment conditions due to installation of new equipment and air conditioning problems. Therefore INRIM received the standard with 2 months delay. At the end the measurements finished 10 months later than scheduled.

[1] The measurements were done but not finalized by NRC, therefore no results were submitted.
[2] No measurement done, the standards were just transferred to LNE. NRC decided to withdraw.
[3] After measurements standards had to be sent back to AS Metrosert / TTU because of customs. Then they have been sent to NPL, this took almost one month.
[4] Softgauge results with 2RC filter : 12/06/2011

4 ARTEFACTS

4.1 Description of the artefacts

The package contains four artefacts in their leather package and enveloped in a lint free tissue: one type A1, two type C1 and one type D1 according to ISO 5436-1.

All the artefacts are manufactured by Rubert & Co (http://www.rubert.co.uk). They are all made from electroformed nickel and have a hard protective top layer of nickel-boron.

4.1.1 Type A1 Standard : Rubert reference specimen model 511E (s/n P 224)

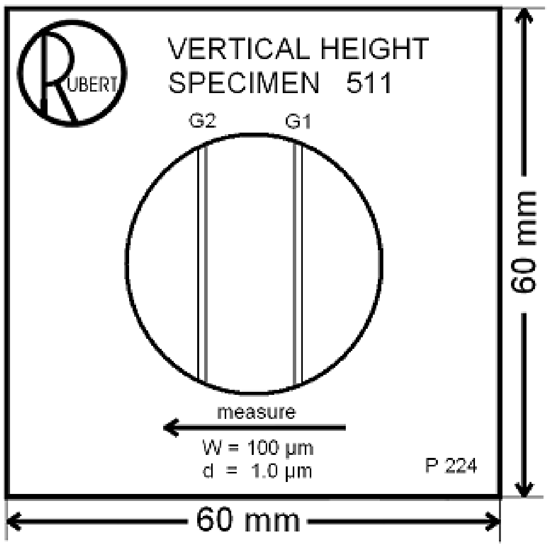


Figure 1 : Reference Specimen model 511 E

This standard has two wide grooves (G1 and G2) with flat bottoms and nominal values *D* = 1 µm and width = 100 µm. The grooves are roughly 25 mm long.

4.1.2 Type C1 standard : Rubert reference specimen model 527E (s/n PA 38)

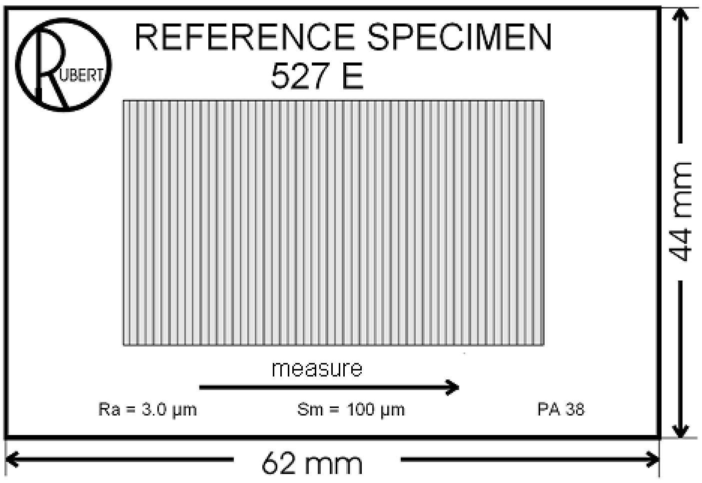


Figure 2 : Reference Specimen model 527 E

This standard has a sine wave of nominal values: *RSm* = 100 µm, *Ra* = 3 µm and *Pt* = 10 µm.

4.1.3 Type C1 standard: Rubert reference specimen model 542E (s/n P 2225)

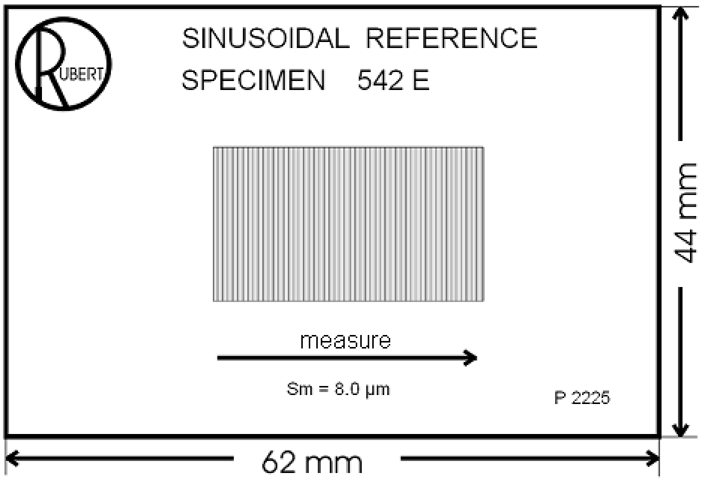


Figure 3 : Reference Specimen model 542 E

This standard has a sine wave of nominal value: *RSm* = 8 µm.

4.1.4 Type D1 standard : Rubert reference specimen model 503E (s/n P 61)

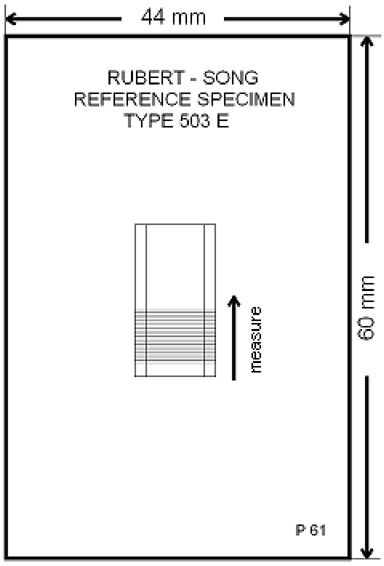


Figure 4 : Reference Specimen model 503 E

This standard has a unidirectional irregular profile with nominal value: *Ra* = 0,1 µm.

It has a 1,25 mm long profile, which is repeated 4 times.

5 MEASURING INSTRUCTIONS

5.1 Step Height

The standard model 511E has two grooves both are to be measured. The stylus instrument should scan the standard in a direction perpendicular to the grooves. The scanned data is to be “levelled” using a least squares best-fit line on the two portions marked A and B on the figure below. The step height is defined as the average depth (*d*) from the best-fitted least squares line to the middle third of the bottom of the groove – see C in Figure 5. A total of 5 scans over the central 2 mm of each groove are to be performed (see Figure 6) and the average result together with a standard deviation is reported in the appropriate table in appendix A of the technical protocol.

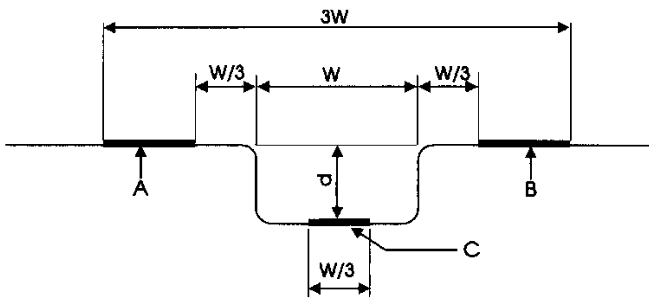


Figure 5: Assessment of the step height samples (ISO 5436-1:2000)

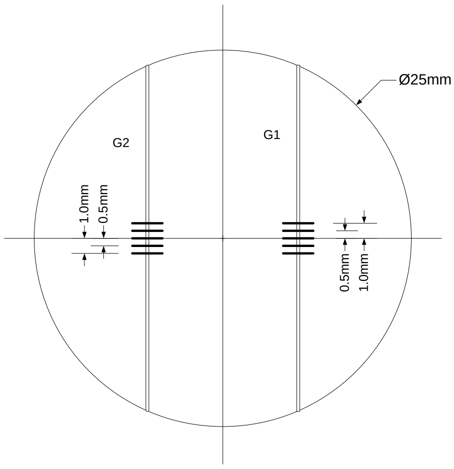


Figure 6: Measurements position for specimen 511E. Orientation is given in Figure 1.

The parameter to be calculated is *d* according to ISO 5436-1. If this cannot be measured, *Pt* (according to ISO 4287) may be substituted as an approximation, however the evaluation length for *Pt* should be limited to the equivalent region for the calculation of *d*.

5.2 Roughness artefacts

In order to reduce the influence of the standards the scans have to be done approximately in the same places. For each standard the measurement positions are given below.

The measurement parameters are given in Table 3. If it's not possible then the parameters should be as close as possible to those mentioned in Table 3.

Standard	**Evaluation length (mm)**	**λc (µm)**	**λs (µm)**	**Measuring force (mN)**	**Speed (mm/s)**	**Sampling spacing (µm)**	**Tip radius (µm)**
C1 : 527E	4,00	800	2,5	< 1	≤ 0,5	≤ 0,5	2
C1 : 542E	0,40	80	2,5	< 1	≤ 0,5	≤ 0,5	2
D1 : 503E	1,25	250	2,5	< 1	≤ 0,5	≤ 0,5	2

Table 3 : Measurement parameters for each standard

A total of twelve measurements are to be performed using a sufficient traversing length so that after filtering the evaluation length amounts to five cut-offs (λc). The cut-offs filter is to be the ISO Gaussian type, discussed in ISO standard 11562:1996.

The average result of the twelve measurements together with a standard deviation σ_{mes} is reported in the appropriate table in appendix A of the technical protocol.

5.2.1 Rubert reference specimen model 527E (s/n PA 38)

The scans are performed approximately according to the Figure 7 below.

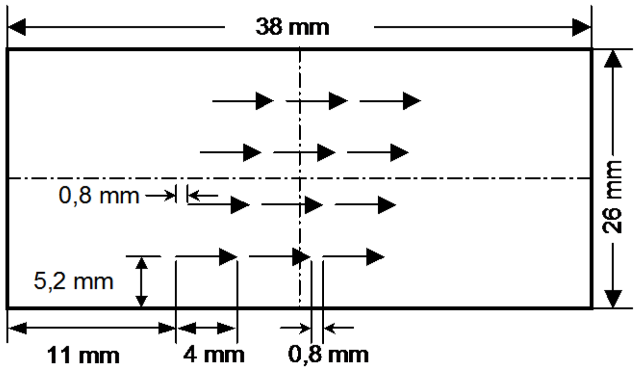


Figure 7: Measurements position for specimen 527E. Orientation is given in Figure 2.

The measurands are *Ra*, *Rz*, *RSm*, *Rt* according to ISO 4287:1997.

5.2.2 Rubert reference specimen model 542E (s/n P 2225)

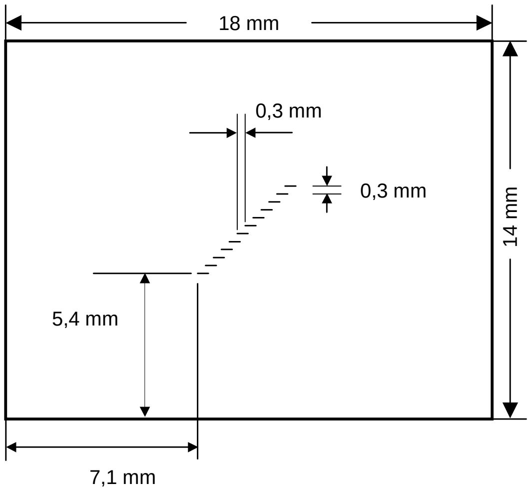


Figure 8: Measurements position for specimen 542E, evaluation length is 0,4 mm. Orientation is given in Figure 3.

The measurands are *Ra*, *Rz*, *RSm*, *Rt* according to ISO 4287:1997

5.2.3 Rubert reference specimen model 503E (s/n P 61)

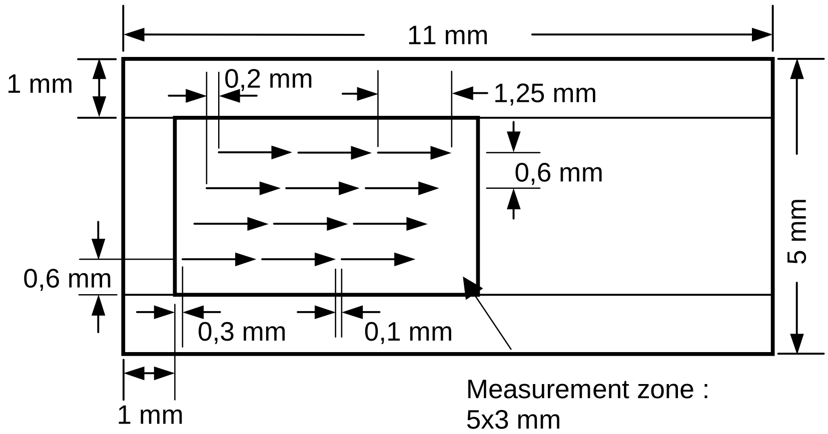


Figure 9: Measurements position for specimen 503E. Orientation is given in Figure 4.

The measurands are: *Ra*, *Rq*, *Rz*, *Rt* according to ISO 4287:1997.

5.2.4 Type F1 Softgauges

Two softgauges in 7-bit ASCII character code (*.smd format) according to ISO 5436-2 were included on a memory stick to investigate software algorithms independently of hardware variation:
LK-8_Aperiodic.smd: Aperiodic profile *LK-8_Periodic.smd*: Periodic profile
The two data files correspond to primary profiles, i.e. after removal of form but before λs filtering.
For laboratories not able to deal with the *.smd format, also files in *.prf format were available.
INRIM and INM were not able to read the files in SMD format. LNE provided them a version in PRF format (ultra, software format).

These softgauges are primary profiles and have had form removed (ISO 5436-2).

The evaluation conditions and parameters are listed in the table below.

File name	Evaluation length (mm)	λc (µm)	λs (µm)	Parameters
LK-8-Periodic	4,00	800	2,5	*Ra*, *Rq*, *Rz*, *Rt*, *RSm*
LK-8-Aperiodic	4,00	800	2,5	*Ra*, *Rq*, *Rz*, *Rt*, *Rsk*, *Rku*

Table 4 : Softgauges evaluation conditions.

6 STABILITY OF ARTEFACTS

6.1 Surfaces damages or scratches

The standard 511E, had 2 major scratches across the grooves (but not in the region of interest). Nevertheless this standard suffered from some marking which might be due to stylus.

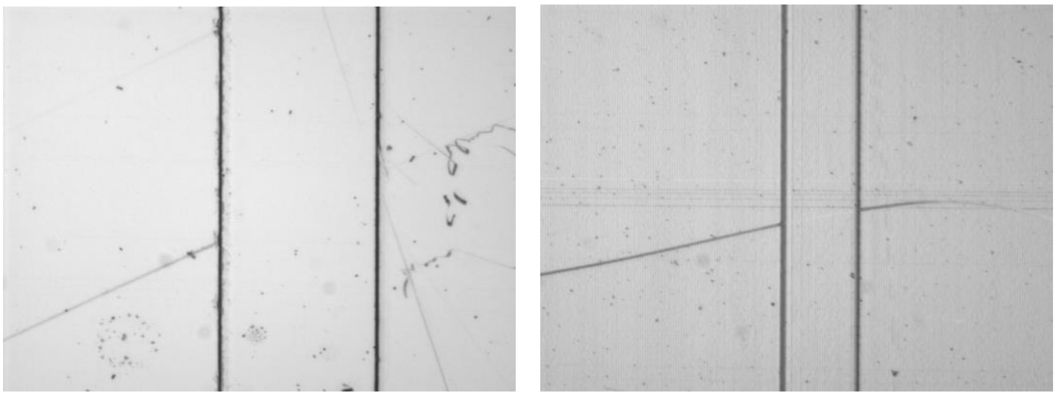


Figure 10 : Image of groove G2 (left) and G1 (right).

During the comparison, marks were generated in the measurement area:

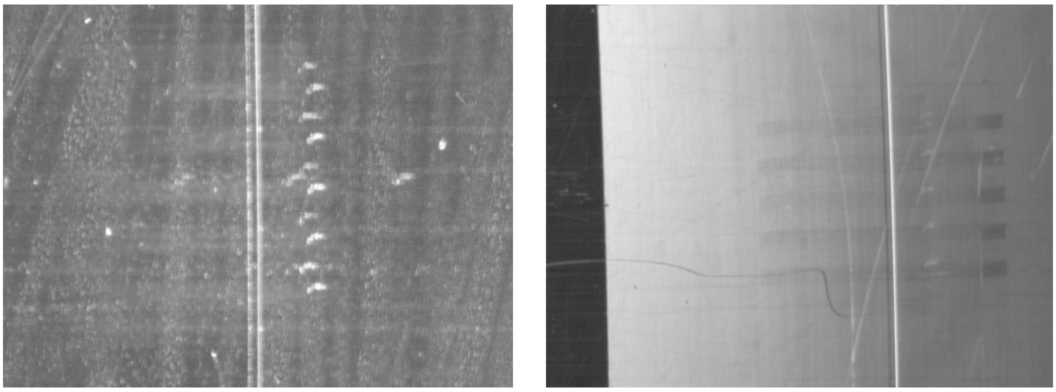


Figure 11: Images of the measurement zone of groove G2 (left) and G1 (right).

6.2 Stability of parameters values

LNE measured the samples in May 2009, in May 2010 and in July 2011, i.e. at the beginning, in the middle and at the end of the comparison. Note that only the first result in May 2009 accounts for the key comparison, the other two were to monitor the stability of the samples. For simplicity, the evaluation of these measurement data was done in the same way as for the participant's results, i.e. the deviation from the weighted mean and the E_n values were calculated for each parameter and each standard.

