# Follow-up Comparison on EUROMET.L-K4.2005

# Calibration of outer diameter standards

## Technical protocol

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Delft, October 2013

**Contents**

# 1 Document control

Version 1.0 Issued on September 2013.
Version 1.1 Issued on October 2013

# 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).

The executive report of the EURAMET L-K4 2005 contains several corrective actions to be performed for several laboratories. A few laboratories had corrective action specifically on the measurement of outer diameter standards. This follow-up comparison has the aim to validate the applied corrective actions.

The standard gauges to be calibrated are chosen to be three plug gauges with a diameter of 6 mm, 25 mm and 50 mm and a sphere with a diameter of 30 mm.

VSL (Netherlands) and SMD (Belgium) will cooperatively pilot the comparison; INRIM (formerly IMGC), Italy provides the link to the EUROMET L-K4 2005.

The procedures outlined in this document cover the technical procedure to be followed during measurement of the diameter gauges. 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) [BIPM, 1999]. 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 Form of the comparison

Since the number of participants is small (5), the form of the comparison will be circular according to the agreed time schedule.

All results are to be communicated directly to the pilot laboratory VSL as soon as possible and certainly within 6 weeks of the completion of the measurements by a laboratory.

The participating laboratories were asked to specify a preferred timetable slot for their own measurements of the gauges - the timetable given below has been drawn up taking these preferences into account.

## 3.2 Participants

| Laboratory | Address | Contact Person /tel/e-mail |
|---|---|---|
| INRIM (link) | Istituto Nazionale di Ricerca Metrologica<br>Strada delle Cacce, 73<br>IT-10135 Torino<br>Italy | Mr. Gian Bartolo Picotto<br>+39 011 3919969<br>g.picotto@inrim.it |
| MIRS | University of Maribor<br>Faculty of Mech. eng.<br>Smetanova 17<br>SI-2000 Maribor<br>Slovenia | Dr. Bojan Acko<br>+386 2 220 7581<br>bojan.acko@uni-mb.si |
| NPL | National Physical Laboratory<br>Hampton Road<br>Teddington, Middlesex<br>TW 11 OLW<br>United Kingdom | Dr. David Flack<br>+44 20 8943 6347<br>andrew.lewis@npl.co.uk |
| SMD | Federal Public Service Economy<br>Directorate-general Quality and Safety<br>Metrology – National Standards SMD<br>North Gate III<br>Koning Albert II straat, 16<br>BE-1000 Brussels<br>Belgium | Mr. Hugo Piree<br>+32 2 277 7610<br>hugo.piree@mineco.fgov.be |
| VSL | VSL<br>Thijsseweg 11<br>NL-2600 AR Delft<br>The Netherlands | Mr. Gerard Kotte<br>+31 15 269 16 01<br>gkotte@vsl.nl |

## 3.3 Time schedule

Time table

| Laboratory | Country | Date |
|---|---|---|
| INRIM | Italy | 14 October 2013 – 24 November 2013 |
| VSL | The Netherlands | 25 November 2013 – 05 January 2014 |
| NPL | United Kingdom | 06 January 2014 – 16 February 2014 |
| MIRS | Slovenia | 17 February 2014 – 30 March 2014 |
| SMD | Belgium | 31 March 2014 – 11 May 2014 |
| VSL | The Netherlands | 12 May 2014 – 31 May 2014 |

Each laboratory has 6 weeks for calibration and transportation. With its confirmation to participate, each laboratory has confirmed that it is capable to perform the measurements in the time allocated to it. It guarantees that the standards arrive in the country of the next participant at the beginning of the next period.

If for some reason, the measurement facility is not ready or customs clearance takes too much time in a country, the laboratory has to contact the pilot laboratory immediately and (according to the arrangement made) eventually to send the standards directly to the next participant before finishing the measurements or even without doing any measurements.

## 3.4 Transport of the artefacts

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.

A case for the artefacts has been made which is be suitably robust to protect the artefacts from being deformed or damaged during transit, see figure 1.


*Figure 1:* Air tight transportation case for the gauges

The packaging should be marked as 'Fragile'.

Transportation is each laboratory's responsibility and cost. Each participating laboratory covers the costs for its own measurements, transportation and any customs charges as well as for any damages that may have occurred within its country. The overall costs for the organisation, initial and interim measurements and the processing of results are covered by the organising pilot laboratories. The pilot laboratories have no insurance for any loss or damage of the standards during transportation.

On short notice after the receipt of the standards the pilot laboratory shall be informed by e-mail on the following details:

- date of receipt of the standards
- remarks about the condition of the package
- remarks of the visual inspection egg if there are damages, the nature of the damages, see: *5.6 Measurement procedure.*

## 3.5 Handling of the artefacts

The gauges should be examined immediately upon receipt. The condition of the gauges should be noted and communicated to the pilot laboratory group.

