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(Istituto Nazionale di Ricerca Metrologica)

National Office of Measures
Hungary

EUROMET Key Comparison, EUROMET.L-K4.2005

(EUROMET Project 812)

Calibration of diameter standards

Technical protocol (Issue 1.9)

Contents

1. Introduction

1.1 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).

1.2 At its meeting in October 2003, the TC group for Length identified several EUROMET key comparisons in the field of dimensional metrology. In particular, it decided that a key comparison on diameter standards shall be carried out. This comparison follows the previous EUROMET 384 (EUROMET.L-K4) comparison.

1.3 Due to the large number of the participants, it has been decided to have 2 groups in the project. The participants for the 2 groups were separated according to the claimed uncertainties. Those whose uncertainties are less that or equal to 0.3 micrometer (for 50 mm gauge) belong to the group 1, the others to the group 2.

1.4 The standard gauges to be calibrated were chosen to be two rings with a diameter of about 40-50 mm and 3-5 mm, two plugs with similar diameters and a sphere with a diameter of about 30 mm.

1.5 Mr. Gian Bartolo Picotto, IMGC (INRiM) Italy acts as the pilot laboratory for the group 1, Ms. Edit Banreti, OMH Hungary acts as the pilot for the group 2.

1.6 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.

1.7 A goal of the EUROMET 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.

2. Organisation

2.1. Participants in the group 1

Laboratory	Address	Contact person /tel/fax/e-mail
LNE	Laboratoire National de Metrologie et d'Essais 1 Rue Gaston Boissier FR-75724 Paris cedex 15 France	Mr. Georges Vailleau +33 1 40 43 38 24 +33 1 40 43 37 37 georges.vailleau@lne.fr
INPL (Euromet corresponding NMI)	The National Physical Laboratory of Israel Givat Ram Jerusalem 91904 Israel	Dr. Ilya Kuselman tel. (972)-2-5661856 fax. (972)-2-6520797 ilya.kuselman@moital.gov.il
IMGC (INRiM)	Instituto di Metrologia G. Colonnetti (Istituto Nazionale di Ricerca Metrologica) Strada delle Cacce, 73 IT-10135 Torino Italy	Mr. Gian Bartolo Picotto +39 011 3977 469 +39 011 3977 459 g.picotto@imgc.cnr.it
METAS	Swiss Federal Office of Metrology and Accreditation Lindenweg 50 CH-3003 Bern-Wabern Switzerland	Dr. Rudolf Thalmann +41 31 32 33 385 +41 31 32 33 210 rudolf.thalmann@metas.ch
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NMI-VSL	Nmi Van Swingen Laboratorium B.V Schoemakerstraat 97 NL-2600 AR Delft The Netherlands	Ing. Gerard Kotte +31 15 269 16 01 +31 15 261 29 71 gkotte@nmi.nl
NPL	National Physical Laboratory Hampton Road Teddington, Middlesex TW 11 OLW United Kingdom	Dr. Andrew Lewis +44 20 8943 6124 +44 20 8614 0533 andrew.lewis@npl.co.uk
OMH	National Office of Measures H-1124 Budapest Németvölgyi út 37-39 Hungary	Ms. Edit Banreti +36 1 458 59 97 +36 1 458 59 27 e.banreti@omh.hu
PTB	Physikalisch-Technische Bundesanstallt Bundesallee 100 DE-38116 Braunschweig Germany	Dr. Otto Jusko +49 531 592 5310 +49 531 592 5305 Otto.Jusko@ptb.de
SMD	Ministere des Affaires Economiques E6-service de la Metrologie North Gate III Boulevard du Roi Albert II, 16 BE-1000 Brussels Belgium	Mr. Hugo Piree +32 2 206 4690 +32 2 206 5745 hugo.piree@mineco.fgov.be
SP	Swedish National testing and Research Institute MT Brinellgatan 4 SE-504 62 BORÅS	Mr. Mikael Frennberg +46 33 16 54 86 +46 33 10 69 73 mikael.frennberg@sp.se
INMETRO	Instituto Nacional de Metrologia (INMETRO) Av. Nossa Senhora das Graças, 50 Xerém - 25250-020 Duques de Caxias Rio de Janeiro, Brazil	Jose Carlos VALENTE DE OLIVEIRA jcoliveira@inmetro.gov.br

CSIR-NML	CSIR-NML Mechanical Metrology Meiring Naude Road, Brummeria Postal Address: PO Box 395 0001 Pretoria South Africa	Oelof Kruger + 27 12 841 4340 + 27 12 841 2131 oakruger@csir.co.za