Parameter	Period	*xi / µm*	*ui / µm*	(x_i-x_{ref})/µm	U(x_i-x_{ref})/µm	E_n
Type A1, 511 E sn P 224						
G1, d	May 2009	0.930	0.007	0.000	0.011	0.01
	May 2010	0.932	0.007	0.002	0.011	0.17
	July 2011	0.928	0.007	-0.002	0.011	0.16
G2, d	May 2009	0.955	0.007	0.000	0.011	0.01
	May 2010	0.955	0.007	0.000	0.011	0.04
	July 2011	0.956	0.007	0.001	0.011	0.05
G1, Pt	May 2009	1.034	0.020	-0.004	0.033	0.11
	May 2010	1.043	0.020	0.005	0.033	0.17
	July 2011	1.036	0.020	-0.002	0.033	0.05
G2, Pt	May 2009	1.005	0.020	0.010	0.033	0.31
	May 2010	0.989	0.020	-0.005	0.033	0.17
	July 2011	0.990	0.020	-0.005	0.033	0.15
Type C1, 527E sn PA 38						
Ra	May 2009	2.997	0.011	-0.001	0.018	0.04
	May 2010	2.998	0.011	0.000	0.018	0.02
	July 2011	2.998	0.011	0.000	0.018	0.02
Rz	May 2009	9.450	0.033	0.006	0.054	0.12
	May 2010	9.437	0.033	-0.007	0.054	0.12
	July 2011	9.444	0.033	0.000	0.054	0.01
Rt	May 2009	9.476	0.036	0.007	0.059	0.11
	May 2010	9.468	0.036	-0.001	0.059	0.02
	July 2011	9.464	0.036	-0.005	0.059	0.09
RSm	May 2009	100.072	0.100	0.006	0.163	0.04
	May 2010	100.063	0.100	-0.003	0.163	0.02
	July 2011	100.062	0.100	-0.004	0.163	0.02
Type C1, 542E sn 2225						
Ra	May 2009	0.053	0.004	0.000	0.007	0.06
	May 2010	0.055	0.004	0.001	0.007	0.21
	July 2011	0.053	0.004	-0.001	0.007	0.15
Rz	May 2009	0.185	0.009	-0.001	0.015	0.05
	May 2010	0.189	0.009	0.003	0.015	0.22
	July 2011	0.183	0.009	-0.002	0.015	0.17
Rt	May 2009	0.195	0.015	-0.002	0.024	0.07
	May 2010	0.199	0.015	0.003	0.024	0.13
	July 2011	0.195	0.015	-0.002	0.024	0.06
RSm	May 2009	7.736	0.100	-0.005	0.163	0.03
	May 2010	7.745	0.100	0.004	0.163	0.03
	July 2011	7.741	0.100	0.000	0.163	0.00
Type D1,503E sn P 61						
Ra	May 2009	0.070	0.004	-0.001	0.007	0.22
	May 2010	0.072	0.004	0.001	0.007	0.17
	July 2011	0.072	0.004	0.000	0.007	0.05
Rq	May 2009	0.098	0.004	-0.001	0.007	0.08
	May 2010	0.100	0.004	0.002	0.007	0.31
	July 2011	0.097	0.004	-0.002	0.007	0.23
Rz	May 2009	0.710	0.015	0.012	0.023	0.54
	May 2010	0.709	0.015	0.012	0.023	0.52
	July 2011	0.630	0.025	-0.068	0.046	1.47

Rt	May 2009	0.928	0.021	0.010	0.032	0.32
	May 2010	0.938	0.021	0.020	0.032	0.63
	July 2011	0.825	0.037	-0.093	0.069	1.36

Table 5: Stability measurements

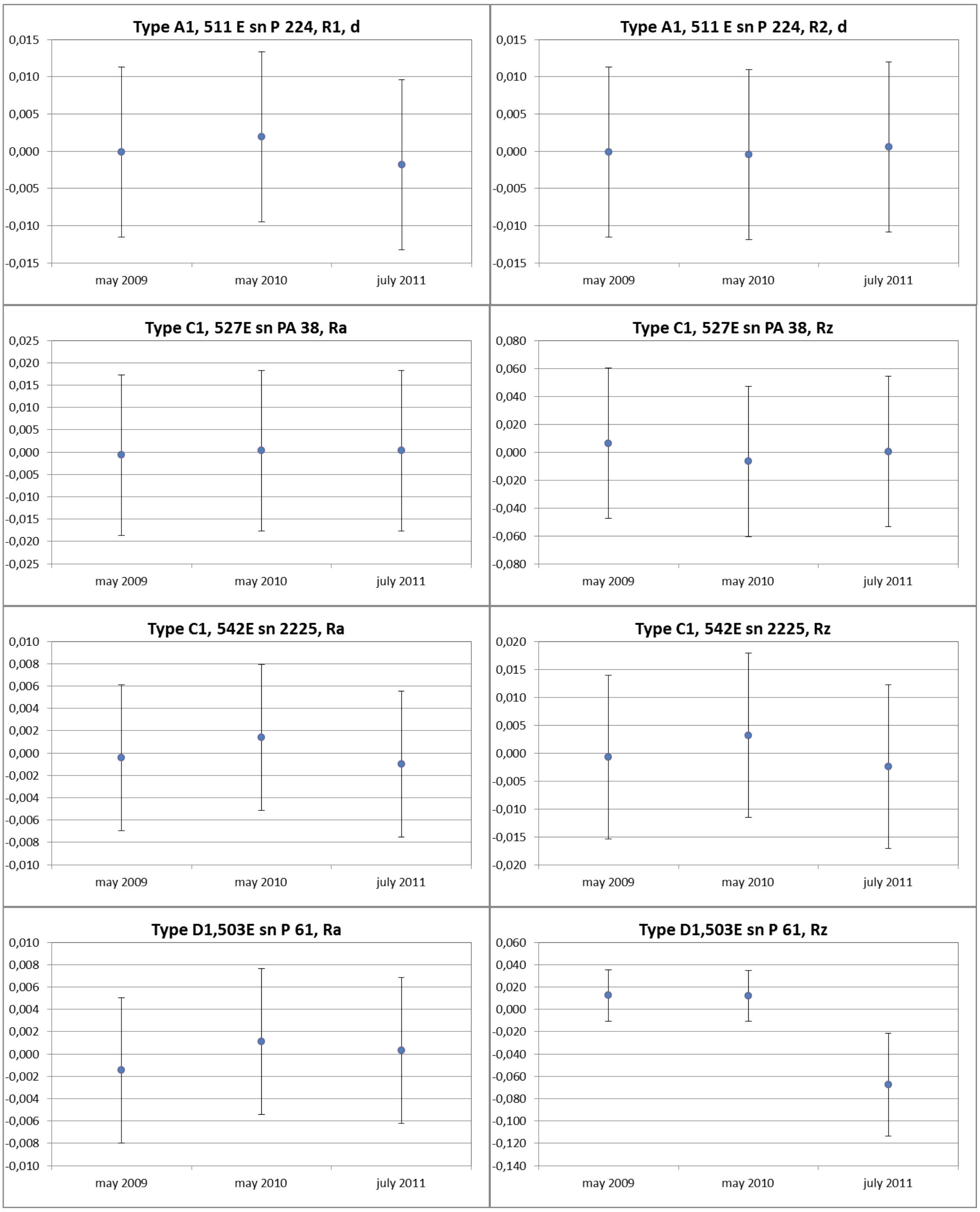
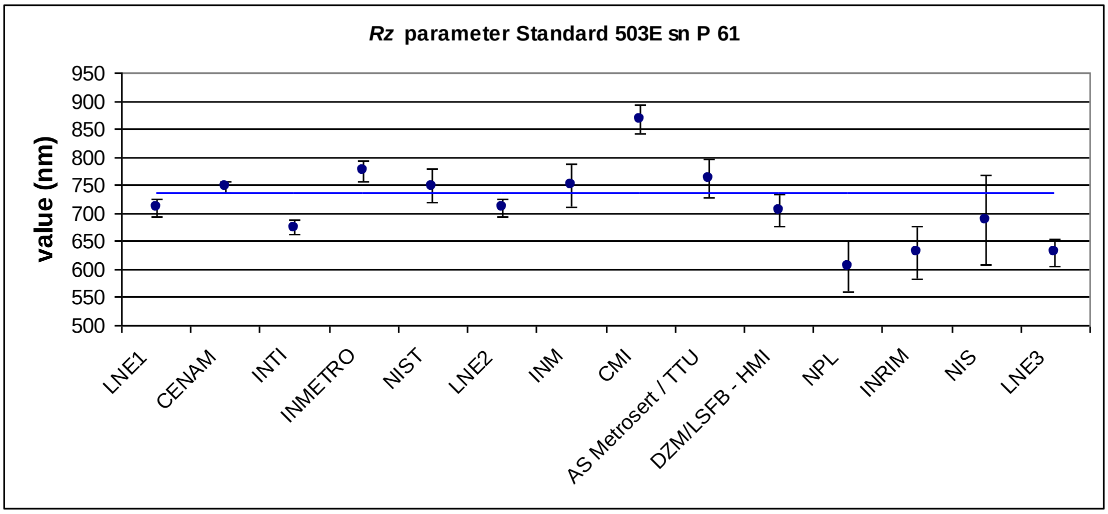


Figure 12: Stability measurements for selected standards and parameters (uncertainty bars for *k* = 2).

The plots representing the set of 3 measurements and it's mean value for each parameter and standards are given in appendix A. Except for reference specimen 503E, no drift or anything else have been seen.

For reference specimen 503E a drop in *Rz* (~70 nm) and *Rt* (~110 nm) occurred between May 2010 and July 2011 (see Figure 12).



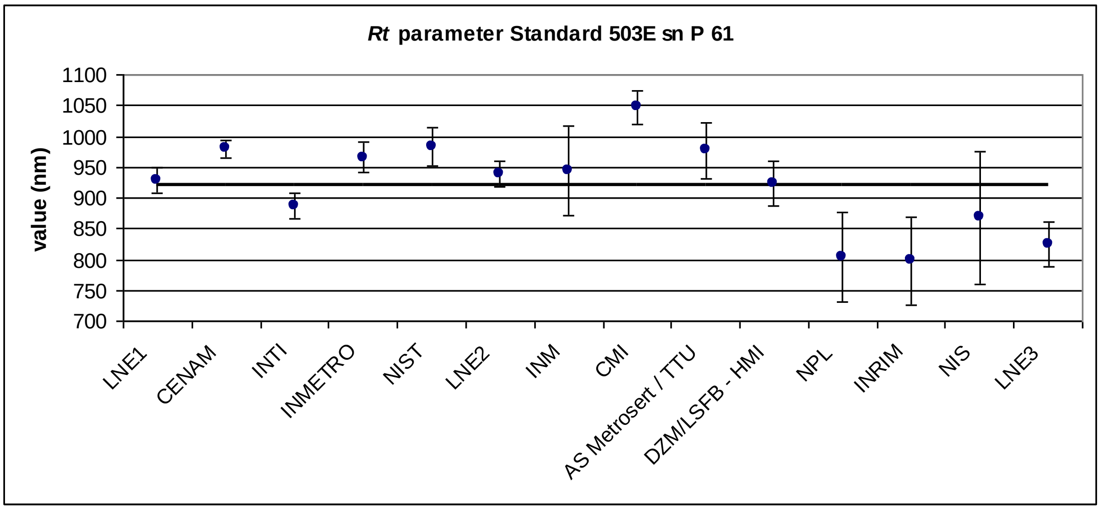


Figure 13: Stability of *Rz* and *Rt* parameter for reference specimen 503E. Errors bars represent the standard uncertainty. Horizontal lines represents the reference value. Results are plotted in chronological order and includes the 3 measurements made by the LNE (see Figure 12)

7 RESULTS

As stated in the technical protocol all the spacing values are given as an order of magnitude. They are not strict values, but following these values as close as possible will be best.

The participating laboratories report results to the pilot laboratory. Their reports should contain:

- the measurement set-up and conditions,

And in a table format (see Table 6)

- the results of measurements (average and standard deviation),
- the combined standard uncertainty,
- the complete uncertainty budget,
- the degrees of freedom.

Parameter	Value (µm)	σ_{mes}	u_C (nm)	n_{eff}
Ra				
Rz				
Rt				
RSm				

Table 6: Format table of how results had to be reported.

8 ANALYSIS OF THE MEASUREMENTS RESULTS

8.1 Reference value and Birge ratio:

For the comparison the distribution of the measured values is assumed to be normal. The reference value KCRV can be calculated using different approaches: the weighted mean (used for some previous Key Comparisons) and the simple arithmetic mean. Since there is a wide spread of uncertainties, the weighted mean is preferred.

Below are the formulae for the weighted mean and its uncertainty:

$$x_{ref} = \sum_{i=1}^{n} w_i \cdot x_i \qquad \text{Eq (1)}$$

Where :

$$w_i = \frac{C}{u^2(x_i)} \quad \text{and} \quad C = \frac{1}{\sum_{i=1}^{n} \frac{1}{u^2(x_i)}} \qquad \text{Eq (2)}$$

The uncertainty of the weighted mean is calculated by :

$$u(x_{ref}) = \sqrt{C} \qquad \text{Eq (3)}$$

After deriving the weighted mean and its associated standard uncertainty, the deviation of each laboratory's result from the weighted mean is determined simply as x_i-x_{ref}. The uncertainty of this deviation is calculated as a combination of the uncertainties of the result, $u(x_i)$, and the uncertainty of the weighted mean $u(x_{ref})$. The uncertainty of the deviation from the weighted mean is given by

$$u(x_i - x_{ref}) = \sqrt{\left(u(x_i)^2 - u(x_{ref})^2\right)} \qquad \text{Eq (4)}$$

In the result x_i contributes to the KCRV, and

$$u(x_i - x_{ref}) = \sqrt{\left(u(x_i)^2 + u(x_{ref})^2\right)} \qquad \text{Eq (5)}$$

In the result x_i doesn't contributes to the KCRV

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 Birge ratio R_B which compares the observed spread of the results with the spread expected from the individual reported uncertainties.

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

$$R_B = \frac{u_{ext}}{u_{in}} \qquad \text{Eq (6)}$$

where u_{in}, the internal standard deviation, is given by the reported uncertainties

$$u_{in} = \left(\sum_{i=1}^{n} u^{-2}(x_i) \right)^{-1/2} \qquad \text{Eq (7)}$$

and the external standard deviation u_{ext} is the standard deviation of the spread of the results x_i, weighted by the associated uncertainties $u(x_i)$:

$$u_{ext} = \sqrt{\frac{\sum_{i=1}^{N} w_i (x_i - x_{ref})^2}{(N-1)\sum_{i=1}^{N} w_i}} \qquad \text{Eq (8)}$$

Where N is 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

$$R_B < \sqrt{1+\sqrt{8/(N-1)}} \qquad \text{Eq (9)}$$

As an example, for the case N = 12, a value R_B < 1.36 indicates consistency (for k = 2).

For each laboratory's result the E_n value is calculated, where E_n is defined as the ratio of the deviation from the weighted mean, divided by the expanded uncertainty of this deviation:

$$E_n = \frac{\left| x_i - x_{ref} \right|}{2 \cdot \sqrt{\left(u^2(x_i) - u^2(x_{ref}) \right)}} \qquad \text{Eq (10)}$$

If statistical consistency according to equation (9) is not given, the result with the largest E_n is identified and excluded from the reference value and R_B is calculated again. This process of excluding the result with the largest E_n from contributing to the weighted mean is iterated until statistical consistency is reached.

Because inconsistent results are no longer correlated with the weighted mean, when calculating their *En* value a positive sign is applied in the denominator of equation (10):

$$E_n = \frac{\left| x_i - x_{ref} \right|}{2 \cdot \sqrt{\left(u^2(x_i) + u^2(x_{ref}) \right)}} \qquad \text{Eq (11)}$$

8.2 Results Reference Values and Degree of Equivalence

In the following, an extract of the Excel table *EURAMET.L-K8.2013-evaluation.xlsx* is given for each standard and each measurand. Laboratories starting with the largest E_n

values were excluded (highlighted) until consistency according to the Birge ratio criterion was reached. E_n values larger than 1 are highlighted. Tables show final values of x_i and E_n for consistent Birge ratio R_B. All graphs show the deviations (x_i - x_w) from the weighted mean key comparison reference value in µm with uncertainties expanded with k = 2.

8.2.1 General comments from participants

NIST: The stylus tip diameter was measured to be 1.46 µm. For specimen 503E, the data profiles were dilated using a morphological filter approximating the nominal tip size of a 2 µm tip. In our experience, surfaces with relatively steep slopes can have significant differences in some calculated parameters depending on the stylus geometry/size used to measure. Therefore, the data was dilated to make sure NIST results were comparable to other laboratory's results where 2 µm tips were used.

8.2.2 Rubert reference specimen model 511E (s/n P 224)

All the reported results for depth standard 511E sn P 224 are given below. INMETRO and DZM/LSFB-HMI have been removed from the calculation of the reference value since the reported errors in there measurements (see §8.4).

