Key Comparison EUROMET.L-K5.2004

Calibration of a Step Gauge

Technical Protocol (V2)

(modified in June 05 by adding a new participant)

COORDINATED by

Centro Español de Metrología (Spain)

&

National Measurement Institute (Australia)

June, 2005

1 Introduction

1.1.1 The metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organised by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).

1.1.2 At its meeting in 2003, the EUROMET Technical Committee Length decided that a new key comparison on step gauge measurements shall be carried out, starting in 2004, with the Centro Español de Metrología (CEM) acting as the pilot laboratory.

1.1.3 Before that meeting, in September 2003, CCL 11 decided to introduce some changes in future Key Comparisons by having interregional participation organized through the Regional Technical Committees for Length (RTCLs) and the WGDM, so leaving the regions in charge of their comparisons but bringing the CCL/WGDM into the loop to be able to monitor and negotiate any difficulties..

1.1.4 So, participants should look at other regional KC with a view to finding a) a better time to do the comparison, b) a better uncertainty range or c) a more appropriate technique or method.

1.1.5 This technical protocol has been drawn up by the Centro Español de Metrología (CEM), based on the previous one drawn in 1999 by the Physikalisch-Technische Bundesanstalt (PTB), Germany, for the first CCL-K5 Key Comparison, but having in mind that this is a new type of interregional comparison, with participants from different regions and a more complicated process linked to the transport of the artefact and customs formalities.

1.1.6 The procedures outlined in this document cover the technical procedure to be followed during measurement of the artefact. The procedure follows the guidelines established by the BIPM[1].

[1] T.J. Quinn, Guidelines for key comparisons carried out by Consultative Committees, BIPM, Paris

2 Organization

2.1 Participants

2.1.1 The list of participants has been taken from the proposed EUROMET Project Form, after circulating it among Euromet members, and from written contacts maintained with other regions through WGDM members.

2.1.2 The participating laboratories should be able to calibrate step-gauges with their best uncertainty, less than 1 µm. All participants must be able to demonstrate independent traceability to the realization of the metre.

2.1.3 There is an additional requirement to measure the artefacts at a temperature sufficiently close to 20 °C that the uncertainty in the measured expansion coefficient does not dominate the overall measurement uncertainty.

2.1.4 By their declared intention to participate in this key comparison, the laboratories accept the general instructions and the technical protocol written down in this document and commit themselves to follow the procedures strictly.

2.1.5 Once the protocol and list of participants has been agreed, no change to the protocol or list of participants may be made without prior agreement of all participants.

2.2 Participants' details

EUROMET

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(*) added in june 05, after agreement of participants.

Other RMOs:

SIM:

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SADCMET:

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COOMET:

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Coordinators:

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2.3 Form of comparison

2.3.1 The comparison will be in a mixed form, both ‘circular’ and ‘star-shaped’. The artefacts will be circulated within a region then returned to the pilot laboratory before circulation in the next region. Because of time constraints, it will not be possible to arrange for a ‘star-shaped’ circulation within each region.

2.3.2 CEM will act as the pilot laboratory and NMIA as co-pilot. All results are to be communicated directly to the pilot laboratory as soon as possible and certainly within 6 weeks of completion of the measurements by a laboratory.

2.3.3 The calibration suitability of the artefact was assessed by measurements prior to the start of the circulation of the artefact.

2.3.4 Each laboratory will receive the artefact in turn, according to the pre-agreed timetable. A final set of measurements will be made at the end of the comparison by the pilot laboratory.

2.3.5 Each laboratory has one month for calibration and transportation. With its confirmation to participate, each laboratory has confirmed that it is capable of performing 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.

2.3.6 If for some reasons, the measurement facility is not ready or customs clearance takes too much time in a country, the laboratory has to contact the pilot and co-pilot laboratories immediately and – according to the arrangement made - eventually to send the standard directly to the next participant before finishing the measurements or even without doing any measurements. If possible the laboratory will be sent the artefact at the end of the comparison.