2.2. Participants in the group 2

Laboratory	Address	Contact person /tel/fax/e-mail
BEV	Bundesamt für Eich – und Vermessungswesen Arltgasse 35 AT-1160 Wien Austria	Dr. Michael Matus +43 1 49 110 540 +43 1 49 20 875 m.matus@metrologie.at
CEM	Centro Espanol de Metrologia Alfar, 2 ES-28760 Tres Cantos (Madrid) Spain	Mr. Emilio Prieto +34 91 807 47 16 +34 91 807 48 07/809 eprieto@cem.es
CMI	Czech Metrological Institute V Botanice 4 CZ 150 70 Praha 5 Czech Republic	Dr. Petr Balling +420 257 288 326 +420 257 32 80 77 pballing@cmi.cz
DFM	Danish Institute of Fundamental Metrology Matematiktorvet 307 DK-2800 Kongens Lyngby Denmark	Dr. Jes Henningsen +45 45 25 58 65 +45 45 93 11 37 jh@dfm.dtu.dk
EIM	Hellenic Institute of Metrology Industrial Area of Thessaloniki Block 45 GR-57 022 Sindos Thessaloniki Greece	Dr. Christos Bandis +30 2310 56 99 99 +30 2310 56 99 96 bandis@eim.org.gr
FSB	University of Zagreb Faculty of Mechanical Eng. and Naval Architecture Ivana Lucica 5 HR 10000 Zagreb Croatia	Mr. Vedran Mudronja +385 1 616 83 27 +385 1 616 85 99 vedran.mudronja@fsb.hr
GUM	Central Office of Measures ul. Elektoralna 2 PL-00950 Warszawa Poland	Mr. Zbigniew Ramotowski +48 22 581 9543 +48 22 620 8378 length@gum.gov.pl
IMGC (link)	Instituto di Metrologia G. Colonnetti Strada delle cacce, 73 IT-10135 Torino Italy	Mr. Gian Bartolo Picotto +39 011 3977 469 +39 011 3977 459 g.picotto@imgc.cnr.it
INM	National Institute of Metrology 11, Sos. Vitan-Barzest RO-042122 Bucharest 4 Romania	Alexandru Duta +40 21 334 55 20 +40 21 334 55 33 Alexandru.duta@inm.ro
LNMC	Latvian National Metrology Centre 157, K. Valdemara Str. Riga, LV-1013 Latvia	Ms. Edite Turka +371 7 362 086 +371 7 362 805 edite.turka@lnmc.lv

METAS (link)	Swiss Federal Office of Metrology and Accreditation Lindenweg 50 CH-3003 Bern-Wabern Switzerland	Dr. Rudolf Thalmann +41 31 32 33 385 +41 31 32 33 210 rudolf.thalmann@metas.ch
METROSERT	AS Metrosert Aru 10 EE-10317 Tallinn Estonia	Mr. Lauri Lillepea +372 6 019 508 +372 6 020 081 lauri.lillepea@metrosert.ee
MIRS	University of Maribor Faculty of Mech. eng. Smetanova 17 SI-2000 Maribor Slovenia	Dr. Bojan Acko +386 2 220 7581 +386 2 220 7990 bojan.acko@uni-mb.si
NML	National Metrology Laboratory Enterprice Ireland Campus Glasnevin IE-Dublin 14 Ireland	Mr. Howard McQuoid +353 1 808 2657 +353 1 808 2026 howard.mcquoid@enterprise-ireland.com
NPL (link)	National physical Laboratory Queens Road Teddington Middlesex TW 11 OLW United Kingdom	Dr. Andrew Lewis +44 20 8943 6124 +44 20 8614 0533 abdrew.lewis@npl.co.uk
OMH	National Office of Measures H-1124 Budapest Németvölgyi út 37-39 Hungary	Ms. Edit Banreti +36 1 458 59 97 +36 1 458 59 27 e.banreti@omh.hu
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NRC	Institute for National Measurement Standards (INMS) National Research Council Canada (NRC) 1200 Montreal Road Ottawa, ON, Canada K1A OR6	Mr. Kostadin Doytchinov +613 991 0265 +613 952 1394 kostadin.doytchinov@nrc.ca

2.3. Form of comparison

2.3.1 The comparison will be in a mixed form, both ‘circular’ and ‘star-shaped’ in both groups. The gauges will be circulated within a group of laboratories then returned to the pilot laboratory in order to prepare the necessary ATA Carnet for the custom formalities before circulation in the second group of laboratories.