8.2.2.1 *d* parameter groove G1

select gauge	1	Type A1, 511 E sn P 224, G1, d			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	*k*	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	0.92990	0.00820	0.00700	32	1	-0.00176	2.00	0.01349	0.13	0.07
CENAM	0.93000	0.00570	0.01190	165	1	-0.00166	2.00	0.02351	0.07	0.02
INTI	0.92900	0.00500	0.01300	17	1	-0.00266	2.00	0.02573	0.10	0.02
INMETRO	0.95400	0.00025	0.01100	68	0	0.02234	2.00	0.02231	1.00	0.00
NIST	0.93024	0.00204	0.00307	10000	1	-0.00142	2.00	0.00488	0.29	0.37
INM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
CMI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
AS Metrosert / TTU	0.93400	0.00500	0.03500	10000	1	0.00234	2.00	0.06990	0.03	0.00
DZM/LSFB - HMI	0.89900	0.00900	0.01510	314	0	-0.03266	2.00	0.03043	1.07	0.00
NPL	0.92920	0.00162	0.00470	3	1	-0.00246	2.00	0.00863	0.29	0.16
INRIM	0.93480	0.00300	0.00320	47	1	0.00314	2.00	0.00520	0.60	0.34
NIS	0.93530	0.00310	0.01450	91	1	0.00364	2.00	0.02876	0.13	0.02

	x_{ref}		$u(x_{ref})$	ν_{eff}	$N - 1$		k_{ref}
Reference value	**0.9317**		**0.0019**	**84**	**7**		**2.00**
C	3.47E-06						

Consistency:		
u_{ext}	0.001	
R_B	0.484	**Birge ok**
Limit	1.438	

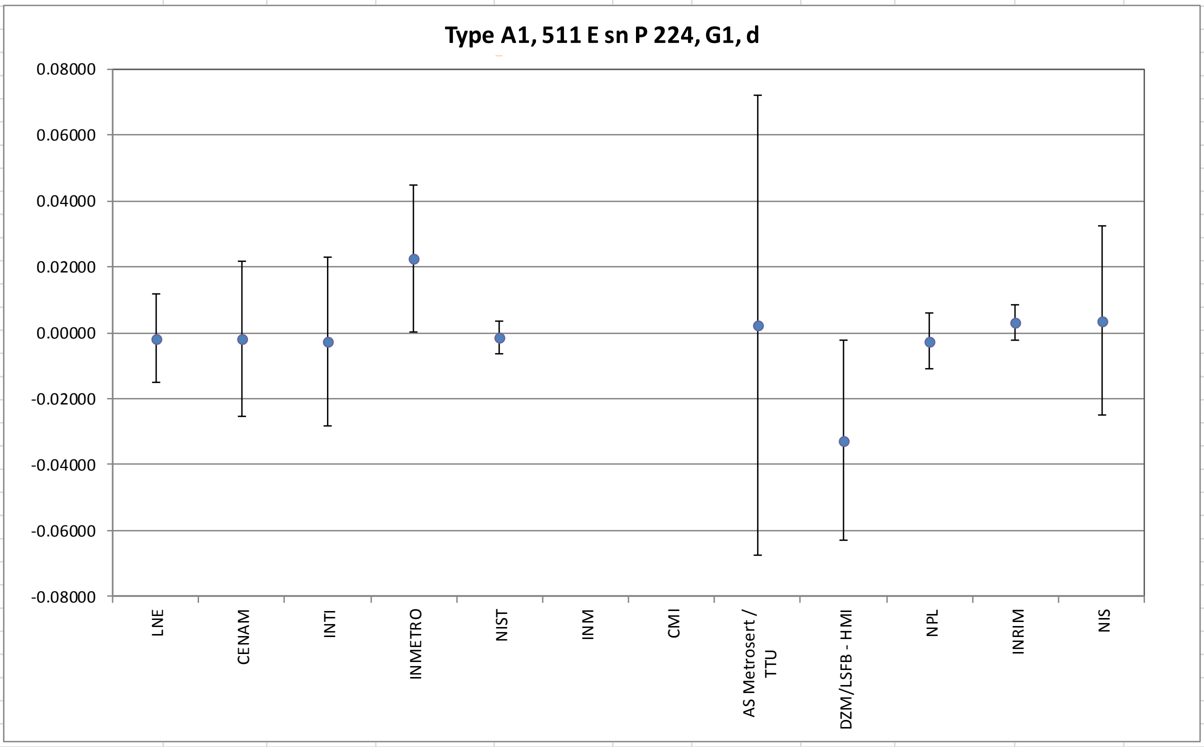


Figure 14: Specimen 511E s/n P224: Groove G1, depth parameter *d* results.

8.2.2.2 *d* parameter groove G2

select gauge	2	Type A1, 511 E sn P 224, G2, d			use 1 or 0 to in- or exclude		choose: $k=2$			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	k	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	0.95480	0.00850	0.00700	32	1	-0.00138	2.00	0.01369	0.10	0.04
CENAM	0.95100	0.00370	0.01190	165	1	-0.00518	2.00	0.02362	0.22	0.01
INTI	0.95600	0.00500	0.01300	17	1	-0.00018	2.00	0.02584	0.01	0.01
INMETRO	0.99600	0.00030	0.01100	68	0	0.03982	2.00	0.02219	1.79	0.00
NIST	0.95240	0.00088	0.00252	10000	1	-0.00378	2.00	0.00411	0.92	0.33
INM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
CMI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
AS Metrosert / TTU	0.95400	0.00300	0.03500	10000	1	-0.00218	2.00	0.06994	0.03	0.00
DZM/LSFB - HMI	0.92180	0.00200	0.00820	212	0	-0.03438	2.00	0.01666	2.06	0.00
NPL	0.95320	0.00115	0.00340	3	1	-0.00298	2.00	0.00615	0.48	0.18
INRIM	0.96100	0.00130	0.00230	126	1	0.00482	2.00	0.00356	1.35	0.40
NIS	0.95770	0.00350	0.01460	93	1	0.00152	2.00	0.02905	0.05	0.01

	x_{ref}		$u(x_{ref})$	ν_{eff}	$N - 1$		k_{ref}
Reference value	**0.9562**		**0.0015**	**68**	**7**		**2.00**
C	2.12E-06						

Consistency:		
u_{ext}	0.002	
R_B	1.046	**Birge ok**
Limit	1.438	

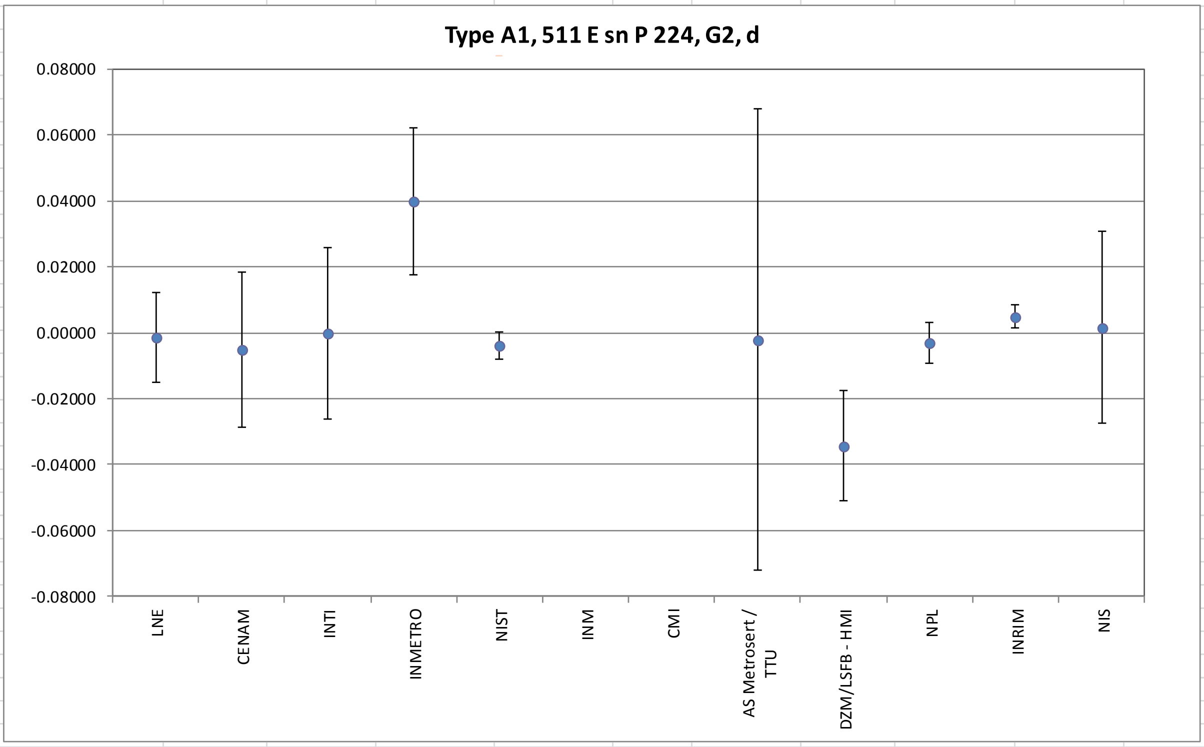


Figure 15: Specimen 511E s/n P224: Groove G2, depth parameter *d* results.

8.2.2.3 *Pt* parameter groove G1

select gauge	3	Type A1, 511 E sn P 224, G1, Pt			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i$-$x_{ref})$/µm	k	$U(x_i$-$x_{ref})$/µm	E_n	w_i
LNE	1.03380	0.01340	0.02000	36	1	-0.00315	2.00	0.02933	0.11	0.46
CENAM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INTI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INMETRO	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NIST	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INM	1.04169	0.01512	0.02616	56	1	0.00474	2.00	0.04469	0.11	0.27
CMI	1.03760	0.00960	0.02630	5653	1	0.00065	2.00	0.04502	0.01	0.27
AS Metrosert / TTU	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
DZM/LSFB - HMI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NPL	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INRIM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NIS	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00

	x_{ref}		$u(x_{ref})$	ν_{eff}	N - 1		k_{ref}
Reference value	**1.0369**		**0.0136**	**138**	**2**		**2.00**
C	1.85E-04						

Consistency:		
u_{ext}	0.002	
R_B	0.171	**Birge ok**
Limit	1.732	

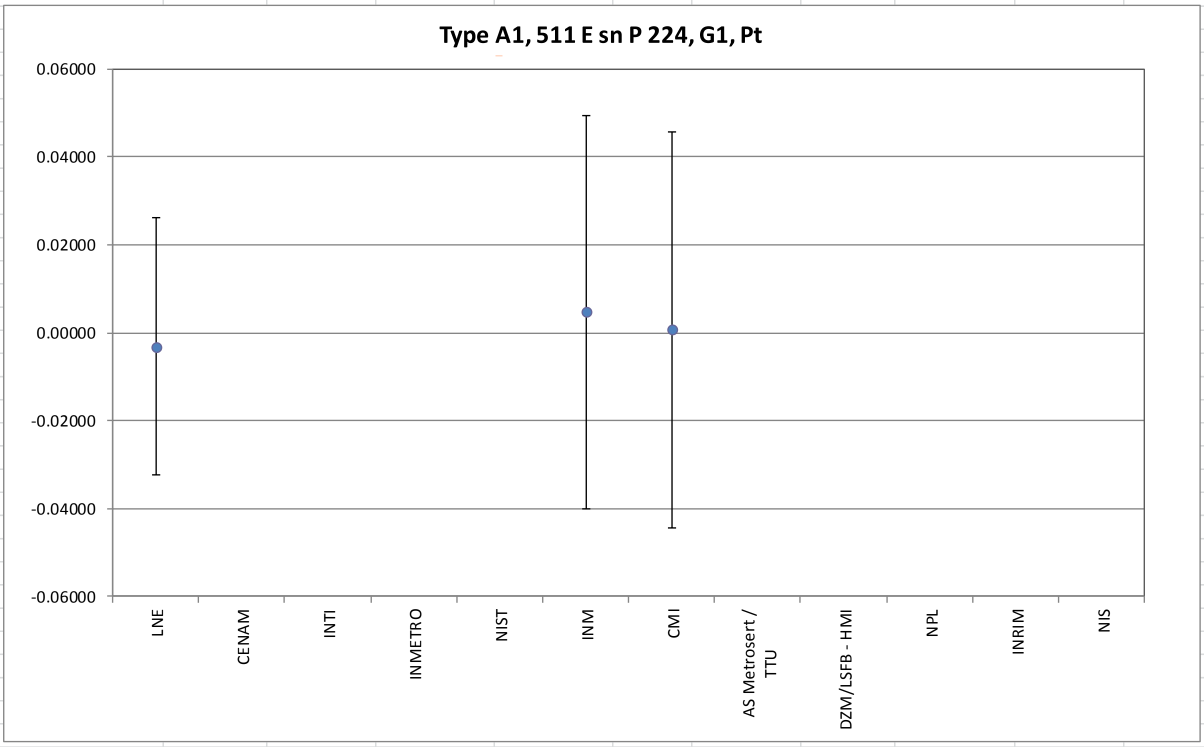


Figure 16: Specimen 511E s/n P224: Groove G1, *Pt* parameter results.

8.2.2.4 *Pt* parameter groove G2

select gauge: 4 — Type A1, 511 E sn P 224, G2, Pt

use 1 or 0 to in- or exclude

choose: k=2

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	k	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	1.00480	0.01120	0.02000	40	1	-0.02398	2.00	0.02816	0.85	0.50
CENAM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INTI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INMETRO	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NIST	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INM	1.07609	0.02125	0.03052	17	1	0.04731	2.00	0.05403	0.88	0.22
CMI	1.03540	0.01630	0.02690	744	1	0.00662	2.00	0.04569	0.14	0.28
AS Metrosert / TTU	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
DZM/LSFB - HMI	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NPL	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
INRIM	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
NIS	0.00000	0.00000	0.00000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00

	x_{ref}	$u(x_{ref})$	ν_{eff}	$N - 1$	k_{ref}
Reference value	**1.0288**	**0.0142**	**108**	**2**	**2.00**

C 2.02E-04

Consistency:		
u_{ext}	0.020	
R_B	1.397	**Birge ok**
Limit	1.732	

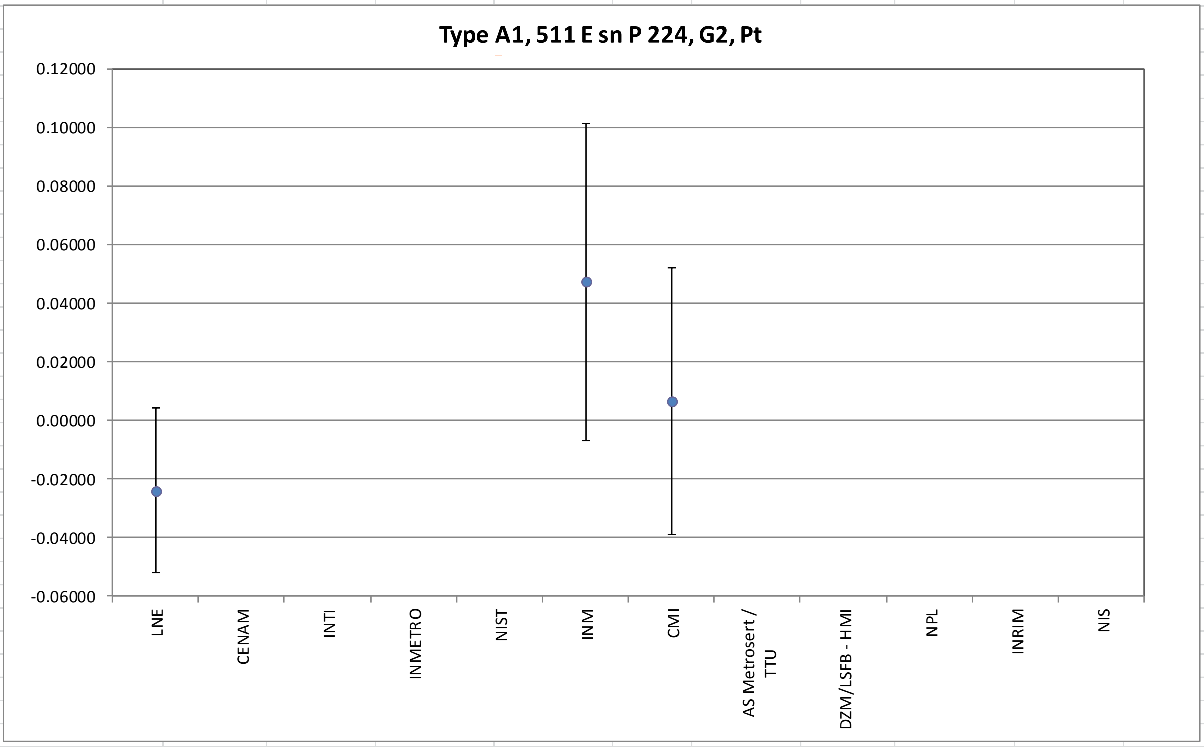


Figure 17: Specimen 511E sn P224: Groove G2, *Pt* parameter results.

8.2.3 Rubert reference specimen model 527E (s/n PA 38)

All the reported results reference specimen 527E sn PA 38 are given below.

