GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO

CEM CENTRO ESPAÑOL DE METROLOGÍA

Supplementary Comparison EURAMET.L-S23 (#1269)

High Precision Roundness Measurement by Error Separation Techniques

Technical protocol

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Tres Cantos, May 2013

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1 Document control

Final version Issued on 15 May 2013.

2 Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by a set of key and supplementary comparisons chosen and organized by the Consultative Committees of the CIPM or by the regional metrology organizations (RMOs) in collaboration with the Consultative Committees.

At its meeting in October 2012, the EURAMET Technical Committee for Length, EURAMET TC-L, decided that a key comparison on high precision roundness measurement by multi-step method shall be carried out with CEM acting as the pilot laboratory. The roundness standards to be calibrated were chosen to be a glass hemisphere with a diameter of about 50 mm and a sphere with a diameter of about 30 mm. The comparison was registered lately in March 2013 as Project EURAMET 1269 and at KCDB as Supplementary Comparison EURAMET.L-S23.2013. Artefacts circulation is supposed to start in May 2013 and finish in mid-end 2014.

The procedures outlined in this document cover the technical procedure to be followed during the measurements of the roundness standards. The procedures are principally intended to allow for a clear description of the required measurements, handling and transportation of the circulating standards and to complete the comparison in the time scale provided for. This technical protocol was prepared following the layout principles of the documents for previous comparisons. The allowance to use parts of this prior work wherever possible is gratefully acknowledged.

A goal of the EURAMET 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 Agreement (MRA). To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

3 Organization

3.1 Participants

Participants are listed in Table 1.

Table 1. List of participant laboratories and their contacts.

Laboratory Code	**Contact person, Laboratory**	**Phone, Fax, email**
CEM (Pilot)	Emilio Prieto CEM C/ del Alfar, 2 Tres Cantos – 28760 Madrid - Spain	Tel. +34 91 8074 716 Fax +34 91 8074 807 e-mail: eprieto@cem.minetur.es
VSL	Rob Bergmans VSL P.O. Box 654 2600 AR Delft, The Netherlands	Tel. +31 (0) 15 - 269 15 00 Fax +31 (0) 15 - 261 29 71 e-mail: rbergmans@vsl.nl
DTI	Maria Holmberg	Tel. +45 72 20 20 00

	DTI, Danish Technological Institute Taastrup Gregersensvej 1 DK-2630 Taastrup - Denmark	Fax +45 72 20 20 19 e-mail: mahg@teknologisk.dk
SMD	Hugo Piree Direction générale de la Qualité et de la Sécurité Service Etalons Nationaux Boulevard du Roi Albert II, 16 1000 Bruxelles – Belgique	Tél: 32 (0)2 277 76 10 Fax: 32 (0)2 277 54 08 e-mail: Hugo.Piree@economie.fgov.be
INRIM	Milena Astrua INRiM, Istituto Nazionale di Ricerca Metrologica Divisione Meccanica strada delle Cacce, 73 - 10135 - Torino - Italy	Tel. +39 011 3919 966 Fax e-mail: m.astrua@inrim.it
IPQ	Fernanda Saraiva IPQ - Instituto Português da Qualidade Rua António Gião, 2 2829-513 Caparica PORTUGAL	Tel. +351 212948160 Fax +351 212948188 e-mail: FSaraiva@ipq.pt
LNE	Hichem NOUIRA LNE 1, rue Gaston Boissier 75724 Paris Cedex 15 - France	Tel. : 01 40 43 37 00 Fax : 01 40 43 37 3 e-mail: hichem.nouira@lne.fr

3.2 Schedule

The participating laboratories are asked to specify a preferred timetable slot for their own measurements of the roundness standards – the timetable given in table 2 has been drawn up taking these preferences into account. The programme is to commence in May 2013 with measurement at the pilot laboratory. **Each laboratory has four weeks** that include 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 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 pilot laboratory will repeat measurements at the end of the schedule to check the stability of the artefacts.