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

2.3.3 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.

In the present draft the laboratories are listed according to the updated time schedule submitted to the participants.

2.3.4 Timetable for the group 1

(laboratories are listed according to the updated time schedule submitted to the participants).

Laboratory	Country	Date
IMGC	Italy	May-June 2005
METAS	Switzerland	July 2005
-	-	August 2005
OMH	Hungary	September 2005
SMD	Belgium	October 2005
SP	Sweden	November 2005
PTB	Germany	December 2005
NMI-VSL	Netherlands	January 2006
NPL	United Kingdom	February 2006
MIKES	Finland	March 2006
LNE	France	April 2006
INPL	Israel	May 2006
IMGC	Italy	June 2006
INMETRO CSIR-NML	Brazil South Africa	July 2006 August 2006

2.3.5 Timetable for the group 2

(laboratories are listed according to the updated time schedule submitted to the participants).

Laboratory	Country	Date
METAS (link)	Switzerland	April 2005
OMH	Hungary	May-June 2005
BEV	Austria	July 2005
-	-	August 2005
CMI	Czech Republic	September 2005
GUM	Poland	October 2005
NML	Ireland	November 2005
DFM	Denmark	December 2005
NPL (link)	United Kingdom	January 2006
MIRS	Slovenia	February 2006
EIM	Greece	March 2006
METROSERT	Estonia	April 2006
LNMC	Latvia	May 2006
OMH (ATA CARNET)	Hungary	June 2006
IMGC (link)	Italy	July 2006
FSB	Croatia	August 2006
INM	Romania	September 2006
UME	Turkey	October 2006
NRC	Canada	November 2006
CEM	Spain	December 2006
OMH	Hungary	January 2007

2.3.6 Each laboratory has one month 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 month.

2.3.7 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 of their group 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.

2.4. Handling of artefacts

2.4.1 The gauges should be examined immediately upon receipt. The condition of the gauges should be noted and communicated to the pilot laboratory of their group. Please use the fax form in appendix A.3.

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

2.4.3 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.

2.4.4 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.

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

2.4.6 After the measurements, the gauges must be cleaned. The steel gauges must be greased immediately after the measurements and put into a rust preventing paper for transportation. Ensure that the content of the package is complete before shipment. Always use the original packaging.

2.5. Transport of artefacts

2.5.1 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.

2.5.2 Packaging for the artefacts has been made which will be suitably robust to protect the artefacts from being deformed or damaged during transit.

2.5.3 The packaging should be marked as ‘Fragile’.

2.5.4 The artefacts will be accompanied by a suitable customs carnet (where appropriate) or documentation identifying the items uniquely. **The carnet ATA shall always be shipped with the package, never inside the box, but apart. Please be certain, that when receiving the package, you also receive the carnet! Every time the carnet is used, it is stamped TWICE – on exit from one country and on entry into the next. In this regard, the EU member states are considered as being one**

country. Please examine the carnet and assure that the transportation company used has arranged for correct stamping of the carnet. Failure to ensure both stamps (exit, entry) subjects the carnet holder to a penalty.

The carnet ATA is kept by the pilot during the circulation (Group 1) within EU countries. Pilot will provide the ATA CARNET for the shipment outside EU.

2.5.5 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.

3. Description of the standards

3.1. Artefacts for group 1

3.1.1 The artefacts to be calibrated for the **group 1** are given in the table below:

Type	**Manufacturer identification**	**Dimensions (mm)**	**Material**
Ring	MG 04-437	Ø 3,5 height 10	Steel
Ring	MG IMGC 92/3	Ø 40 height 24	Steel
Plug	Microtool 2534	Ø 4 height 9 total height 45	Steel
Plug	Microtool 2535	Ø 50 height 25 total height 102	Steel
Ball	SWIP D4769	Ø 30	Ceramic (Al_2O_3)
Plug for optional measurements			
Plug	MG 04-253	Ø 7,5 height 10 total height 74	Steel

Inscriptions:
Ring gauges: the two ring gauges are all marked on their upper surface with their identification and two lines indicating the measurement direction.

Plug gauges: the two plug gauges (and the optional plug) are all marked on their handle with their identification and two lines indicating the measurement direction. The upper side shall be opposite to the handle.

Ball: the identification number and two lines indicating the measurement direction are marked on the ball support. The measurement direction is also given by three paint marks at the top of the ball.

Fixing the devices:
The ring and plug standards shall be clamped by each laboratory's own usual methods which have to be described shortly on the report form.