8.2.3.1 *Ra* parameter

select gauge	5	Type C1, 527E sn PA 38, Ra			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE	2,9970	0,0020	0,0110	32	1	0,011	2,00	0,022	0,51	0,03
CENAM	2,9930	0,0039	0,0101	108	1	0,007	2,00	0,020	0,36	0,03
INTI	3,0000	0,0050	0,0400	16	1	0,014	2,00	0,080	0,18	0,00
INMETRO	3,0000	0,0012	0,0350	10000	1	0,014	2,00	0,070	0,20	0,00
NIST	2,9967	0,0005	0,0061	10000	1	0,011	2,00	0,012	0,93	0,09
INM	2,9925	0,0020	0,0595	51	1	0,007	2,00	0,119	0,06	0,00
CMI	2,9560	0,0050	0,0440	9773442	1	-0,030	2,00	0,088	0,34	0,00
AS Metrosert / TTU	2,9900	0,0050	0,1500	10000	1	0,004	2,00	0,300	0,01	0,00
DZM/LSFB - HMI	3,0200	0,0160	0,0660	246	1	0,034	2,00	0,132	0,26	0,00
NPL	2,9834	0,0008	0,0021	2	1	-0,002	2,00	0,002	1,34	0,81
INRIM	3,0000	0,0010	0,0450	51	1	0,014	2,00	0,090	0,16	0,00
NIS	2,9990	0,0010	0,0119	30	1	0,013	2,00	0,023	0,56	0,03

	x_{ref}		$u(x_{ref})$	ν_{eff}	N - 1		k_{ref}
Reference value	**2,9859**		**0,0019**	**3**	**11**		**2,00**
C	3,55E-06						

Consistency:		
u_{ext}	0,002	
R_B	0,872	Birge ok
Limit	1,361	

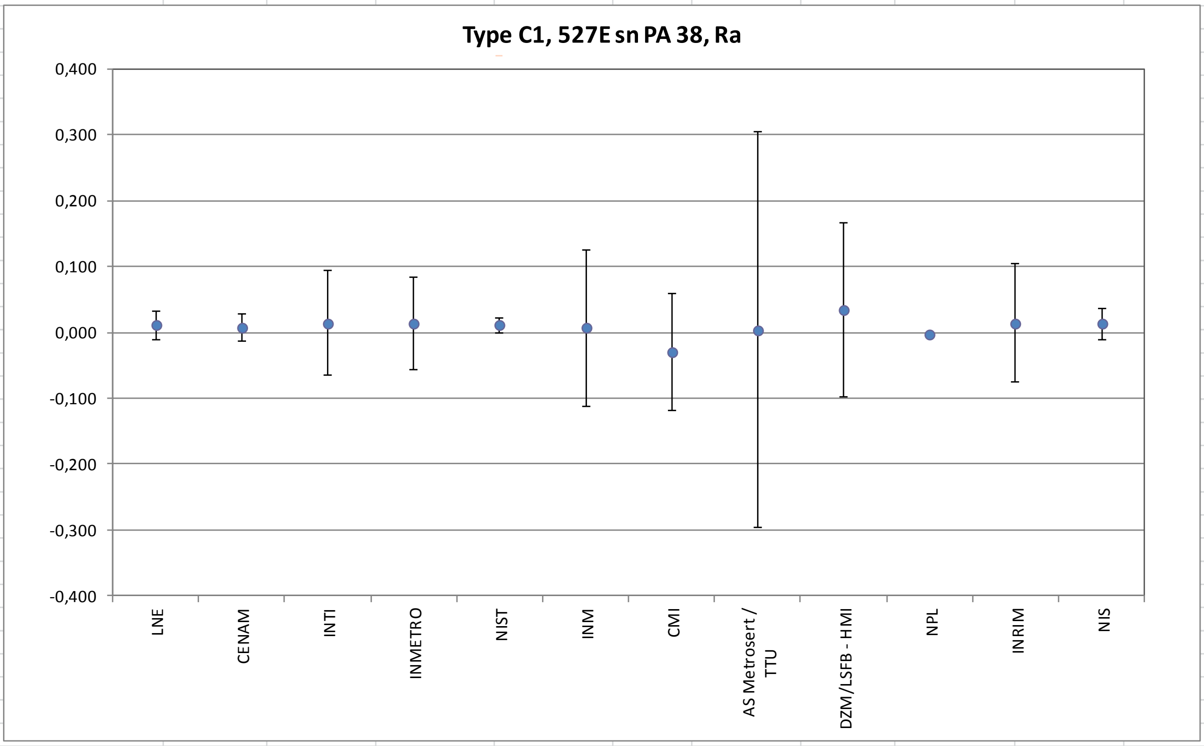


Figure 18: Specimen 527E s/n PA 38: *Ra* parameter results.

8.2.3.2 *Rz* parameter

select gauge 6 **Type C1, 527E sn PA 38, Rz**

use 1 or 0 to in- or exclude

choose: *k=2*

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	k	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	9,4500	0,0110	0,0330	15	1	0,012	2,00	0,064	0,19	0,05
CENAM	9,4320	0,0180	0,0239	38	1	-0,006	2,00	0,045	0,12	0,09
INTI	9,4800	0,0200	0,1260	16	1	0,042	2,00	0,252	0,17	0,00
INMETRO	9,4530	0,0038	0,1050	10000	1	0,015	2,00	0,209	0,07	0,00
NIST	9,4279	0,0013	0,0320	10000	1	-0,010	2,00	0,062	0,16	0,05
INM	9,4269	0,0115	0,1830	51	1	-0,011	2,00	0,366	0,03	0,00
CMI	9,3150	0,0110	0,1860	130729291	1	-0,123	2,00	0,372	0,33	0,00
AS Metrosert / TTU	9,4700	0,0080	0,6500	10000	1	0,032	2,00	1,300	0,02	0,00
DZM/LSFB - HMI	9,5020	0,0550	0,2810	161	1	0,064	2,00	0,562	0,11	0,00
NPL	9,4381	0,0036	0,0084	2	1	0,001	2,00	0,008	0,06	0,77
INRIM	9,4280	0,0420	0,1460	56	1	-0,010	2,00	0,292	0,03	0,00
NIS	9,4380	0,0100	0,0498	50	1	0,000	2,00	0,099	0,00	0,02

	x_{ref}	$u(x_{ref})$	ν_{eff}	$N - 1$	k_{ref}
Reference value	**9,4376**	**0,0074**	**4**	**11**	**2,00**
C	5,41E-05				

Consistency:		
u_{ext}	0,002	
R_B	0,290	**Birge ok**
Limit	1,361	

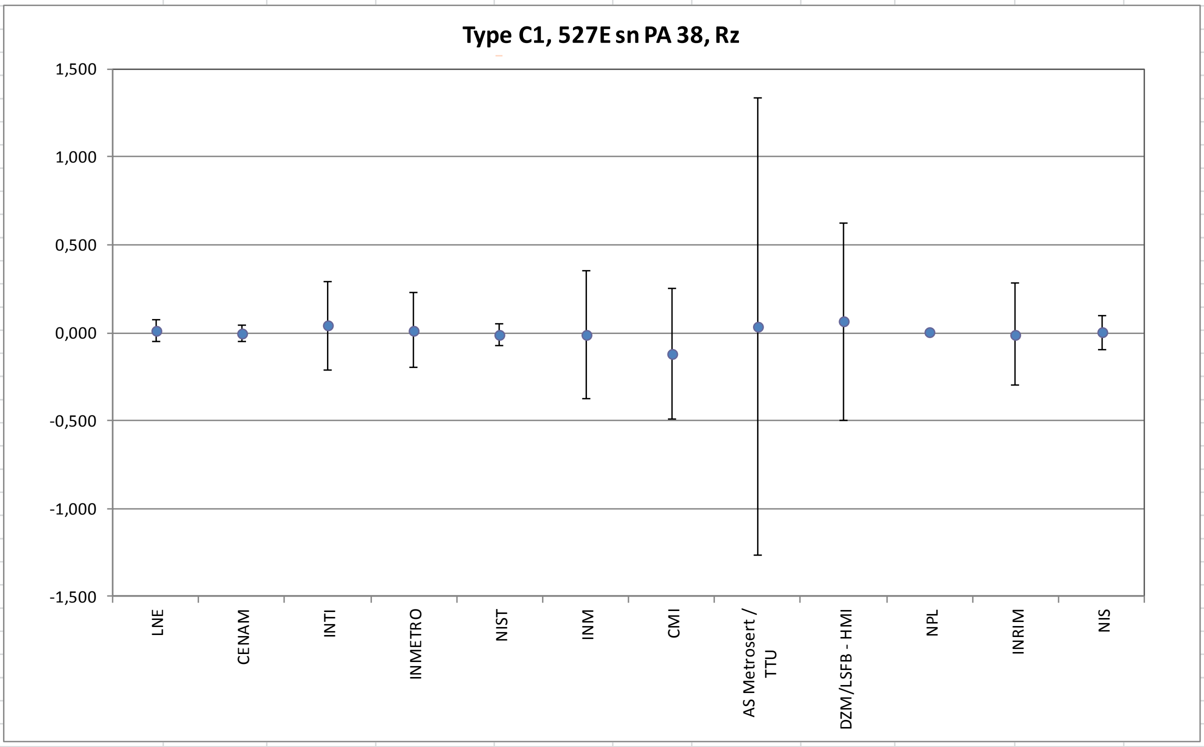


Figure 19: Specimen 527E s/n PA 38: *Rz* parameter results.

8.2.3.3 *Rt* parameter

select gauge 7 Type C1, 527E sn PA 38, Rt

use 1 or 0 to in- or exclude

choose: *k*=2

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	*k*	$U(x_i-x_{ref})$/µm	*E* n	w_i
LNE	9,4760	0,0280	0,0360	20	1	0,010	2,00	0,066	0,16	0,16
CENAM	9,4630	0,0530	0,0346	38	1	-0,003	2,00	0,063	0,04	0,17
INTI	9,5100	0,0300	0,1270	16	1	0,044	2,00	0,252	0,18	0,01
INMETRO	9,5140	0,0178	0,1050	10000	1	0,048	2,00	0,208	0,23	0,02
NIST	9,4416	0,0027	0,0336	10000	1	-0,024	2,00	0,061	0,40	0,18
INM	9,4680	0,0340	0,0360	20	1	0,002	2,00	0,066	0,04	0,16
CMI	9,3550	0,0440	0,1880	523979	1	-0,111	2,00	0,375	0,30	0,01
AS Metrosert / TTU	9,5600	0,0190	0,6500	10000	1	0,094	2,00	1,300	0,07	0,00
DZM/LSFB - HMI	9,5420	0,0740	0,2820	92	1	0,076	2,00	0,563	0,14	0,00
NPL	9,4764	0,0134	0,0306	2	1	0,011	2,00	0,054	0,20	0,22
INRIM	9,4560	0,0440	0,1490	59	1	-0,010	2,00	0,297	0,03	0,01
NIS	9,4570	0,0230	0,0577	71	1	-0,009	2,00	0,112	0,08	0,06

	x_{ref}	$u(x_{ref})$	ν_{eff}	*N* - 1	k_{ref}
Reference value	**9,4656**	**0,0143**	**41**	**11**	**2,00**
C	2,05E-04				

Consistency:		
u_{ext}	0,005	
R_B	0,373	**Birge ok**
Limit	1,361	

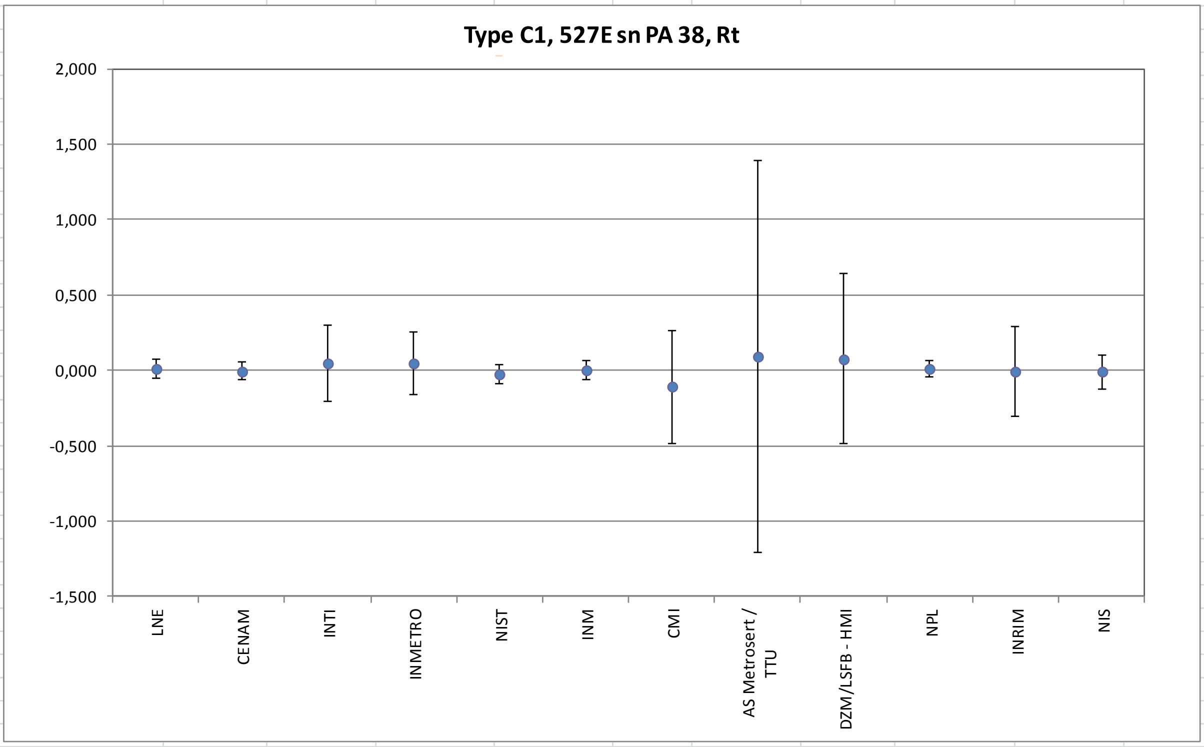


Figure 20: Specimen 527E s/n PA 38: *Rt* parameter results.

8.2.3.4 *RSm* parameter

select gauge: 8 — Type C1, 527E sn PA 38, RSm

use 1 or 0 to in- or exclude

choose: *k*=2

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	k	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	100,0720	0,0380	0,1000	18	1	-0,007	2,00	0,196	0,04	0,04
CENAM	100,0760	0,0430	0,0406	52	1	-0,003	2,00	0,070	0,04	0,26
INTI	100,2000	0,1400	1,1580	50	1	0,121	2,00	2,316	0,05	0,00
INMETRO	99,5075	0,2787	1,0000	10000	1	-0,572	2,00	2,000	0,29	0,00
NIST	100,0740	0,0097	0,0286	10000	1	-0,005	2,00	0,040	0,13	0,52
INM	99,5842	0,3481	4,9914	51	1	-0,495	2,00	9,983	0,05	0,00
CMI	95,4000	0,7000	2,3790	211407	1	-4,679	2,00	4,758	0,98	0,00
AS Metrosert / TTU	99,0000	0,0360	6,0000	10000	1	-1,079	2,00	12,000	0,09	0,00
DZM/LSFB - HMI	100,0510	1,0600	1,0370	92	1	-0,028	2,00	2,074	0,01	0,00
NPL	100,1230	0,0254	0,0580	2	1	0,044	2,00	0,108	0,41	0,13
INRIM	100,0690	0,0360	0,1000	143	1	-0,010	2,00	0,196	0,05	0,04
NIS	99,2600	0,5000	0,6659	54	1	-0,819	2,00	1,331	0,62	0,00

	x_{ref}	$u(x_{ref})$	ν_{eff}	$N - 1$	k_{ref}
Reference value	**100,0791**	**0,0207**	**116**	**11**	**2,00**

C 4,30E-04

Consistency:		
u_{ext}	0,016	
R_B	0,762	Birge ok
Limit	1,361	

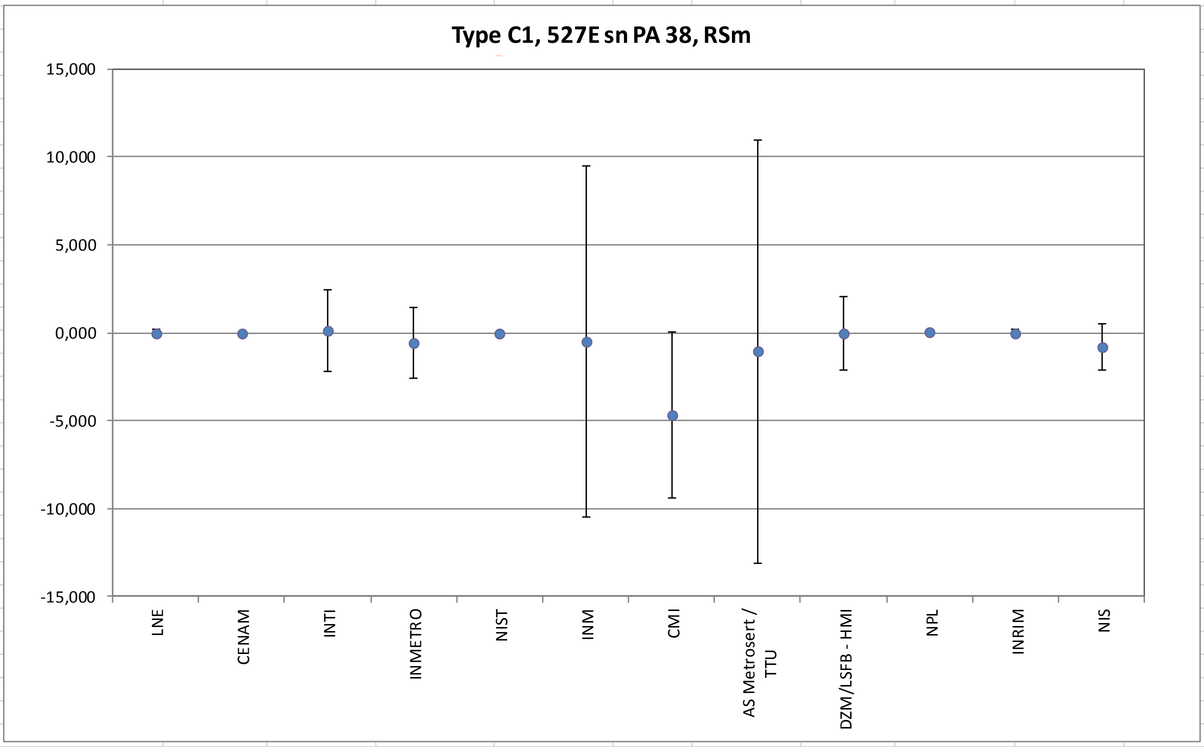


Figure 21: Specimen 527E s/n PA 38: *RSm* parameter results.