Table 2. Schedule of the comparison.

RMO	Laboratory	Starting date of measurement
EURAMET	CEM (Pilot Lab)	May-June 2013
	INRIM	July 2013
		August 2013
	SMD	September 2013
	IPQ	October 2013
	LNE	November 2013
	DTI	December 2013
	VSL	January 2014
EURAMET	CEM (Pilot Lab)	February 2014

3.3 Reception, transportation, insurance, costs

A cardboard box containing the two roundness standards is used for the transportation of the artefacts (Figure 1). A copy of this protocol will be inside the box.

Upon reception of the package, each laboratory has to check that the content is complete and that there is no apparent damage on the box or any of the standards. The reception has to be confirmed immediately to the pilot with a copy to the former participant (sender), preferably using the form of Appendix A.

It is of utmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by un-authorised persons. Packaging for the artefacts has been made which will be suitably robust to protect the artefacts from being deformed or damaged during transit. The packaging should be marked as 'Fragile'.

Figure 1 – Transporting box

Once the measurements have been completed, the package shall be sent to the following participant.

Each participating laboratory shall cover the costs of shipping and transport insurance against loss or damage. The package should be shipped with a reliable parcel service of its choice. Once the measurements have been completed, please inform the pilot laboratory and the following participant when the package leaves your installations indicating all pertinent information. If, at any point during circulation, the package is damaged, it shall be repaired by the laboratory before shipping it again.

4 Artefacts

4.1 Description of artefacts

The artefacts to be calibrated are given in the table below

Table 3. List of artefacts.

Type	Manufacturer identification	Dimensions (mm)	Material
Hemisphere	Perthen 11279	Ø 50	Glass
Sphere	Saphirwerk 30-96-216	Ø 30	Ceramic (Al_2O_3)

Figure 2 – Glass hemisphere (Perthen 11279) and sphere (Saphirwerk 30-96-216)

Inscriptions:

Hemisphere: the identification number and one line indicating 0º position are marked on the mount.

Ball: the identification number is marked on the ball support.

Fixing the devices:

The standards shall be clamped by each laboratory's own usual methods which have to be described shortly on the report form. The sphere standard is permanently glued to a base support (made of Al); do not try to remove the ball from the base. The ball shall be measured by clamping its base support.

5 Measuring instructions

5.1 Handling the artefacts

The roundness standards should only be handled by authorized persons and stored in such a way as to prevent damage. Before making the measurements, the roundness standards 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.

No other measurements are to be attempted by the participants and the roundness standards should not be used for any purpose other than described in this document. The artefacts may not be given to any party other than the participants in the comparison.

The roundness standard should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory. Ensure that the content of the package is complete before shipment. Always use the original packaging.

5.2 Traceability

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 Measurands

The measurand is the roundness defect of each artefact. Peak-to-valley roundness deviation (*RON*t) shall be evaluated with reference to the least squares reference circle (LSCI) and, if possible, to the minimum zone reference circles (MZCI), in accordance with the ISO/TS 12181-1:2003.

All measurements must be performed at the speed of traverse not more than 10 revolutions per minute. Probing force must be specified and should not exceed 0.25 N. Stylus tip radius must be specified (see following paragraphs). Probing direction for measurement should be perpendicular to the axis of rotation (glass hemisphere) or in the direction of the normal to the spherical surface (sphere). In case a different orientation is used, this should be clearly reported. Results shall be reported using a Gaussian filter. Each measurement shall be preferably accompanied by its relevant plots.

Each laboratory shall use an error separation technique to remove the contribution of the spindle error. In case of using a multistep technique, as it is the common case, it is advisable to inform on the number of steps used.

Glass hemisphere

The reference mark (indicating 0^o) should be aligned with the 0^o reference position of the rotating element. The plane of measurement is 5 mm above the top of the mount as shown in Figure 3.