The plugs shall be clamped on their handle cylinder/holder; the optional plug of ∅ 7,5 mm is permanently mounted into an holder made of Al.

The ball 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.

3.2. Artefacts for group 2

3.1.2 The artefacts to be calibrated for the **group 2** is in the table below:

Type	Manufacturer	Identification	Dimension (mm)
Ring	Microtool	2619	5
Ring	Microtool	2618	40
Plug	Microtool	2621	5
Plug	Microtool	2620	50
Sphere	SWIP	D 4901	30

4. Measurement instructions

4.1. Traceability

4.1.1 Length measurements should be traceable to the latest realisation of the metre as set out in the current "*Mise en Pratique*".

4.1.2 Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90).

4.2. Measurand

4.2.1 The measurand is the diameter of each gauge at 20°C and corrected to zero force. The diameter of the ring and plug gauges should be measured at the marked lines in 3 different heights according to the table below. The diameter of the sphere should be measured at the marked lines.

Note that the lines 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.

„*x* mm↑" and „*x* mm↓" refer to the required measurement locations *x* mm above and below the mid height of the cylinder. The upper side of the rings is defined by the inscription; for the plugs the handle or the holding cylinder are assumed to be below.

4.2.2 The measurement locations for the cylindrical gauges are shown below:

Cylindrical gauges - Group 1

Gauge	Manufacturer identification	Diameter and roundness measurement locations
Ring Ø 3,5 mm	MG 04-437	2mm↑ Middle 2mm↓
Ring Ø 40 mm	MG IMGC 92/3	6mm↑ Middle 6mm↓
Plug Ø 4 mm	Microtool 2534	2mm↑ Middle 2mm↓
Plug Ø 50 mm	Microtool 2535	6mm↑ Middle 6mm↓
Plug for optional measurements		
Plug Ø 7,5 mm	MG 04-253	2mm↑ Middle 2mm↓

Cylindrical gauges - Group 2

∅ 5 mm ring gauge	∅ 40 mm ring gauge	∅ 5 mm plug gauge	∅ 50 mm plug gauge
3 mm↑	10 mm↑	2 mm↑	6 mm↑
middle	middle	middle	middle
3 mm↓	10 mm↓	2 mm↓	6 mm↓

4.2.3 The roundness of the ring and plug gauges should also be measured at the same heights as the diameter measurements and one roundness measurement for the sphere on the equator.

4.2.4 Also the straightness of the ring and plug gauges should be measured in the marked lines (0 and 180°).

4.2.5 The calibration should be carried out as for a normal customer. It means that there is no information about the form error of the artefacts. The measurements have to be reported for zero measuring force and at the reference temperature 20° C, using a thermal expansion coefficient of $11{,}6 \cdot 10^{-6}$ K^{-1} for the cylindrical standard and of $8{,}1 \cdot 10^{-6}$ K^{-1} for the ceramic ball, which are both assumed values because they have not been measured.

4.2.6 The roundness and straightness measurements are required only if they are done normally for the customers as well.

4.2.7 Whenever possible, the participants are invited to report the deviation from roundness at given cut-off frequencies (in UPR) of the long-pass filter, in order to achieve a better comparability of the results. If available, a Gaussian filter should be used, but in any case the participants are asked to specify which type of filter is used.

By assuming that many participants use a roundness measuring system with 2000 sample points or less and spherical tips not smaller than 1 mm diameter, the preferred filters are given in the following table:

Ring/plug	Filter
3,5 mm ring 4 mm plug 5 mm plug/ring	15 UPR
7,5 mm plug	50 UPR
40 mm ring 50 mm plug	150 UPR

For the 30 mm sphere, the participants are invited to report the deviation from roundness at 500 UPR, 150 UPR and 50 UPR.

In addition, following a decision at the 2005 EUROMET TC-L meeting, it is hoped to use the results of roundness measurement on the sphere as evidence for proving CMC claims of those NMIs offering a roundness measuring service, or planning to submit a CMC for such a service, especially where such NMIs have no previous comparison evidence available. Participants are therefore invited to report the deviation from roundness of the sphere (at 500, 150 and 50 UPR). These measurements should be performed using the roundness measuring service for which the CMC claims are to be tested.

4.3. Measurement instructions

4.3.1 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.

4.3.2 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.

4.3.3 The measurement results (appropriately corrected to the reference temperature of 20 °C and the measuring force of zero) have to be reported using the table in appendix A.1.

4.3.4 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.