8.2.4 Type C1, 542E sn 2225

All the reported results reference specimen 542E sn 2225 are given below.

8.2.4.1 *Ra* parameter

use 1 or 0 to in- or exclude

choose: $k=2$

select gauge 9 **Type C1, 542E sn 2225, Ra**

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE	0,0532	0,0003	0,0040	42	1	-0,005	2,00	0,008	0,64	0,03
CENAM	0,0595	0,0012	0,0050	39	1	0,001	2,00	0,010	0,13	0,02
INTI	0,0580	0,0010	0,0030	11	1	0,000	2,00	0,006	0,04	0,06
INMETRO	0,0574	0,0001	0,0060	10000	1	-0,001	2,00	0,012	0,07	0,01
NIST	0,0569	0,0002	0,0037	10000	1	-0,001	2,00	0,007	0,18	0,04
INM	0,0580	0,0007	0,0054	69	1	0,000	2,00	0,011	0,02	0,02
CMI	0,0600	0,0010	0,0010	1259	1	0,002	2,00	0,001	1,26	0,50
AS Metrosert / TTU	0,0600	0,0010	0,0020	10000	1	0,002	2,00	0,004	0,48	0,13
DZM/LSFB - HMI	0,0590	0,0010	0,0071	196	1	0,001	2,00	0,014	0,06	0,01
NPL	0,0534	0,0006	0,0018	2	1	-0,005	2,00	0,003	1,46	0,15
INRIM	0,0530	0,0030	0,0042	130	1	-0,005	2,00	0,008	0,63	0,03
NIS	0,0540	0,0040	0,0093	170	1	-0,004	2,00	0,019	0,23	0,01

	x_{ref}	$u(x_{ref})$	ν_{eff}	$N-1$	k_{ref}
Reference value	**0,0582**	**0,0007**	**82**	**11**	**2,00**
C	5,02E-07				

Consistency:		
u_{ext}	0,001	
R_B	1,155	**Birge ok**
Limit	1,361	

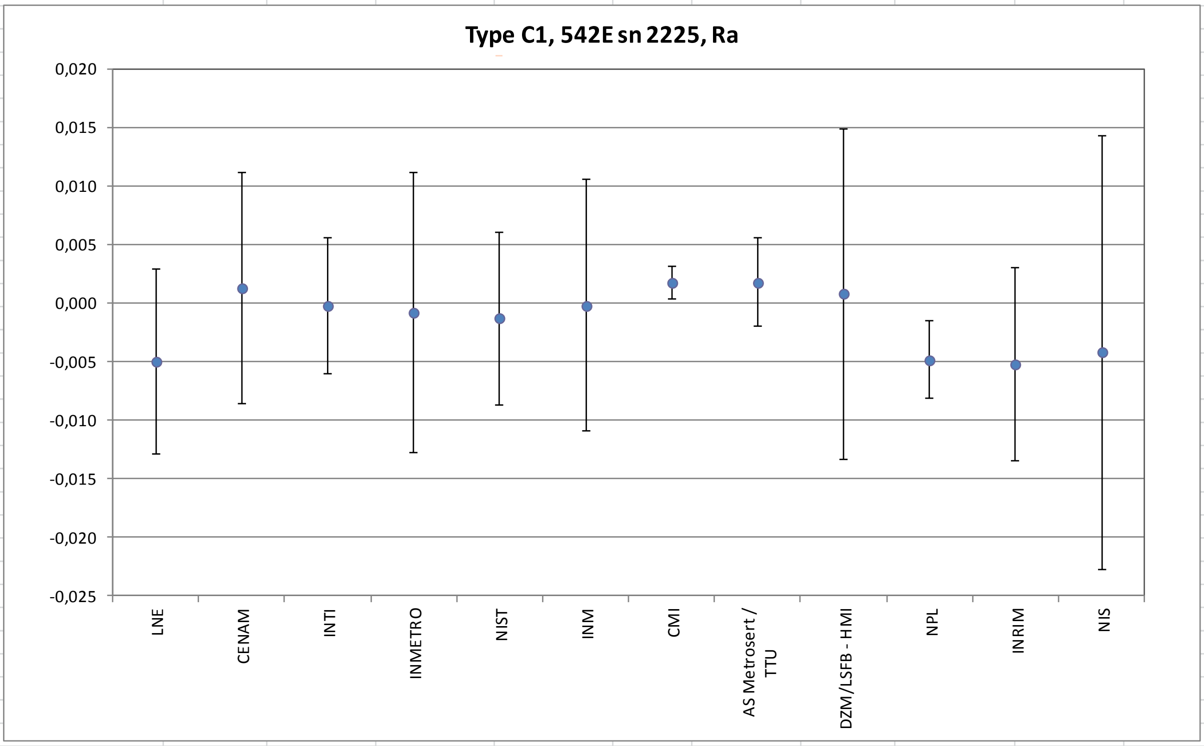


Figure 22: Specimen 542E s/n 2225: *Ra* parameter results.

8.2.4.2 *Rz* parameter

select gauge 10 Type C1, 542E sn 2225, Rz

use 1 or 0 to in- or exclude

choose: *k*=2

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	*k*	$U(x_i - x_{ref})$/µm	*E* n	w_i
LNE	0,1850	0,0020	0,0090	22	1	-0,013	2,00	0,017	0,77	0,09
CENAM	0,2200	0,0060	0,0073	45	0	0,022	2,00	0,016	1,40	0,00
INTI	0,1990	0,0040	0,0040	26	1	0,001	2,00	0,006	0,13	0,46
INMETRO	0,1912	0,0003	0,0070	10000	1	-0,007	2,00	0,013	0,55	0,15
NIST	0,1901	0,0006	0,0281	10000	1	-0,008	2,00	0,056	0,15	0,01
INM	0,2039	0,0030	0,0073	112	1	0,006	2,00	0,014	0,42	0,14
CMI	0,2200	0,0050	0,0050	1168	0	0,022	2,00	0,011	1,91	0,00
AS Metrosert / TTU	0,2210	0,0030	0,0100	10000	1	0,023	2,00	0,019	1,18	0,07
DZM/LSFB - HMI	0,2020	0,0030	0,0159	124	1	0,004	2,00	0,031	0,12	0,03
NPL	0,1817	0,0022	0,0052	2	0	-0,017	2,00	0,012	1,41	0,00
INRIM	0,1840	0,0110	0,0144	52	1	-0,014	2,00	0,028	0,50	0,04
NIS	0,1820	0,0140	0,0396	58	1	-0,016	2,00	0,079	0,21	0,00

	x_{ref}	$u(x_{ref})$	ν_{eff}	*N* - 1	k_{ref}
Reference value	**0,1982**	**0,0027**	**113**	**8**	**2,00**

C 7,42E-06

Consistency:		
u_{ext}	0,003	
R_B	1,134	**Birge ok**
Limit	1,414	

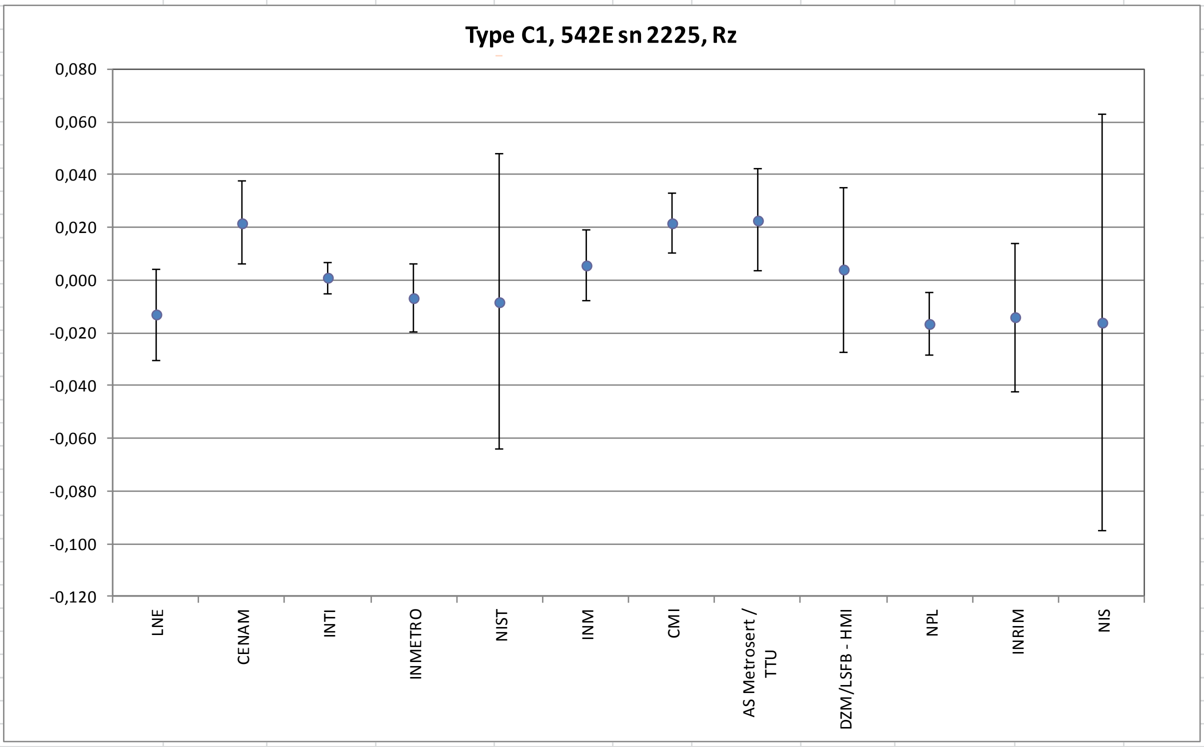


Figure 23: Specimen 542E s/n 2225: *Rz* parameter *r*esults.

8.2.4.3 *Rt* parameter

select gauge	11	Type C1, 542E sn 2225, Rt			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE	0,1947	0,0041	0,0150	18	1	-0,012	2,00	0,029	0,40	0,04
CENAM	0,2370	0,0180	0,0075	49	0	0,030	2,00	0,016	1,88	0,00
INTI	0,2100	0,0060	0,0050	30	1	0,003	2,00	0,008	0,44	0,37
INMETRO	0,1957	0,0009	0,0070	10000	1	-0,011	2,00	0,013	0,86	0,19
NIST	0,1986	0,0019	0,0299	10000	1	-0,008	2,00	0,059	0,13	0,01
INM	0,2147	0,0093	0,0115	26	1	0,008	2,00	0,022	0,37	0,07
CMI	0,2340	0,0070	0,0050	446	0	0,027	2,00	0,012	2,34	0,00
AS Metrosert / TTU	0,2360	0,0070	0,0100	10000	1	0,029	2,00	0,019	1,55	0,09
DZM/LSFB - HMI	0,2120	0,0030	0,0162	124	1	0,005	2,00	0,032	0,17	0,04
NPL	0,1937	0,0035	0,0081	2	1	-0,013	2,00	0,015	0,86	0,14
INRIM	0,1980	0,0120	0,0162	47	1	-0,009	2,00	0,032	0,27	0,04
NIS	0,1960	0,0150	0,0434	56	1	-0,011	2,00	0,087	0,12	0,00

	x_{ref}	$u(x_{ref})$	ν_{eff}	N - 1	k_{ref}
Reference value	**0,2065**	**0,0031**	**72**	**9**	**2,00**
C	9,35E-06				

Consistency:		
u_{ext}	0,004	
R_B	1,321	Birge ok
Limit	1,394	

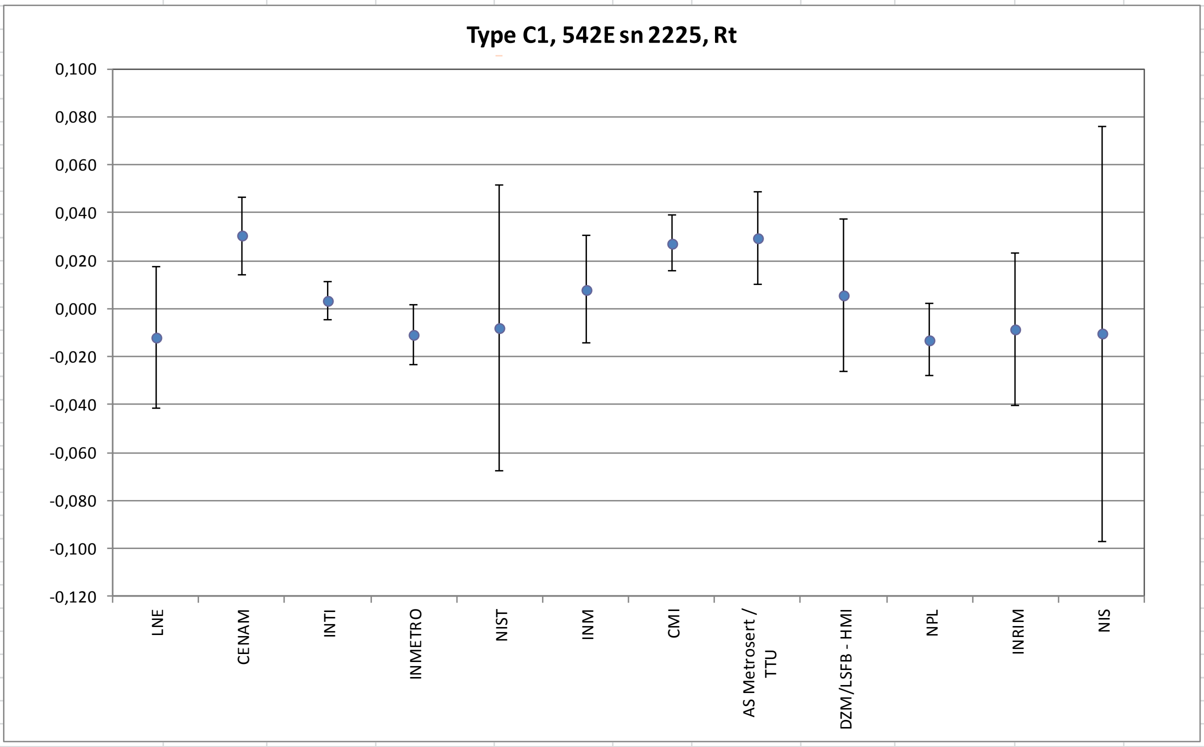


Figure 24: Specimen 542E s/n 2225: *Rt* parameter results.

8.2.4.4 *RSm* parameter

select gauge	12	Type C1, 542E sn 2225, RSm			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i - x_{ref})$/µm	k	$U(x_i - x_{ref})$/µm	E_n	w_i
LNE	7,7360	0,0070	0,1000	18	1	-0,007	2,00	0,200	0,04	0,00
CENAM	7,7330	0,0390	0,0406	52	1	-0,010	2,00	0,081	0,12	0,00
INTI	7,7700	0,0500	0,0930	56	1	0,027	2,00	0,186	0,15	0,00
INMETRO	7,6949	0,0064	0,1250	10000	1	-0,048	2,00	0,250	0,19	0,00
NIST	7,7396	0,0010	0,0023	10000	1	-0,003	2,00	0,002	1,40	0,73
INM	7,7033	0,0318	0,2372	52	1	-0,040	2,00	0,474	0,08	0,00
CMI	6,3300	0,1400	0,1620	2869	0	-1,413	2,00	0,324	4,36	0,00
AS Metrosert / TTU	7,7070	0,0140	0,3500	10000	1	-0,036	2,00	0,700	0,05	0,00
DZM/LSFB - HMI	7,7710	0,0610	0,2620	120	1	0,028	2,00	0,524	0,05	0,00
NPL	7,7526	0,0016	0,0038	2	1	0,010	2,00	0,007	1,48	0,27
INRIM	7,7210	0,0420	0,1040	142	1	-0,022	2,00	0,208	0,11	0,00
NIS	7,7100	0,0300	0,0416	63	1	-0,033	2,00	0,083	0,40	0,00

	x_{ref}	$u(x_{ref})$	ν_{eff}	$N - 1$	k_{ref}
Reference value	**7,7430**	**0,0020**	**31**	**10**	**2,00**
C	3,87E-06				

Consistency:		
u_{ext}	0,002	
R_B	0,978	**Birge ok**
Limit	1,376	

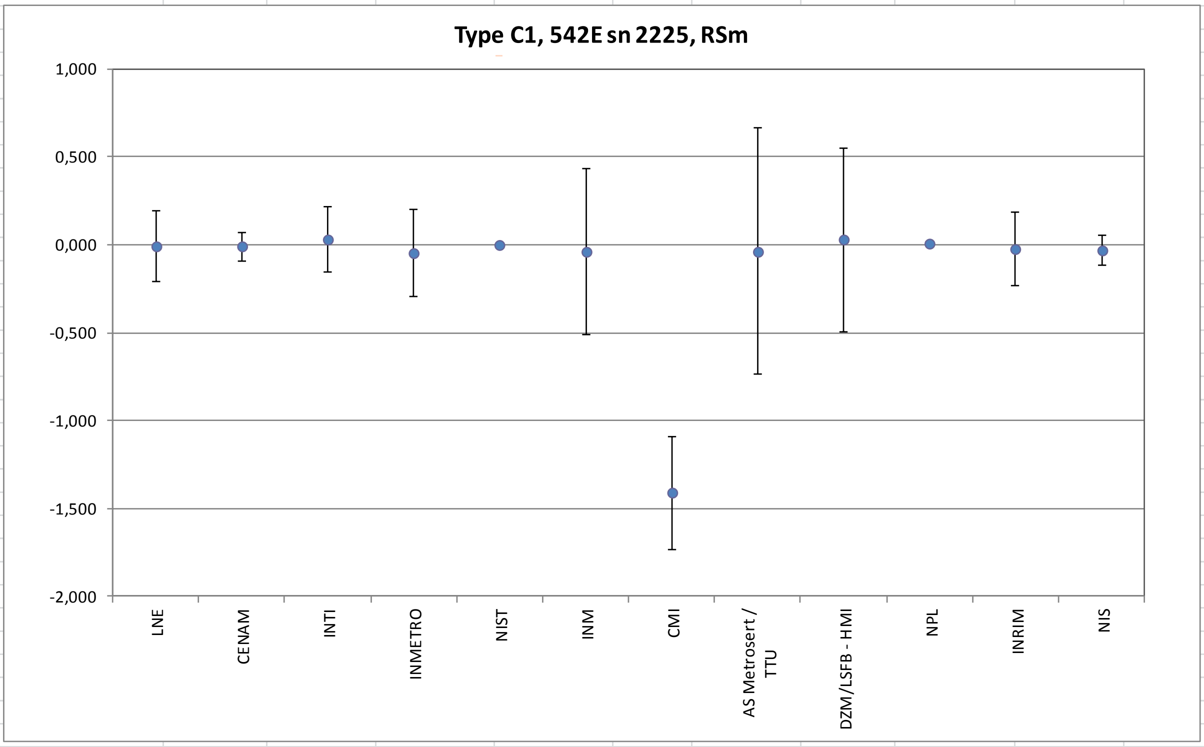


Figure 25: Specimen 542E s/n 2225: *RSm* parameter results.