The gauges should only be handled by authorized persons and stored in such a way as to prevent damage.

No re-finishing of the gauges should be attempted. If a gauge becomes un-measurable it will be removed from the remainder of the comparison. Laboratories should attempt to measure all gauges unless doing so would damage their equipment.

The gauges should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory.

Please inform the pilot laboratory and the next laboratory via e-mail when the gauges are about to be sent to the next recipient.

After the measurements the gauges must be greased immediately, preferably using acid-free vaseline, to prevent rust. Ensure that the content of the package is complete before shipment. Always use the original packaging.

To prevent the interior of the case to become greasy and to secure them firmly in the case the gauges are additionally wrapped in cleaning cloth and plastic, see figure 2


*Figure 2:* Gauges in the case with- and without the additionally wrapping

# 4 Artefacts

## 4.1 Description of artefacts

The artefacts to be calibrated are described and shown in the table below and in figure 3.

The identification of the plug gauges is marked on their handle by inscription. The identification of the ball is applied on its support using a sticker.

*Note: be aware with cleaning agents it might whip the text on the sticker.*

| Type | Manufacturer | Identification | Nominal diameter /mm | Material |
|---|---|---|---|---|
| Plug | Microtool | 606 | 6 | steel |
| Plug | Microtool | 2517 | 25 | steel |
| Plug | SIP / Etalon | 5773 | 50 | steel |
| Sphere | ZEISS | SPH30LK4 | 30 | steel |


*Figure 3:* The four standards to be measured.

# 5 Measuring instructions

## 5.1 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).

## 5.2 Fixing the standards

The artefacts shall be handled and positioned by each laboratory's own usual methods but in such a way that the measuring surfaces of the gauges are not damaged. Please describe the applied method shortly on the report form.

## 5.3 Measurands

The measurand for each gauge is the diameter at the reference temperature of 20°C and corrected to zero force. For the correction to 20°C the thermal expansion coefficient of $11.6 \cdot 10^{-6}\,K^{-1}$ should be used.

## 5.4 Measurement position

The diameter of the plug gauges should be measured at 3 different heights according to the table below.

| Gauge | Diameter measurement locations |
|---|---|
| Plug Ø 6 mm | 3 mm ↑<br>Middle<br>3 mm ↓ |
| Plug Ø 25 mm | 7 mm ↑<br>Middle<br>7 mm ↓ |
| Plug Ø 50 mm | 7 mm ↑<br>Middle<br>7 mm ↓ |

„x mm ↑“ refers to the measurement location x mm *above the mid height* of the cylinder.
„x mm ↓“ refers to the measurement location x mm *below the mid height* of the cylinder.
“*Below the mid height*” is defined in the direction of the handle.

For the ball the measurement position is fully determined by the measurement direction.

## 5.5 Measurement direction

The measurement direction is perpendicular to the core line through the gauge.

For the plug gauges the radial orientation of the measurement direction is parallel to the marks on the upper side of the gauge body. If those measurement indication marks are not present, as with the SIP plug gauge, the measurement direction is parallel to the flat part of the handle, see figure 4.
The side opposite to the handle is considered to be the upper side.

*Note: the lines on the plug gauges defining the measurement direction does unfortunately not always cross precisely the centre of the cylinder/sphere. The measurement direction shall therefore always be parallel to this line, but not necessarily coincident.*

For the ball the radial direction is indicated by a small indication pin, see figure 5.