4.3.5 Measurement uncertainty

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

The participants are required to report their measurement uncertainty budget in the table of appendix A.2.

4.4. Transmission of results

4.4. Transmission of results

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

4.4.2 The measurement report forms in appendix A.1 of this document will be sent by e-mail (Word document) to all participating laboratories. It would be appreciated if the report forms (in particular the results sheet) could be completed by computer and sent back electronically to the 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.

4.4.3 Following receipt of all measurement reports from the participating laboratories, the pilot laboratories will analyse the results and prepare a first draft 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.

A.1 Measurement results (Group 1)

I. Short description of the instrument / measurement method

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II. Diameter measurements (Group 1)

∅ 3,5 mm ring gauge, identification number: MG 04-437

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
2 mm↑				
middle				
2 mm↓				

∅ 40 mm ring gauge, identification number: MG IMGC 92/3

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
6 mm↑				
middle				
6 mm↓				

∅ 4 mm plug gauge, identification number: Microtool 2534

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
2 mm↑				
middle				
2 mm↓				

∅ 50 mm plug gauge, identification number: Microtool 2535

∅ 50 mm plug gauge, identification number: Microtool 2535

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
6 mm↑				
middle				
6 mm↓				

∅ 30 mm sphere gauge, identification number: D4769

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
at marked lines				

Optional measurements: ∅ 7,5 mm plug gauge, identification number: MG 04-253

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
2 mm↑				
middle				
2 mm↓				

III. Roundness and straightness measurements (Group 1)

Gauge	Roundness (µm)	u_{round} k=1 (µm)	Straightness (µm)	u_{str} k=1 (µm)
∅ 3,5 mm ring gauge	2 mm↑ middle 2 mm↓		0° 180°	
∅ 40 mm ring gauge	6 mm↑ middle 6 mm↓		0° 180°	
∅ 4 mm plug gauge	2 mm↑ middle 2 mm↓		0° 180°	
∅ 50 mm plug gauge	6 mm↑ middle 6 mm↓		0° 180°	

optional ∅ 7,5 mm plug gauge	2 mm↑ middle 2 mm↓		0° 180°	
∅ 30 mm sphere	equator		-	-

A.1 Measurement results

I. Short description of the instrument / measurement method

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II. Diameter measurements (Group 2)

∅ 5 mm ring gauge

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
3 mm↑				
middle				
3 mm↓				

∅ 40 mm ring gauge

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
10 mm↑				
middle				
10 mm↓				

∅ 5 mm plug gauge

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
2 mm↑				
middle				
2 mm↓				

∅50 mm plug gauge
∅50 mm plug gauge

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
6 mm↑				
middle				
6 mm↓				

∅ 30 mm sphere gauge

location	diameter (mm)	std. uncert. k=1 (µm)	mat. temp. (°C)	probe (∅, form) meas. force (mN)
at marked lines				

III. Roundness and straightness measurements (Group 2)

Gauge	Roundness (µm)	u_{round} k=1 (µm)	Straightness	u_{str} k=1 (µm)
∅ 5 mm ring gauge	3 mm↑ middle 3 mm↓		0° 180°	
∅ 40 mm ring gauge	10 mm↑ middle 10 mm↓		0° 180°	
∅ 5 mm plug gauge	2 mm↑ middle 2 mm↓		0° 180°	
∅ 50 mm plug gauge	6 mm↑ middle 6 mm↓		0° 180°	
∅ 30 mm sphere	equator		-	-

A.4 Uncertainty of measurement

A.4 Uncertainty of measurement

x_i	$u(x_i)$	ν_i	$c_i = \partial l / \partial x_i$	$u_i(l)$ / nm

Combined standard uncertainty: $u_c(l) =$

A.3 Receipt confirmation

FAX

To:

Group 1	**Group 2**
Mr. Gian Bartolo Picotto tel.: +39 011 3977 469 fax:+39 011 3977 459 g.picotto@imgc.cnr.it Instituto di Metrologia G. Colonnetti Strada delle Cacce, 73 IT-10135 Torino Italy	Ms. Edit Banreti tel.:+36 1 458 59 97 or .:+36 1 458 59 44 fax: +36 1 458 59 27 e.banreti@omh.hu National Office of Measures H-1124 Budapest Németvölgyi út 37-39 Hungary

From: (participating laboratory)

We confirm having received the standards of the *EUROMET key comparison on diameter standards* on .....(date).

After visual inspection

- o no damage has been noticed;
- o the following damage must be reported:
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