8.2.5 Type D1,503E sn P 61

As discussed in §6.2, it appears that something happened to the standard between DZM/HMI and NPL. We see a drop in value around 110 and 120 nm for *Rz* and *Rt* parameters. In order to take this into account we decided to separate the data in two sets. The first set contains the results from participants until DZM/HMI, the second one contains the results from NPL, INRIM, NIS and LNE3. The 2 sets can be considered as independent, each one having its own reference value x_{ref1} and x_{ref2}.

8.2.5.1 *Ra* parameter

select gauge: 13 — Type D1,503E sn P 61, Ra

use 1 or 0 to in- or exclude

choose: *k=2*

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	$(x_i\text{-}x_{ref})$/µm	*k*	$U(x_i\text{-}x_{ref})$/µm	*E*n	w_i
LNE1	0.0697	0.0022	0.0040	42	1	-0.003	2.00	0.007	0.47	0.19
CENAM	0.0735	0.0021	0.0057	54	1	0.000	2.00	0.011	0.04	0.09
INTI	0.0700	0.0020	0.0030	12	1	-0.003	2.00	0.005	0.63	0.34
INMETRO	0.0853	0.0021	0.0170	8	1	0.012	2.00	0.034	0.36	0.01
NIST	0.0746	0.0005	0.0038	10000	1	0.001	2.00	0.007	0.22	0.21
INM	0.0860	0.0015	0.0057	82	1	0.013	2.00	0.011	1.18	0.09
CMI	0.0860	0.0010	0.0020	14691	0	0.013	2.00	0.005	2.43	0.00
AS Metrosert / TTU	0.0830	0.0020	0.0030	10000	0	0.010	2.00	0.007	1.43	0.00
DZM/LSFB - HMI	0.0730	0.0030	0.0073	194	1	0.000	2.00	0.014	0.01	0.06
NPL	0.0664	0.0011	0.0028	2	1	-0.003	2.00	0.004	0.74	0.52
INRIM	0.0730	0.0030	0.0049	57	1	0.004	2.00	0.009	0.42	0.17
NIS	0.0750	0.0040	0.0093	195	1	0.006	2.00	0.018	0.32	0.05
LNE3	0.0715	0.0046	0.0040	42	1	0.002	2.00	0.007	0.33	0.26

	x_{ref1}	$u(x_{ref1})$	ν_{eff1}	N_1 - 1	k_{ref1}
Reference value 1	**0.0731**	**0.0017**	**93**	**6**	**2.00**
C	3.05E-06				

Consistency part 1:		
u_{ext1}	0.002	
R_{B1}	1.120	Birge ok
Limit1	1.468	

	x_{ref2}	$u(x_{ref2})$	ν_{eff2}	N_2 - 1	k_{ref2}
Reference value 2	**0.0692**	**0.0020**	**8**	**3**	**2.00**
C	4.11E-06				

Consistency part 2:		
u_{ext2}	0.001	
R_{B2}	0.622	Birge ok
Limit2	3.386	

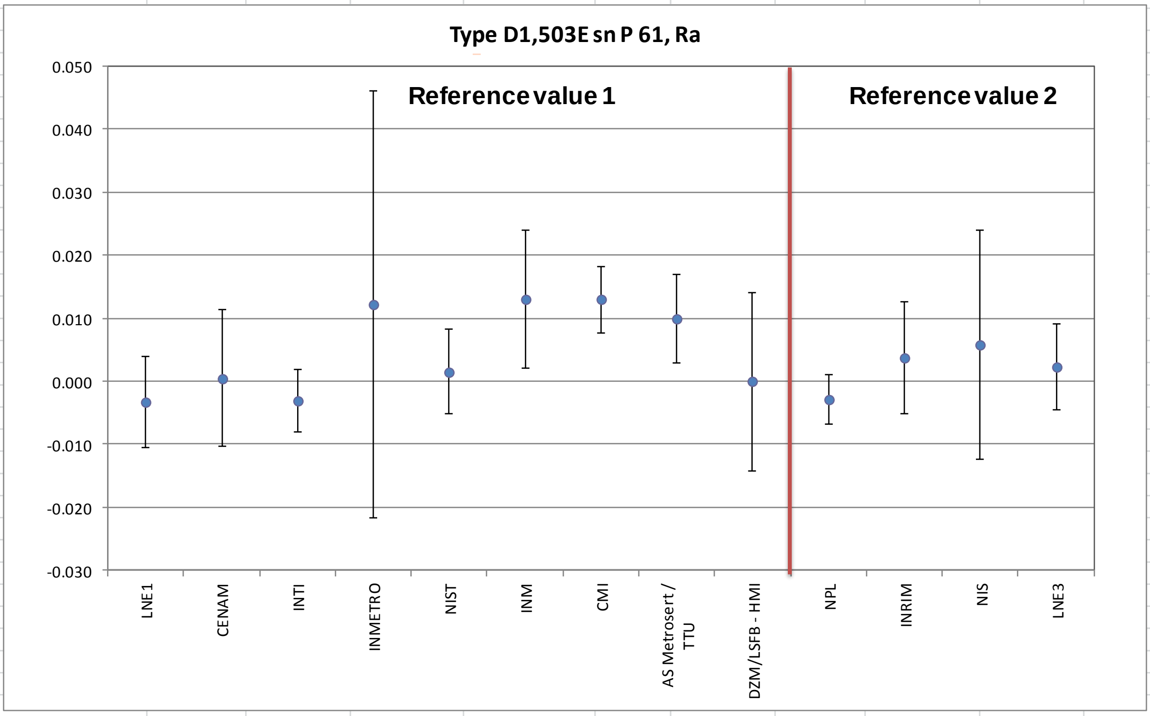


Figure 26: Specimen 503E s/n P61: *Ra* parameter *r*esults.

8.2.5.2 *Rq* parameter

select gauge	14	Type D1,503E sn P 61, Rq			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE1	0.0977	0.0022	0.0040	42	1	-0.004	2.00	0.007	0.50	0.21
CENAM	0.1035	0.0022	0.0057	54	1	0.002	2.00	0.011	0.21	0.10
INTI	0.0980	0.0020	0.0030	4	1	-0.003	2.00	0.005	0.68	0.37
INMETRO	0.1147	0.0021	0.0210	10000	1	0.013	2.00	0.042	0.32	0.01
NIST	0.1032	0.0006	0.0047	10000	1	0.002	2.00	0.009	0.23	0.15
INM	0.1145	0.0017	0.0058	83	1	0.013	2.00	0.011	1.21	0.10
CMI	0.1190	0.0020	0.0010	311	0	0.018	2.00	0.004	4.25	0.00
AS Metrosert / TTU	0.0000	0.0000	0.0000	#N/A	0	#N/A	#N/A	#N/A	#N/A	0.00
DZM/LSFB - HMI	0.1010	0.0050	0.0078	192	1	0.000	2.00	0.015	0.02	0.06
NPL	0.0915	0.0017	0.0041	2	1	-0.004	2.00	0.007	0.64	0.36
INRIM	0.0990	0.0040	0.0059	36	1	0.003	2.00	0.011	0.31	0.18
NIS	0.1030	0.0040	0.0088	259	1	0.007	2.00	0.017	0.43	0.08
LNE3	0.0967	0.0064	0.0040	42	1	0.001	2.00	0.006	0.16	0.38

	x_{ref1}	$u(x_{ref1})$	ν_{eff1}	$N_1 - 1$	k_{ref1}
Reference value 1	**0.1012**	**0.0018**	**28**	**6**	**2.00**
C	3.36E-06				

Consistency part 1:		
u_{ext1}	0.002	
R_{B1}	1.152	Birge ok
Limit1	1.468	

	x_{ref2}	$u(x_{ref2})$	ν_{eff2}	$N_2 - 1$	k_{ref2}
Reference value 2	**0.0957**	**0.0025**	**16**	**3**	**2.00**
C	6.11E-06				

Consistency part 2:		
u_{ext2}	0.001	
R_{B2}	0.593	Birge ok
Limit2	3.145	

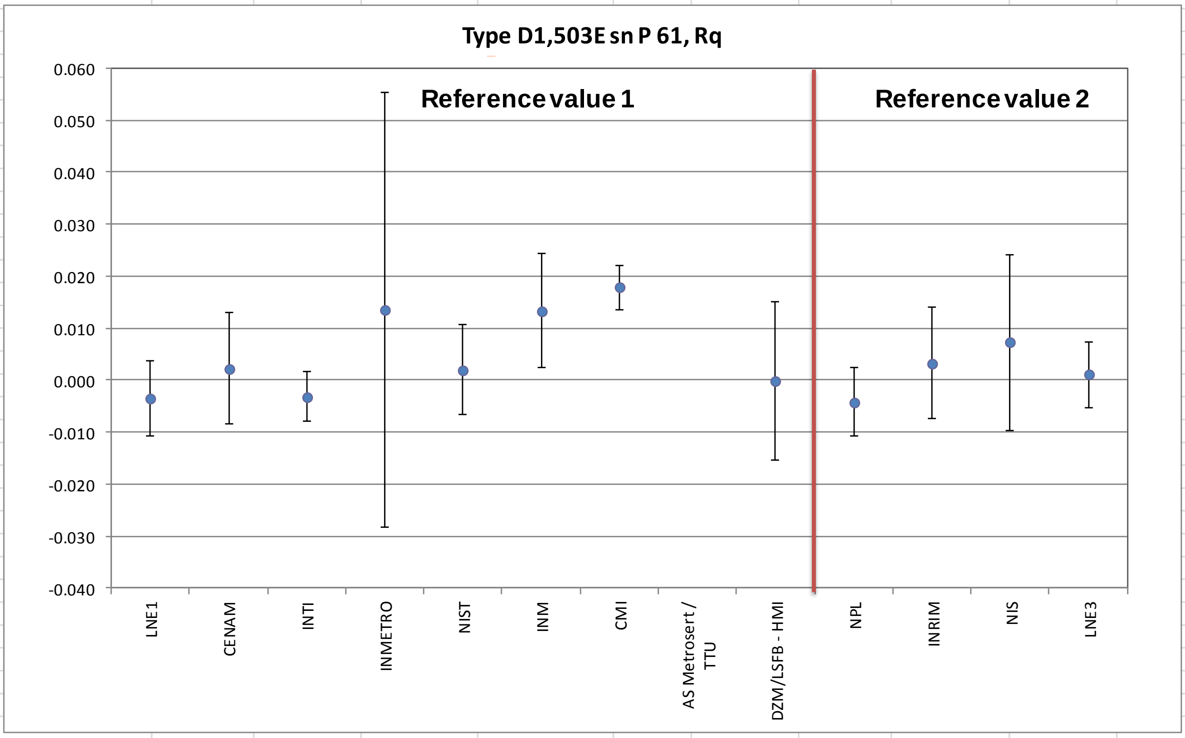


Figure 27: Specimen 503E s/n P61: *Rq* parameter *r*esults.

8.2.5.3 *Rz* parameter

select gauge	15	Type D1,503E sn P 61, Rz	use 1 or 0 to in- or exclude	choose: k=2

Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE1	0.7099	0.0264	0.0150	113	1	-0.032	2.00	0.027	1.20	0.21
CENAM	0.7470	0.0300	0.0101	190	1	0.005	2.00	0.015	0.35	0.46
INTI	0.6750	0.0240	0.0120	30	0	-0.067	2.00	0.028	2.41	0.00
INMETRO	0.7749	0.0267	0.0180	8	1	0.033	2.00	0.033	1.00	0.15
NIST	0.7491	0.0090	0.0295	10000	1	0.007	2.00	0.057	0.13	0.05
INM	0.7495	0.0352	0.0386	16	1	0.008	2.00	0.076	0.10	0.03
CMI	0.8680	0.0400	0.0250	223	0	0.126	2.00	0.052	2.43	0.00
AS Metrosert / TTU	0.7620	0.0260	0.0350	10000	1	0.020	2.00	0.069	0.29	0.04
DZM/LSFB - HMI	0.7050	0.0470	0.0298	135	1	-0.037	2.00	0.058	0.63	0.05
NPL	0.6061	0.0201	0.0459	2	1	-0.023	2.00	0.083	0.28	0.18
INRIM	0.6300	0.0460	0.0470	16	1	0.001	2.00	0.086	0.01	0.17
NIS	0.6880	0.0530	0.0785	55	1	0.059	2.00	0.152	0.39	0.06
LNE3	0.6300	0.0722	0.0250	26	1	0.001	2.00	0.032	0.02	0.59

	x_{ref1}	$u(x_{ref1})$	ν_{eff1}	$N_1 - 1$	k_{ref1}
Reference value 1	**0.7418**	**0.0069**	**233**	**6**	**2.00**
C	4.74E-05				

Consistency part 1:		
u_{ext1}	0.009	
R_{B1}	1.299	**Birge ok**
Limit1	1.468	

	x_{ref2}	$u(x_{ref2})$	ν_{eff2}	$N_2 - 1$	k_{ref2}
Reference value 2	**0.6293**	**0.0193**	**34**	**3**	**2.00**
C	3.72E-04				

Consistency part 2:		
u_{ext2}	0.007	
R_{B2}	0.369	**Birge ok**
Limit2	2.070	

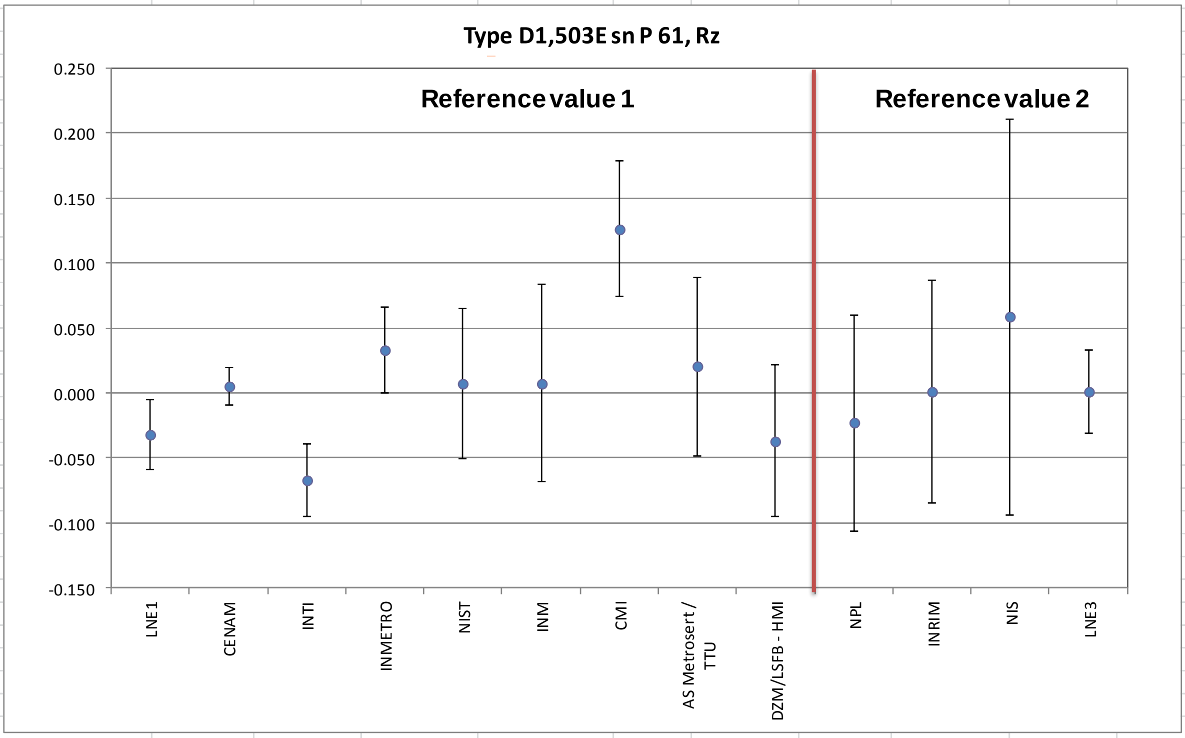


Figure 28: Specimen 503E s/n P61: *Rz* parameter results.