2.4 Timetable

Region	NMI	Country	Date
EUROMET	CEM	Spain	Dec 04/Jan 05
	BEV	Austria	February 05
	NML	Ireland	March 05
	BNM-LNE	France	April 05
	OMH	Hungary	May 05
	SP	Sweden	June 05
1st return to pilot laboratory	CEM	Spain	July 05
	NPL	United Kingdom	August 05
	NGM	Denmark	September 05
	CMI	Czech Republic	October 05
	GUM	Poland	November 05
	INM	Romania	Dec 05/Jan 06
	IMGC	Italy	February 06
2nd return to pilot laboratory	CEM	Spain	March 06
SIM	NRC	Canada	April 06
	INMETRO	Brazil	May 06
SADCMET	CSIR-NML	South Africa	June 06
APMP	NMIA	Australia	July 06
COOMET	VNIIM	Russia	August 06
EUROMET	MIKES	Finland	September 06
	NMi-VSL	Netherlands	October 06
	IPQ **(*)**	Portugal	November 06
3rd return to pilot laboratory	CEM	Spain	December 06

(*) added in june 05, after agreement of participants.

2.5 Handling of the artefact

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

2.5.2 The artefact should only be handled by authorised persons and stored in such a way as to prevent damage.

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

2.5.4 Please inform the pilot laboratory and the next laboratory via fax or e-mail when the artefact is about to be sent to the next recipient.

2.5.5 Before and after the measurements, the artefact must be cleaned. Ensure that the content of the package is complete before shipment. Always use the original packaging.

2.6 Transport of the artefact

2.6.1 It is of utmost importance that the artefact be transported in a manner in which it will not be lost, damaged or handled by un-authorised persons.

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

2.6.3 Artefact should be sent via courier or delivery company. It should be marked as ‘Fragile’ and ‘Handle with care’.

2.6.4 For loops outside UE the artefact is accompanied by an **ATA carnet** identifying the item uniquely. Please note that an ATA carnet expires at a certain date and the shipping back to the pilot laboratory has to be initiated early enough. As said, the ATA carnet is only needed for countries outside the European Union.

2.6.5 Each participant must pay for the cost of collecting the artefact from their customs (and any customs charges) and the cost of shipping the artefact to the next participant’s country. Participants also cover the costs for their own measurements, and for any damage that may have occurred to the artefact within their own country. The overall costs for the organisation and for the artefact are covered by the organising pilot laboratory. The pilot laboratory has no insurance for any loss or damage of the standard during transportation.

3 Description of the Standard

3.1 Artefact

The measurement artefact is a **step-gauge KOBA**, steel frame, tungsten carbide gauges, 420 mm nominal length, thermal expansion coefficient $\alpha = 11.5 \times 10^{-6}\ K^{-1}$