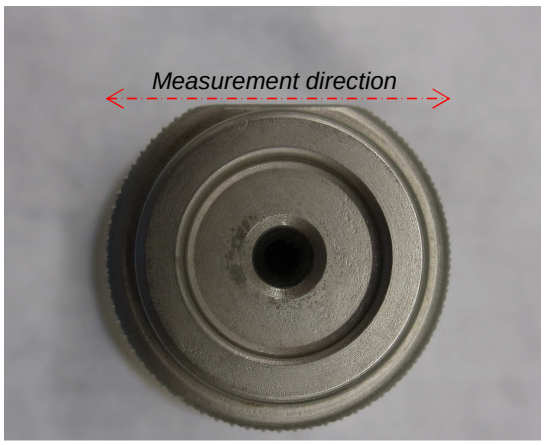


*Figure 4:* Measurement direction for the SIP plug gauge

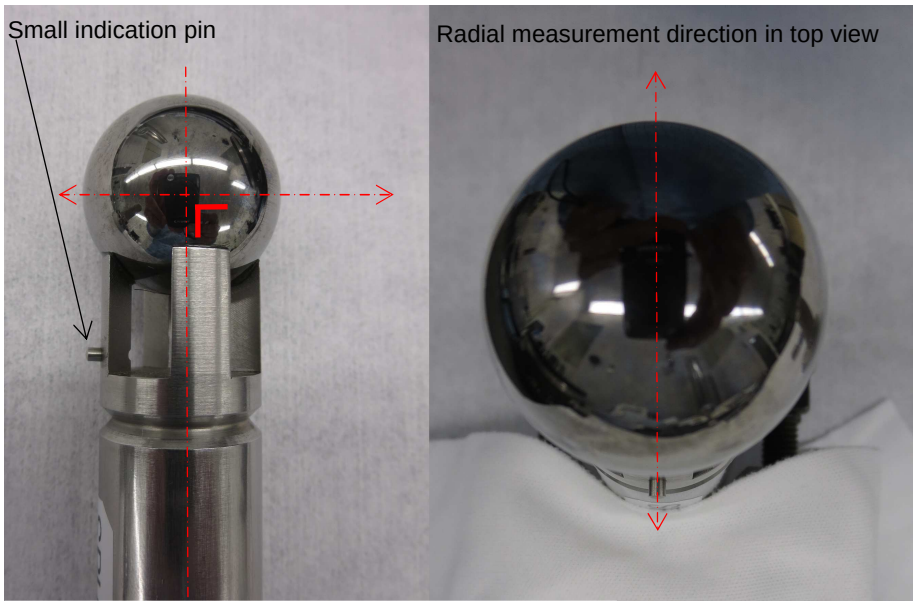


*Figure 5:* Measurement direction of the sphere

### 5.6 Measurement procedure

A goal of this EUROMET key comparison is to demonstrate the equivalence of routine calibration services for diameter standards offered by NMIs to clients, as listed by them in Appendix C of the Mutual Recognition Agreement (MRA) [BIPM, 1999]. To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts. Participants are free to tune and operate their systems to best-measurement performance, and to take extra measurements needed to produce a best-measurement result, provided that these extra efforts would also be available to a client if requested.

Before calibration, the gauges must be inspected for damage to the measurement surfaces and side faces. Any scratches, rusty spots or other damages have to be documented and communicated, see: *3.5 Transport of the artefacts.*

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

### 5.7 Measurement uncertainty

The uncertainty of measurement shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement.

## 6 Reporting of results

### 6.1 Results and standard uncertainties as reported by participants

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

It is urged to complete the report forms as presented in appendix A, or like-wise, by computer and sent back electronically to the pilot. In any case, the signed report must also be sent in paper form by mail or electronically as a scanned pdf document. In case of any differences, the signed forms are considered to be the definitive version.

For the measurement uncertainty budget and the resulting combined standard uncertainty the form as presented in appendix B, or like-wise, can be used.

Following receipt of all measurement and uncertainty reports from the participating laboratories, the pilot laboratory 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. The procedure outlined in the BIPM ‘Guidelines for CIPM key comparisons’ and EUROMET Guide 3 will be followed.

# 7 Appendix A: Measurement results

Please expand the available space for the description if not sufficient

## 7.1 Description of the measurement set-up and measurement method

*Measurement of plug gauges.*

*Measurement of spheres.*

## 7.2 Measurement results.

| ∅ 6 mm plug gauge, identification number: Microtool 606 | | | | |
|---|---|---|---|---|
| Location | Diameter /mm | Std. uncert. *k*=1 /µm | Mat. temp. /°C | Probe (∅, form) Meas. force (N) |
| 3 mm ↑ | | | | |
| Middle | | | | |
| 3 mm ↓ | | | | |

| ∅ 25 mm plug gauge, identification number: Microtool 2517 | | | | |
|---|---|---|---|---|
| Location | Diameter /mm | Std. uncert. *k*=1 /µm | Mat. temp. /°C | Probe (∅, form) Meas. force (N) |
| 7 mm ↑ | | | | |
| Middle | | | | |
| 7 mm ↓ | | | | |

| ∅ 50 mm plug gauge, identification number: SIP / Etalon 5773 | | | | |
|---|---|---|---|---|
| Location | Diameter /mm | Std. uncert. *k*=1 /µm | Mat. temp. /°C | Probe (∅, form) Meas. force (N) |
| 7 mm ↑ | | | | |
| Middle | | | | |
| 7 mm ↓ | | | | |

| ∅ 30 mm sphere, identification number: Zeiss SPH30LK4 | | | | |
|---|---|---|---|---|
| Location | Diameter /mm | Std. uncert. *k*=1 /µm | Mat. temp. /°C | Probe (∅, form) Meas. force (N) |
| As determined by the measurement direction | | | | |

# 8 Appendix B: uncertainty of measurement for gauge type:

| $x_i$ | $u(x_i)$ | $\nu_i$ | $c_i = \partial l / \partial x_i$ | $u_i(l)$ / nm |
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| Combined standard uncertainty: $u_c(l) =$ | | | | |