8.2.5.4 *Rt* parameter

select gauge	16	Type D1,503E sn P 61, Rt			use 1 or 0 to in- or exclude		choose: k=2			
Institute	x_i / µm	σ_i / µm	u_i / µm	ν_{eff}	on/off	(x_i-x_{ref})/µm	k	$U(x_i-x_{ref})$/µm	E_n	w_i
LNE1	0.9283	0.0490	0.0210	32	1	-0.034	2.00	0.037	0.92	0.21
CENAM	0.9800	0.0510	0.0147	157	1	0.017	2.00	0.022	0.78	0.42
INTI	0.8870	0.0590	0.0210	22	0	-0.076	2.00	0.046	1.64	0.00
INMETRO	0.9654	0.0445	0.0250	10000	1	0.003	2.00	0.046	0.06	0.15
NIST	0.9824	0.0102	0.0316	10000	1	0.020	2.00	0.060	0.33	0.09
INM	0.9451	0.0705	0.0729	13	1	-0.018	2.00	0.145	0.12	0.02
CMI	1.0470	0.0360	0.0280	586	0	0.084	2.00	0.059	1.43	0.00
AS Metrosert / TTU	0.9770	0.0330	0.0450	10000	1	0.014	2.00	0.088	0.16	0.05
DZM/LSFB - HMI	0.9230	0.0580	0.0360	138	1	-0.040	2.00	0.069	0.57	0.07
NPL	0.8043	0.0316	0.0721	2	1	-0.016	2.00	0.132	0.12	0.16
INRIM	0.7980	0.0680	0.0710	15	1	-0.022	2.00	0.130	0.17	0.16
NIS	0.8680	0.0780	0.1086	50	1	0.048	2.00	0.209	0.23	0.07
LNE3	0.8248	0.1127	0.0370	19	1	0.005	2.00	0.046	0.10	0.61

	x_{ref1}	$u(x_{ref1})$	ν_{eff1}	$N_1 - 1$	k_{ref1}
Reference value 1	**0.9626**	**0.0096**	**394**	**6**	**2.00**
C	9.13E-05				

Consistency part 1:		
u_{ext1}	0.009	
R_{B1}	0.987	Birge ok
Limit1	1.468	

	x_{ref2}	$u(x_{ref2})$	ν_{eff2}	$N_2 - 1$	k_{ref2}
Reference value 2	**0.8202**	**0.0288**	**31**	**3**	**2.00**
C	8.29E-04				

Consistency part 2:		
u_{ext2}	0.007	
R_{B2}	0.243	Birge ok
Limit2	1.970	

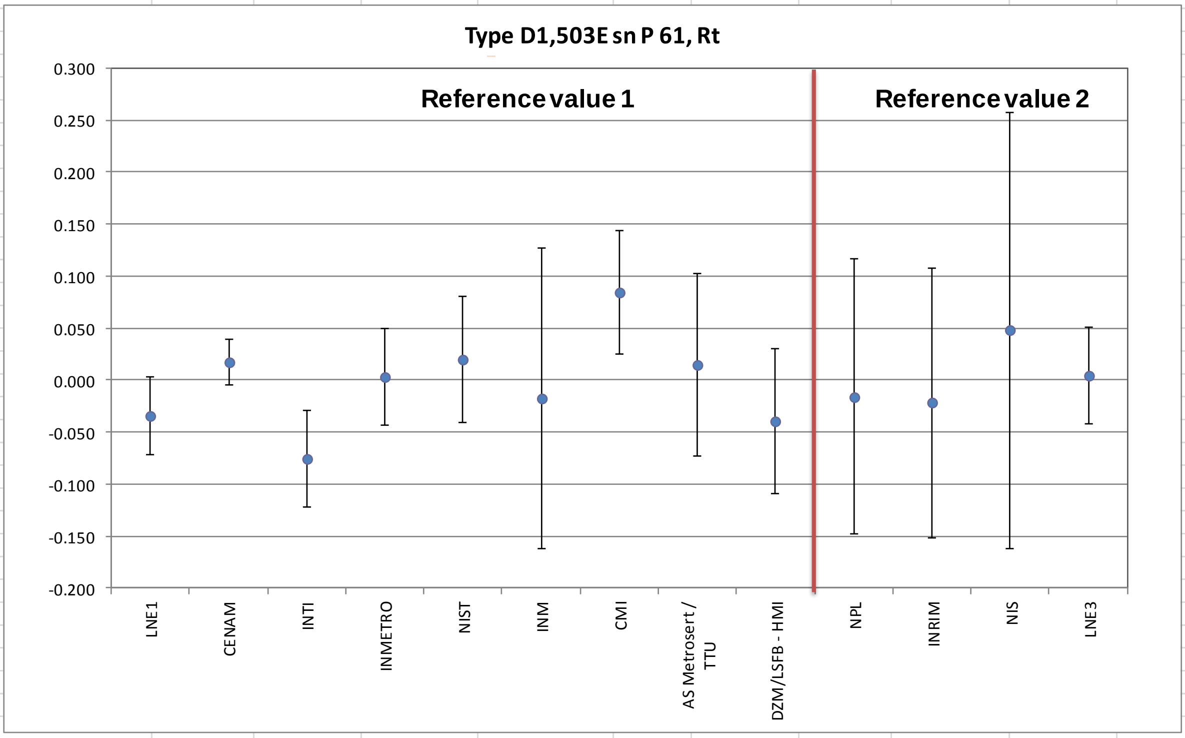


Figure 29: Specimen 503E s/n P61: *Rt* parameter *r*esults.

8.3 Summary of En values

Table 7 is a summary of all the En values for the participants per standard. A total of 27 En values were greater than 1.

	Type A1, 511 E sn P 224				Type C1, 527E sn PA 38			
Institute	G1, d	G2, d	G1, Pt	G2, Pt	Ra	Rz	Rt	RSm
LNE	0.13	0.10	0.11	0.85	0.51	0.19	0.16	0.04
CENAM	0.07	0.22			0.36	0.12	0.04	0.04
INTI	0.10	0.01			0.18	0.17	0.18	0.05
INMETRO	1.00	1.79			0.20	0.07	0.23	0.29
NIST	0.29	0.92			0.93	0.16	0.40	0.13
INM			0.11	0.88	0.06	0.03	0.04	0.05
CMI			0.01	0.14	0.34	0.33	0.30	0.98
AS Metrosert / TTU	0.03	0.03			0.01	0.02	0.07	0.09
DZM/LSFB - HMI	1.07	2.06			0.26	0.11	0.14	0.01
NPL	0.29	0.48			1.34	0.06	0.20	0.41
INRIM	0.60	1.35			0.16	0.03	0.03	0.05
NIS	0.13	0.05			0.56	0.00	0.08	0.62
	Type C1, 542E sn 2225				Type D1,503E sn P 61			
Institute	Ra	Rz	Rt	RSm	Ra	Rq	Rz	Rt
LNE	0.64	0.77	0.40	0.04	0.47	0.50	1.20	0.92
CENAM	0.13	1.40	1.88	0.12	0.04	0.21	0.35	0.78
INTI	0.04	0.13	0.44	0.15	0.63	0.68	2.41	1.64
INMETRO	0.07	0.55	0.86	0.19	0.36	0.32	1.00	0.06
NIST	0.18	0.15	0.13	1.40	0.22	0.23	0.13	0.33
INM	0.02	0.42	0.37	0.08	1.18	1.21	0.10	0.12
CMI	1.26	1.91	2.34	4.36	2.43	4.25	2.43	1.43
AS Metrosert / TTU	0.48	1.18	1.55	0.05	1.43		0.29	0.16
DZM/LSFB - HMI	0.06	0.12	0.17	0.05	0.01	0.02	0.63	0.57
NPL	1.46	1.41	0.86	1.48	0.74	0.64	0.28	0.12
INRIM	0.63	0.50	0.27	0.11	0.42	0.31	0.01	0.17
NIS	0.23	0.21	0.12	0.40	0.32	0.43	0.39	0.23
LNE3					0.33	0.16	0.02	0.10

Table 7: En values for all the artefacts

A summary of En values for standard depth 511E taking into account the corrected results from INMETRO, DZM-LSFB-HMI and INRIM is presented §8.5. This would reduce the number of En values>1 to 1.

8.4 Changes after Draft A

8.4.1 INM Request on 09/10/2012

"Regarding the softgauges results we have reported the results only for filter ISO 2CR, the results that are included in the Draft A.
But, in the meantime, we have used as well the Gaussian and the 2CR-PC filters, as a consequence, I have included now these results in the attached file. If possible, please, take into consideration this issue as well."

Attached MSWord file with new results.

8.4.2 HMI FSB-LPMD request on 19/10/2012

“After reading the Draft A report, I noticed that we made a mistake in reporting our results for grooves G1 and G2.
We discovered that a mistake was made when the results were retrieved from the software- a correction that should have been applied was left out.
I have attached a detailed report on this subject, and I hope that you will be able to accept our corrections. If you require any additional information we will provide it as soon as possible. “

Attached PDF files with explanation.

8.4.3 INMETRO request on 30/10/2012 and complementary information from 24/10/2016

1- I made two mistakes. First of all I put the G1 groove values in the result of G2 and vice versa. And in G2 result I put the value of Pt instead of the d result.

2-About the parameters in the 503E standard, I think there were problems in the positioning and alignment of the sample.

Actually, we think that we has solved all these problems, since we had good results in the EURAMET.L-K8.2013 (EURAMET project #1245)

Attached : 2 zip files, Excel sheet.

8.4.4 INRIM Request on 07/12/2012

“I would first report you about our check of the INRIM results, namely with reference to the step-height standard, sample 511E, groove G2. We have re-analyzed all the profile records and image files of the stylus and optical-based measurements of the G2 groove. The reported step-heigth values are confirmed, whereas the uncertainty budgets have been revised, namely the contribution due to local effects/geometries in the profile/image has been corrected. Due to a numerical error this component was first underestimated for the stylus-based G2 measurements, whereas for the optical measurements this component is now estimated also from the analysis of images of different sizes (x20 and x50 objectives). The amount of this term was then re-calculated as given below for the G2 groove; no changes were obtained for the G1 groove.

Please find attached our revised measurement report.
Track of changes:
- sample 511E - measurements performed with a stylus profilometer
groove G2: u_C, n_{eff}, s_{mes} *values have been corrected;*
- sample 511E - measurements performed with an optical profilometer
groove G2: u_C, n_{eff} *values have been corrected;*
- the uncertainty budgets of step-height measurements of the groove G2 - sample 511E by stylus and optical profilometry have been corrected.”

LNE : The change in uncertainty is small (< 1nm), don’t change the En values.

8.4.5 INMETRO request on 18/12/012

“After reviewing our declared uncertainties, I noticed that I had sent you miscalculated values.
On reality, our right uncertainty values are based on our CMCs, published in the App. C.
I am not sure about the rules to be obeyed when a Draft A is issued.

But, if possible, I would ask you to replace our declared uncertainties by the ones, which are published in the App. C (BIPM database).”

LNE: Since the request is just to apply the CMC the request have been taken into account.

8.5 En-values with results revised after draft A report

If we use the corrected values sent by INMETRO and DZM/LSB-HMI for the depth standard type A1, and also taking into account the revised standard uncertainty from INRIM, the En values are impacted as shown in Table 8.

	Type A1, 511 E sn P 224			
Institute	G1, d	G2, d	G1, Pt	G2, Pt
LNE	0.12	0.03	0.11	0.85
CENAM	0.06	0.14		
INTI	0.10	0.06		
INMETRO	0.05	0.02		
NIST	0.26	0.51		
INM			0.11	0.88
CMI			0.01	0.14
AS Metrosert / TTU	0.04	0.01		
DZM/LSFB - HMI	0.27	0.47		
NPL	0.27	0.19		
INRIM	0.63	1.03		
NIS	0.13	0.12		

Table 8: En values revisited for all the artefacts, in red the changed values.

Only one En value >1 remains.

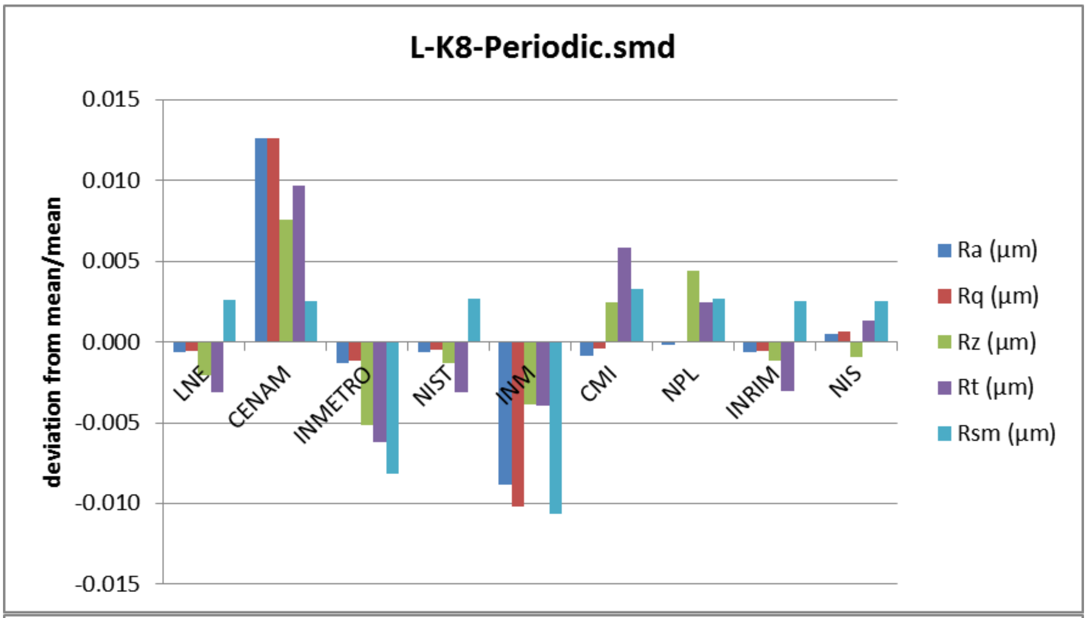
9 SOFTGAUGES RESULTS

The reported results are shown in Table 9 and Table 10 with their graphical representations. The results from INM are excluded from the evaluation of the mean and standard deviation since they used a 2RC filter instead of a Gaussian filter.

9.1 File LK-8-Periodic

	Ra (µm)	Rq (µm)	Rz (µm)	Rt (µm)	Rsm (µm)
LNE	0.4379	0.4994	1.5293	1.5421	100.0527
CENAM	0.4437	0.5060	1.5440	1.5620	100.0500
INMETRO	0.4376	0.4991	1.5245	1.5374	98.9800
NIST	0.4379	0.4995	1.5304	1.5422	100.0622
INM	0.4343	0.4946	1.5265	1.5409	98.7300
CMI	0.4378	0.4995	1.5362	1.5560	100.1200
NPL	0.4381	0.4997	1.5391	1.5507	100.0616
INRIM	0.4379	0.4994	1.5306	1.5423	100.0500
NIS	0.4384	0.5000	1.5310	1.5490	100.0500
deviation	0.4387	0.5003	1.5332	1.5477	99.9283
Standard deviation	0.0020	0.0023	0.0062	0.0083	0.3839

Table 9: Reported results for softgauge “L-K8 Periodic”.



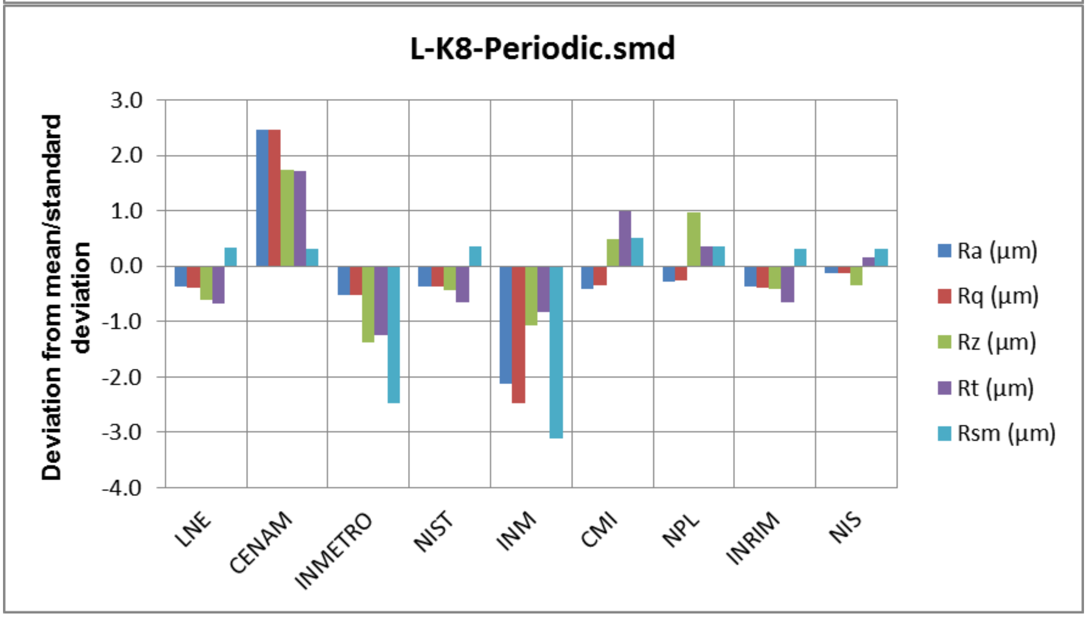


Figure 30: Deviation from mean relative to the mean value of the reported results (upper graph) or to the standard deviation of the reported results (lower graph.) for softgauge LK-8 Periodic.