According with ISO/TS 12181-2:2003 and assuming that most of the participants use a roundness measuring system with 1050 sample points or more and spherical tips not smaller than 1 mm diameter, measurements shall be made with the following filter transmissions: 1-15 UPR, 1-50 UPR and 1-150 UPR.

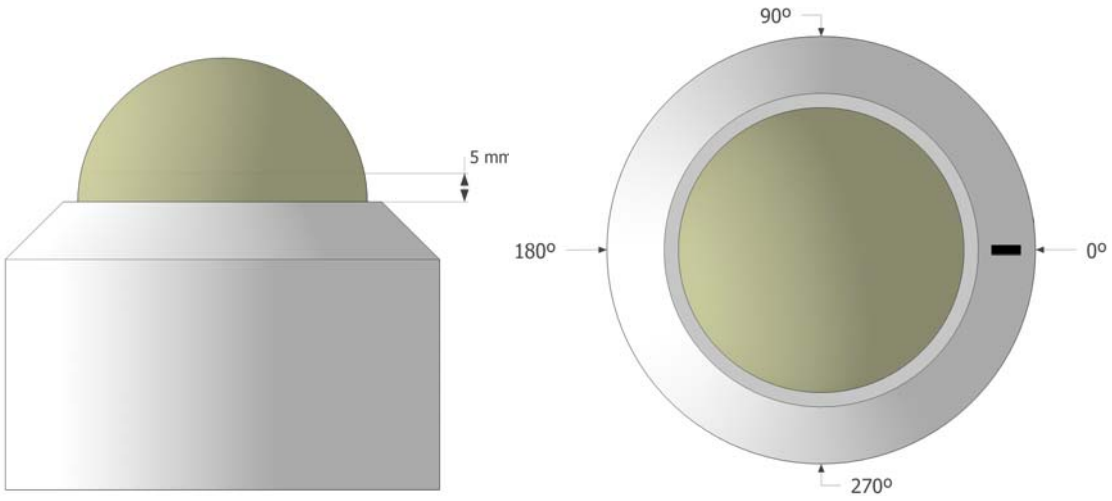

Figure 3 – Measurement plane and alignment of the glass hemisphere.

Sphere

The roundness of the sphere should be measured on the equator (figure 4).

According with ISO/TS 12181-2:2003 and assuming that most of the participants use a roundness measuring system with 350 sample points or more and spherical tips not smaller than 1 mm diameter, measurements shall be made with the following filter transmissions: 1-15 UPR and 1-50 UPR.

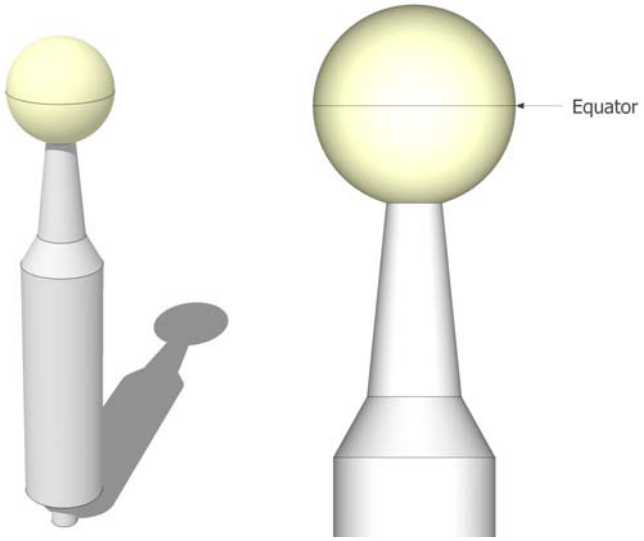

Figure 4 – Measurement plane of the sphere.

5.4 Measurement uncertainty

The uncertainty of measurement shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement. The participating laboratories are encouraged to use their usual model for the uncertainty calculation.