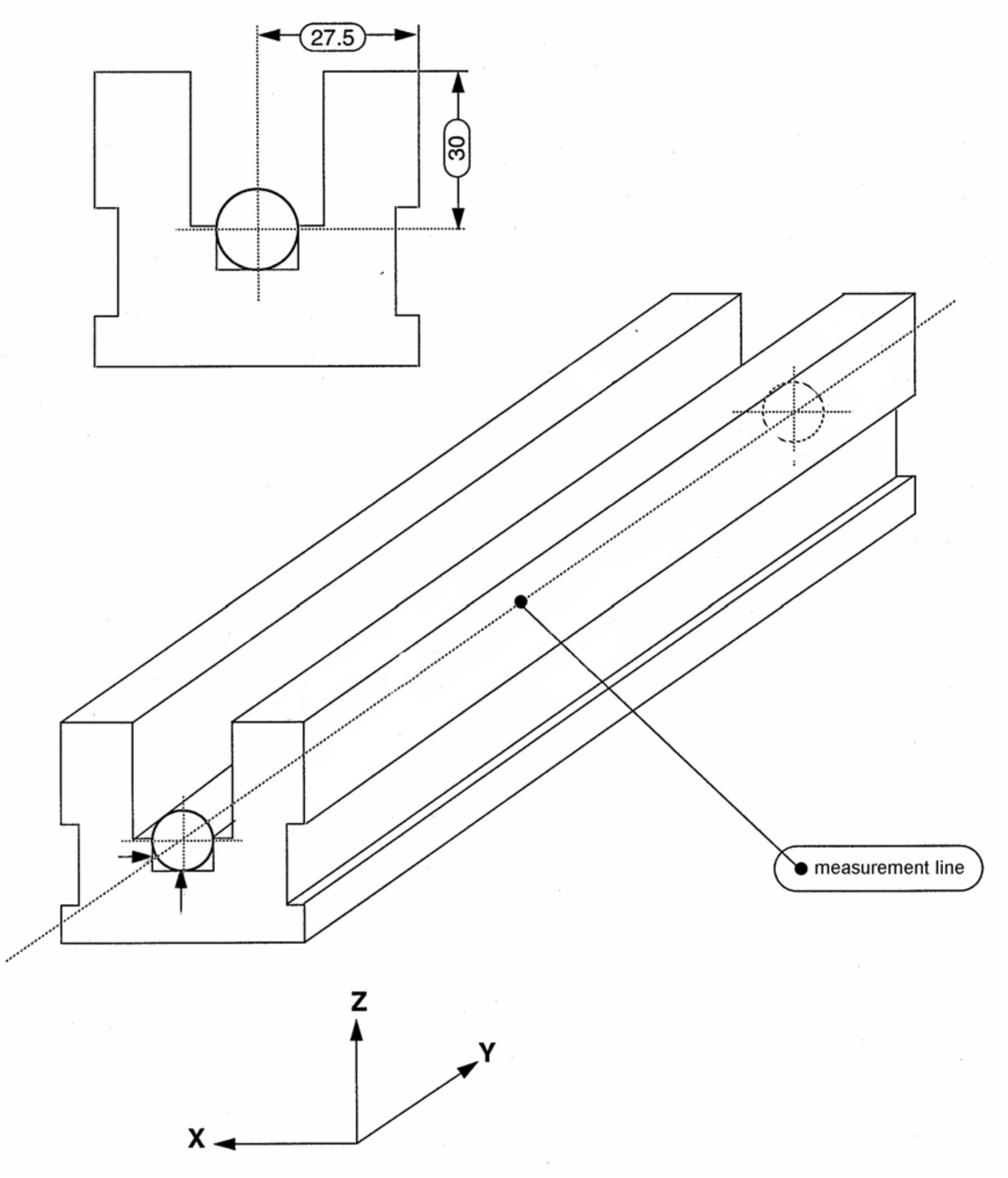

Fig. 1:

Drawing of the KOBA step-gauge

4 Measurement instructions

4.1 Traceability

4.1.1 Length measurements should be independently traceable to the latest realisation of the metre as set out in the current ”Mise en Pratique”. This means that if for example the step gauge would be measured by a CMM, the tracebility chain should not rely on another step-gauge, but for example on a calibration by interferometric means.

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

4.2 Measurands

4.2.1 The measurands of the step gauge are the distances of the centres of the front and back faces of the individual gauges of the step-gauge with respect to the centre of the front face of the first gauge. The measurements shall be carried out as much as possible near the centres of the front faces of the gauges or along an axis which passes through the centre of the measuring face No. 0 and is parallel to both the bottom face and the side alignment face.

4.2.2 The thermal expansion coefficient indicated for the artefact should be used by Laboratories when measuring the artefact. Laboratories should report the temperatures at which the length measurements were made. Laboratories should only measure the artefact at a temperature close to 20 °C.

4.3 Measurement instructions

4.3.1. Before calibration, the artefact must be inspected for damage to the measurement surfaces and side faces. Any scratches, rusty spots or other damages have to be documented.

4.3.2. The alignment of the step gauge will be done by using the bottom face of the groove where the gauges are fixed and the side-walls. If a different alignment procedure is preferred by your laboratory or needed because of equipment constraints then please document it together with the results. The step-gauge should be supported in the Bessel points.

4.3.3. The measurement results have to be appropriately corrected to the reference temperature of 20 °C using the values of the thermal expansion coefficient provided.

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

4.3.5. If for any reason a laboratory is not able to measure all positions of gauges on the step, it is still encouraged to report as much results as it can.