9.2 File LK-8-Aperiodic

	Ra (µm)	Rq (µm)	Rz (µm)	Rt (µm)	Rsk	Rku
LNE	0.14314	0.17936	1.06687	1.37771	-0.1521	3.0785
CENAM	0.14170	0.17900	1.08400	1.35000	-0.2490	3.2430
INMETRO	0.14090	0.17780	1.03540	1.34220	-0.2488	3.3611
NIST	0.14359	0.17997	1.07328	1.38325	-0.1561	3.0795
INM	0.15340	0.19300	1.17410	1.48770	-0.3137	3.2317
CMI	0.14360	0.18180	1.12660	1.43000	-0.1663	3.2572
NPL	0.14621	0.18331	1.11809	1.42612	-0.1569	3.0813
INRIM	0.14380	0.18160	1.07580	1.38740	-0.2307	3.2402
NIS	0.14340	0.18120	1.11300	1.38700	-0.2345	3.2460
deviation	0.1433	0.1805	1.0866	1.3855	-0.1993	3.1983
Standard deviation	0.0016	0.0018	0.0307	0.0313	0.0449	0.1057

Table 10: Reported results for softgauge “L-K8 Aperiodic”.

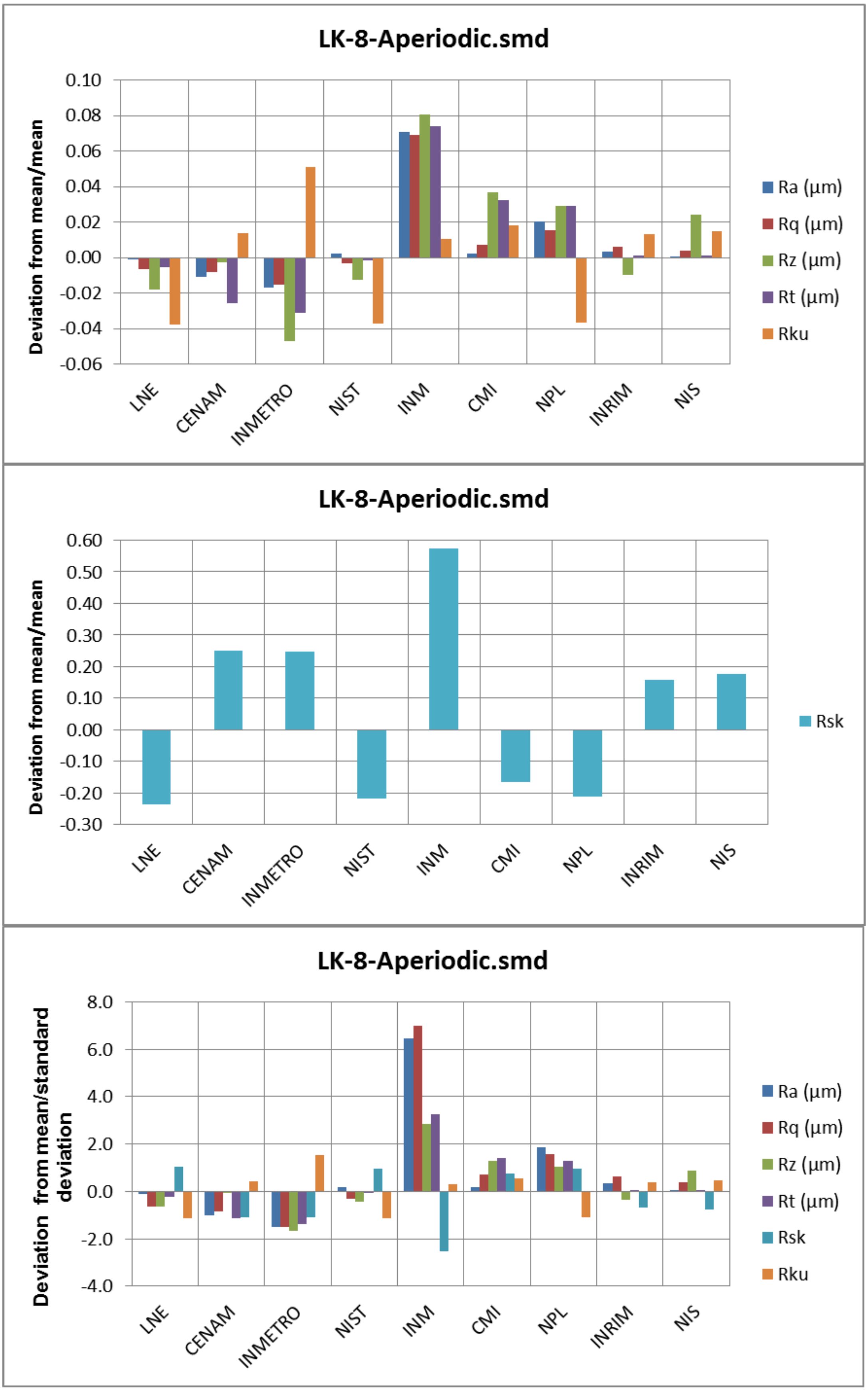


Figure 31: Deviation from mean relative to the mean value of the reported results (upper graph) or to the standard deviation of the reported results (lower graph.) for softgauge LK-8 Aperiodic.

10 RESULTS ANALYSIS

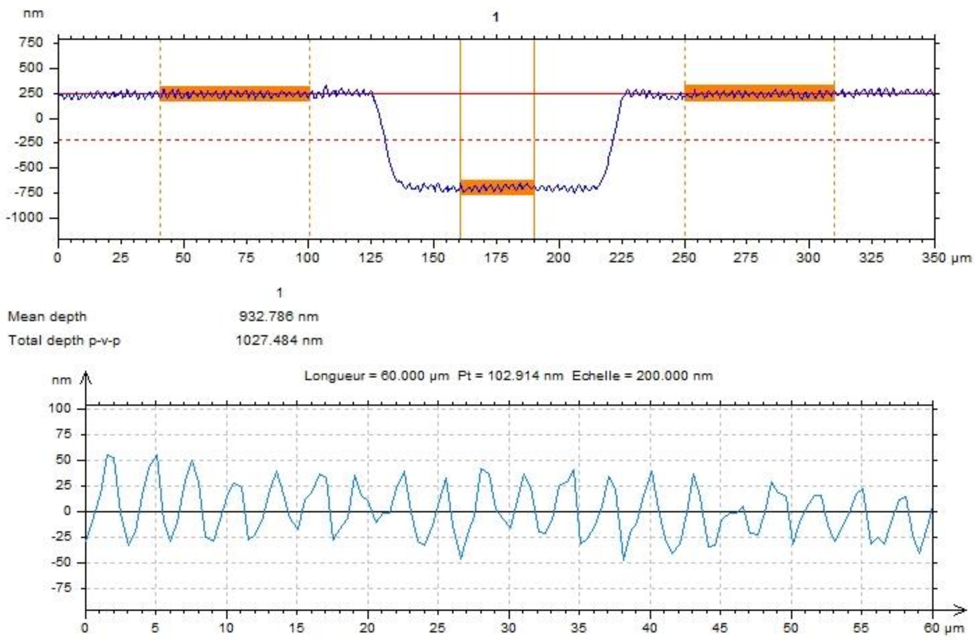
We can see that the proportion of outliers is significant and amounts to 27 out of 170 measurements (15.9%). These numbers are surprisingly high. The reference specimen 503 is the one who had more damage. A change occurred in parameters *Rz* and *Rt* but we were unable to find the origin of this change. No visual damage could be seen, another explanation could be the use of an excessive measuring forces with stylus which could explain the drop in *Rz, Rt*, but from Table 12, §12 appendix B, all the measuring forces were comparable. Most of the outliers concerns reference specimen 503E (10 outliers) and reference specimen 542E (12 outliers). These artefacts are the one with the smaller texture (*Rz* 700 and 200 nm respectively).

10.1 Parameters according to ISO 5436-1:2000 (*d*, *Pt*)

Only two participants (INM, CMI) were not able to assess the depth parameter according to ISO 5436-1:2000. The spread of the results is almost the same for G1 (12 nm) and G2 (14 nm) if we take into account the corrected values from INMETRO and DZM/HMI. The trend is to overestimate the uncertainties. This despite the fact that standard 511E suffered during the comparison.

For Pt parameter the spread is low (6nm) for G1 but much more important for G2 (87 nm), this could reflect the fact that groove G2 surface was the one which suffered the most (see Figure 10 and Figure 11.)

The difference between *Pt* value and *d* is higher for groove G1 (~ 110 nm) than G2 (~ 55 nm) and this is normal because G1 profile shows an oscillating structure with 100 nm amplitude that does not appear in G2 profile (see Figure 32).



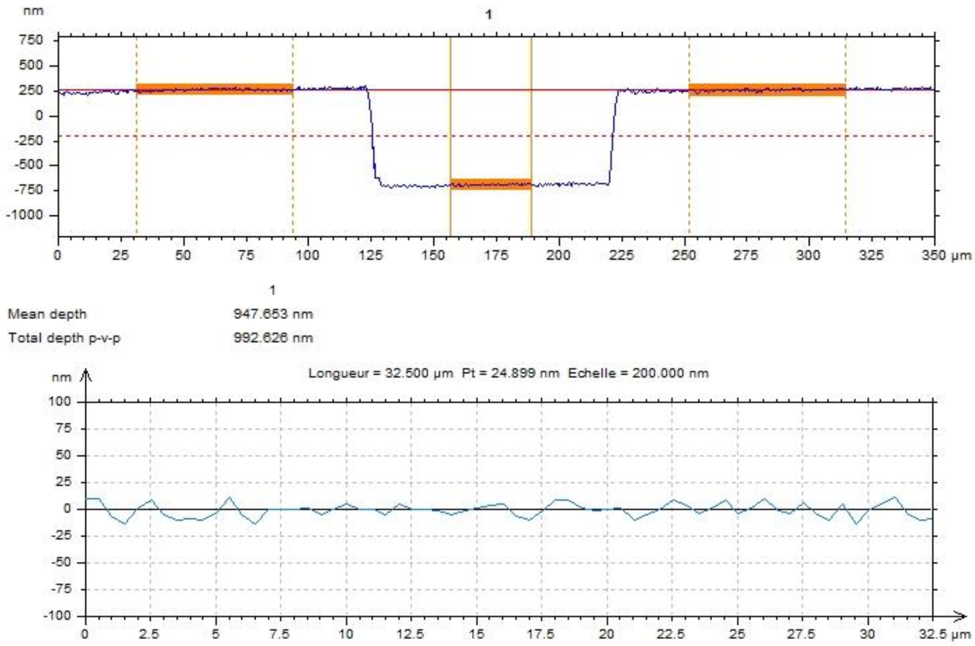


Figure 32: From up to down: groove G1 profile, zoom on the left zone of the reference line for G1, groove G2 profile, zoom on the left zone of the reference line for G2.

Therefore, one would expect that *Pt1* should be smaller than *Pt2* despite the depth difference (~25nm). This is not the case for INM where *Pt2* is 35 nm larger than *Pt1*, and CMI measured almost the same value for *Pt1* and *Pt2*.

10.2 Softgauges

We can see even for a simple periodic artefact, the variation from one software to another is quite important. This means that the contributions due to the evaluation software should be included in the uncertainty budgets.

For the aperiodic file, the more sensitive parameter seems to be Rsk (skewness) parameter.

11 APPENDIX A: DESCRIPTION OF MEASURING INSTRUMENTS

The instrument descriptions as reported by the participants are summarized in Table 11.

Institute	Instrument	Software	Standards	Traceability
LNE	Home made with 3 laser interferometer and an inductive pick-up.	Mountains Premium v5.1.1.5944	Laser interferometers.	LNE Iodine stabilized He-Ne laser source.
CENAM	Rank Taylor Hobson (RTH) with 120 mm inductive pick-up	RTH FTSS v6.10	Tungsten carbide sphere (12.5 mm) Transverse : Laser interferometer	CENAM CNM-PNM-2
INMETRO	RTH PGI 830	RTH Ultra v5.14.9.70 Talymap Gold K510/3057-01 v4.12.4434	A2 (0.264 to 9.457 µm), 3 x D1	Vertical : To PTB Transverse : INMETRO
INTI	Federal Surfanalyzer 5000.	Federal software v4.70e. Step Height : Homemade Matlab software.	A1 (5,76 µm), C3	Vertical and Transverse : To PTB
NIST	Roughness: Taylor Hobson Form Talysurf PGI 1240 Step Height: Taylor Hobson Talystep	Custom web based software (http://physics.nist.gov/smats) Step Height: Custom LabVIEW / Matlab programming	22 mm radius sphere + C1, A1	Interferometric methods. NIST Laser calibration group
INM	RTH Talysurf series 2	RTH µltra v4.3.14	C1 Transverse : Laser interferometer	Vertical : to NPL Transverse : INM
CMI	HOMMEL TESTER T 8000	Hommelwerke TURBO roughness software v 3.34	1 A2 (0.194 to 9.465 µm) 3x D1	Vertical and Transverse : To PTB
AS Metrosert / TTU	Perthometer Concept Roughness and Contour measuring station.	Perthometer Concept v 7.21	?	Vertical and transverse : To PTB or DKD
DZM/LSFB - HMI	Step Height : Interference microscope Roughness : Perthometer S8P	Original commercial software installed in instrument	Step Height : He-Ne laser Type C 3	Step Height : Iodine-stabilized He-Ne laser
NPL	NanoSurf IV	Homemade	Vertical and Transverse : laser interferometer	NPL Frequency stabilized laser source.
INRIM	Roughness :RTH TalySurf II (interferometric head) Step Height :RTH Talystep 1 and optical profilometer Sensofar plu2300 using	RTH Ultra software v 5.1.14 : RTH Groove v 3.02P IMGC and SPIP v 5.1.3	Talysurf II : Vertical : Ceramic Ball Transverse : Grating or stage	INRIM 1D comparator.

	Vertical Scanning Interferometry.		micrometer	
NIS	RTH TalySurf i60	RTH Ultra v5.16.2.0 Step Height : Homemade Matlab software.	Vertical : Sphere Transverse : RTH sphere	Vertical : KRISS Transverse : RTH (UKAS ?)

Table 11 : Instruments and software description.

12 APPENDIX B: MEASUREMENT CONDITIONS

The measurements conditions as reported by the participants are summarized in the Table 12.

Institute	speed	spacing	force	radius	angle
LNE	0.5 mm/s	0.5 µm	1 mN	2 µm	90°
CENAM	0.5 mm/s	0.5 µm	0.98 mN	2 µm	90°
INMETRO	0.25 mm/s	0.5 µm	1 mN	2 µm	90°
INTI	0.25 mm/s	?	0.7 mN	2 µm	?
NIST	0.03 mm/s (511E) 0.5 mm/s (527E) 0.1 mm/s (542E] 0.25 mm/s (503E)	0.042 µm 0.125 µm " "	20µN 1 mN " "	2 µm (nominal) 1.46 µm measured.	90°
INM	0.5 mm/s	0.25 µm	0.8 mN	2 µm	90°
CMI	0.0 to 2.0 mm/s	l_n / 9600	0.75 mN	2 µm	90°
AS Metrosert / TTU	0.5 mm/s	0.5 µm	< 0.8 mN	2 µm	90°
DZM/LSFB - HMI	0,5 mm/s	0,7 µm	1,3 mN	2 µm	90°
NPL	0.5 mm/min (511E, 542E) 5 mm/min (527E) 2 mm/min (503E)	0.17 µm 0.25 µm 0.28 µm	?	2 µm	?
INRIM	25 µm/s (511E) 0.5 mm/s	0.15 µm 0.25 µm	~50 µN 1 mN	2 µm	90°
NIS	0.25 mm/s	0.12 µm	1 mN	2 µm	90°

Table 12 : Measurement conditions for each institute

13 APPENDIX C: INRIM RESULTS FOR STEP HEIGHT STANDARD.

Here are the reported results from INRIM for both instruments (contact – non contact). Only the ones issued on 01/08/2011 from the stylus profilometer were taken into account in § 8.2.2. In red the changes compare to the initial report.

Original Report (01/08/2011)

- measurements performed with a stylus profilometer

Groove	Parameter	Value (nm)	σ_{mes} /nm	u_c (nm)	n_{eff}
G1	*d*	934.8	3.0	3.2	47
G2	*d*	961.0	1.3	2.3	126

- measurements performed with an optical profilometer operating in the VSI mode (Vertical Scanning Interferometry)

Groove	Parameter	Value (nm)	σ_{mes} /nm	u_c (nm)	n_{eff}
G1	*d*	937.8	1.1	2.2	125
G2	*d*	962.8	0.7	3.2	136

Revised Report (05/11/2012)

- measurements performed with a stylus profilometer

Groove	Parameter	Value (nm)	σ_{mes} /nm	u_c (nm)	n_{eff}
G1	*d*	934.8	3.0	3.2	47
G2	*d*	961.0	1.6	3.6	21

- measurements performed with an optical profilometer operating in the VSI mode (Vertical Scanning Interferometry)

Groove	Parameter	Value (nm)	σ_{mes} /nm	u_c (nm)	n_{eff}
G1	*d*	937.8	1.1	2.2	124
G2	*d*	962.8	0.7	3.2	27

14 APPENDIX D: INM SOFTGAUGES RESULTS USING GAUSSIAN FILTER

After draft A was issued, INM reported results for softgauges using a Gaussian filter instead of a 2RC filter. There results were not used in the comparison.

Parameter	LK-8 periodic	LK-8 Aperiodic
Ra (nm)	438.400	143.400
Rq (nm)	500.000	181.200
Rz (µm)	1.530800	1.113000
Rt (µm)	1.548700	1.387400
RSm (µm)	100.0500	
Rsk		-0.2344
Rku		3.2457