All measurement uncertainties shall be stated as standard uncertainties. If appropriate the corresponding effective degrees of freedom might be stated by the participants. If none is given, ∞ is assumed. For efficient evaluation and subsequent assessment of CMC claims an uncertainty statement in the functional form (1) is preferred, with indication of the factor *k* used, typically 2, or the one corresponding to a level of confidence of a 95 %, in case it was different.

$$U(R) = Q[a, bR] = \sqrt{a^2 + (bR)^2} \quad (1)$$

6 Reporting of results

As soon as possible after measurements have been completed, the results should be communicated to the pilot laboratory **within six weeks** at the latest.

The measurement report forms in Appendix B of this document will be sent by email (Word document) to all participating laboratories. It would be appreciated if the report forms could be completed by computer and sent back electronically to the co-ordinator. In any case, the signed report must also be sent in paper form by mail. In case of any differences, the paper forms are considered to be the definitive version.

Following receipt of all measurement reports from the participating laboratories, the pilot laboratories will analyse the results and prepare within 3 months a first draft A.1 report on the comparison. This will be circulated to the participants for comments, additions and corrections.

7 Analysis of results

7.1 Calculation of the KCRV

The key comparison reference value (KCRV) is calculated as the weighted mean of the participants results. The check for consistency of the comparison results with their associated uncertainties will be made based on Birge ratio. The degrees of equivalence for each laboratory and standard with respect to the KCRV will be evaluated using E_n values, along the lines of the *WG-MRA-KC-report-template*. If necessary, artefact instability, correlations between institutes and the necessity for linking to another comparison will be taken into account.

7.2 Artefacts instability

The instability of the standards must be determined in course of the comparison. For this check the measurements of the pilot laboratory are used exclusively, not that of the other participants.

To avoid biasing the weighted mean, only one set of measurements from the pilot laboratory will be included in the reference value determination.

Appendix A – Reception of Standards

To:	Centro Español de Metrología (CEM) Alfar 2, Tres Cantos, 28760-Madrid Fax: +34 918074807 e-mail: eprieto@cem.minetur.es
From:	NMI: …… Name: …… Signature: …… Date: ……

We confirm having received the standards for the EURAMET.L-S23.2013 comparison on the date given above.

After a visual inspection:

☐ There are no apparent damages; their precise state will be reported in the form provided in Annex B once inspected in the laboratory along with the measurement results.

☐ We have detected severe damages putting the measurement results at risk. Please indicate the damages, specifying every detail and, if possible, include photos. If it is necessary use additional sheets to report it.

Appendix B – Measurement Results

To:	Centro Español de Metrología (CEM) Alfar 2, Tres Cantos, 28760-Madrid Fax: +34 918074807 e-mail: eprieto@cem.minetur.es
From:	NMI: …… Name: …… Signature: …… Date: ……

Description of the measurement methods and instruments

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Measurement conditions

Table B1. Conditions during measurements

Set-up	Detail
Rotating workpiece or probe (CW or CCW)	
Rotation speed (rev/min)	
Number of measured values per revolution	
Filtering conditions	
Error separation technique/ Number of steps	
Stylus static force (mN)	
Ball tip diameter (mm)	

Measurement results

Table B2. Results and uncertainties on the glass hemisphere (Perthen 11279)

Filtering	***RON*t (LSCI) µm**	***U* (*k*=2) µm**	***RON*t (MZCI) µm**	***U* (*k*=2) µm**
1-15 UPR				
1-50 UPR				
1-150 UPR				

Table B3. Results and uncertainties on the sphere (Saphirwerk 30-96-216)

Filtering	***RON*t (LSCI) µm**	***U* (*k*=2) µm**	***RON*t (MZCI) µm**	***U* (*k*=2) µm**
1-15 UPR				
1-50 UPR				

Appendix C – Uncertainty of measurement

Table B4. Uncertainty budget of measurement

x_i	$u(x_i)$	v_i	$c_i = \partial y/\partial x_i$	$u_i(y)$

Combined standard uncertainty: $u_c(R)$=

Expanded uncertainty: $U(R)$ (k =) =

$U(R) = Q[a, bR] = \sqrt{a^2 + (bR)^2}$ =