5 Measurement uncertainty

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

Because for this key comparison the measurement equipment and procedure is not completely fixed it is not possible to develop a full mathematical model for the measurement uncertainty for all participants. There are broad categories that uncertainties can be grouped into, in order to produce a comparative table. Table A2 in the Appendix does this for a measurement setup involving an interferometric - probe setup. The participant can append a more detailed analysis, but for the final report, summarise your uncertainties into the broad categories listed in Table A2. Leave blank those components that don't apply and add additional components if necessary. List or highlight any influence factors which prevent you from achieving your Best Measurement Capability (BMC). For example your BMC may be achieved with an artefact made from a different material (perhaps with a lower temperature coefficient). Highlight this component and provide a note, as this will make it easier for an assessor to compare your results with your claimed BMC.

The uncertainty should be reduced to the form provided in your laboratory's CMC claim for this service. This is normally given as a quadratic sum, expressed in short hand as Q[a, b.L] where a is the fixed part and b the proportional part (see CCL/WGDM/00-51c.doc "CCL-WGDM Supplement to the JCRB Instructions for Appendix C").

Please note that the gauge cylinders may not be aligned to the measurement axis and that additionally, the faces of the gauge cylinders may be non-orthogonal to the cylinder axes. These effects are contributions to the overall uncertainty budget.

6 Reporting of results

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.

Please note, that you have to state your results, the uncertainty and the uncertainty budget. The uncertainty shall be stated as combined standard uncertainty with no coverage factor applied.

The measurement report forms in appendix A 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 coordinator. **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.

The measurement results of the step gauge calibration should be sent additionally as Excel data file by e-mail.

The format should be:

- a column with the dimensional data

- an adjacent column with the uncertainty for the individual data point. When this differs significantly from the quadric form given in section A2, provide a brief explanation.

- cut and paste the uncertainty Table A2 into the spread sheet.

Following receipt of all measurement reports from the participating laboratories, the pilot laboratory 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. Subsequently, the procedure outlined in the BIPM Guidelines will be followed.

For comparison of the measurement results a reference value will be needed. The method for the calculation of the reference value will be fixed after the completion of the measurements, once evaluated the most suitable one.

7 Measurement results

Contact Person	National Metrology Institute Address	Tel. Fax e-mail:

Measurement dates	
Start	
Finish	

7.1 Inspection of the measurement surfaces

Notes:

Laboratory**:** ……………………………………………………Report Ref…………

Date:…………………..Signature:……………………………………………………

Description of the measurement instrument

Make and type of instrument

(If you use a non-commercial or significant modified commercial equipment, please add drawings, explaining papers etc.)

Traceability path (scale, interferometer, calibration std.):

Description of the measuring technique:

Range of artefact temperature during measurements & description of temperature measurement method:

Laboratory**:** ……………………………………………………Report Ref………….

Date:…………………..Signature:…………………………………………………….

8 Receipt confirmation

FAX

To: **Emilio Prieto**

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Length Division
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SPAIN

Fax: +34 91 8074 807

e-mail: eprieto@cem.es

From:

We confirm having received the standard of the *EUROMET.L-K5.2004 key comparison on step gauge* on ....(date).

After visual inspection

o no damage has been noticed;

o the following damage must be reported:
....
....
....
....

A.1 Measurement results

Laboratory**:** ……………………………………………………Report Ref………….

Date:………………………Signature:…………………………………………………

A.2 Uncertainty of measurement

Table A2: Measurement uncertainty

Description	Quantity xi	Standard uncertainty u(xi)	Sensitivity coefficient ci = ∂l/∂xi	Standard uncertainty (Fixed component μm)	Standard uncertainty (proportional component μm L in m)
Gauge temperature error (measured - actual)					
Gauge expansion coeff. (uncert.* temperature error from 20ºC)					
Gauge aligment to measurement axis (includes face)					
Gauge alignment errors due to the gauge reference surfaces					
Laser interferometer wavelength (traceability)					
Optical refractive index (air monitoring)					
Optical dead path					
Probe(system) repeatability(resolution)					
Probe diameter – or bidirectional uncertainty					
Abbe error					

Combined standard uncertainty (give fixed and proportional parts, k=1):

$$u_c(l) = \sqrt{\text{(fixed^2+(proportional*L)^2)}} = Q[\textit{fixed, proportional*L}]\text{ , } L \text{ in mm}$$

Laboratory**:** ……………………………………………………Report Ref………….

Date:………………………Signature:………………………………………………..