NATIONAL METROLOGY INSTITUTE OF SOUTH AFRICA
LENGTH METROLOGY

CCL Key Comparison, Afrimets.L-K1

Calibration of Gauge Blocks by Interferometry

Instructions and Technical Protocols.

DRAFT

CONTENT

1. Introduction.

At the latest TCL Afrimets meeting held in 2014 it was decided to start a new comparison on Gauge Block (GB) calibration by interferometry. It was decided to conduct the short GB comparison (0,5 mm to 100 mm), CCL-K1. The Pilot laboratory is the NMISA from South Africa.

The participants are requested to strictly follow the measurement protocol included in this document, which is consistent with the corresponding gauge block comparisons of *CCL*. Due to the large number of participants, it is very important that participating *NMIs* perform their measurements during assigned dates. Participants should keep in mind that the allocated time period is not only for measurements, but transportation and customs clearance as well.

In order to have uncertainties from the participants that can be compared, they should be estimated in a similar way, therefore, it is strongly recommended to apply the models suggested in this document[1], as we estimate that all participants apply similar methods. Only in those cases where the calibration method, and therefore the model equation, is substantially different, would it be justified to use other uncertainty budget. Otherwise, participants should review the suggested uncertainty budget and, in case of noticing an omission or error, please inform the pilot, and if he agrees on the correction, he should modify the suggested model in order for all participants to apply it in the same way.

By their declared intention to participate in this *Key* comparison, laboratory accept the general instructions and to strictly follow the technical protocol of this document.

2. Organization.

The organization will be coordinated by the pilot laboratory, particularly by Mr. Oelof Kruger and Mr. Patrick Masina both from NMISA.

2.1 Requirements for participation.

According to the WGDM recommendation No. 2 (document CCDM/WGDM/97-50b), the participating laboratories should offer these measurements regularly as calibration service to their clients, their participation needs to be voluntary and they should declare a measurement uncertainty (k=1).

[1] Decker J. E., Pekelsky J. R. “Uncertainty evaluation for the measurement of gauge blocks by optical interferometry," *Metrologia*, **34**, 479-493 (1997)”

2.2 Participants.

Contact	NMI	Information
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Table 1: Participants.

2.3 Time Schedule.

Each laboratory has six weeks that include customs clearance, calibration and transportation to the following participant. With its confirmation to participate, each laboratory has confirmed that it is capable of performing the measurements in the limited time allocated. It guarantees that the standards arrive in the country on time. 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 coordinator 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. The comparison will be carried out in a mixed form, circulation and star-type. The settled dates are indicated in table 2.

By accepting these outlines, **the participating laboratories compromise to get the standards to the next laboratory on time.**

Region	***Laboratory***	***City***	***Date***
Pilot Laboratory, AFRIMETS	NMISA	Pretoria	March 2020
SIM	NRC	Ontario	May 2020
SIM	National Institute of Industrial Technology	Argentina	July 2020
APMP	National Institute of Metrology Thailand	Thailand	September 2020
COOMET	Kazfkhstan Institute of Metrology	Almaty	November 2020
GULFMET	Emirates Metrology Institute	Abu Dhabi	January 2021
EURAMET	INM - National Institute of Metrology - Romania	Bucharest	March 2021
EURAMET	DMDM	Serbia	May 2021
EURAMET	CEM	Spain	July 2021
AFRIMETS	NIS, Egypt	Giza	September 2021
Pilot Laboratory, AFRIMETS	NMISA	Pretoria	November 2021

Table 2: Date of measurement.

2.4 Transportation.

Transportation to the next laboratory, according to the program, section 2.3, of this document, is the responsibility of each participant, including associated shipping costs.

The standards are packed in a plastic box (dimensions WW x YY x ZZ cm^3) ready to be shipped. Inside this box, the gauge blocks are disposed in other individual boxes.

The package contains the following items:

- 6 steel short gauge blocks
- 6 ceramic short gauges blocks
- 5 tungsten carbide short gauge blocks
- Temperature data logger
- 1 copy of instructions and technical protocol
- A pair of cotton gloves (**If the gloves are in poor condition, please replace them**)

The steel gauge blocks need to be protected against oxidation by means of oil, pure petrolatum or some protective agent.

The package should be sent with a reliable transportation method, preferably with a carrier like DHL, UPS, etc.

Please inform the pilot laboratory by fax or email immediately after receiving the standards, using the attached form from the Annex A of this document.

Immediately after having completed the measurements, the package should be sent to the next laboratory. Preferably all administrative formalities should be prepared before finishing measurements. Please inform again the pilot laboratory and the next laboratory when the package has left your installations (using the same form from Annex A), indicating shipping date, transportation company and identification number of the shipment (tracking number), all details, etc.

2.4 Financial aspects and insurance.

Each participating laboratory covers the costs for the measurements, transportation, custom formalities and as well the insurance for the shipment against loss or damage. The organization costs will be covered by the pilot laboratory this include suitcase and packaging and the ATA Carnet. The pilot laboratory has no insurance for any loss or damage of the standards during transportation.

3. Description of the Standards.

The package will contain 17 short gauge blocks, 6 made of steel and 6 made of ceramic and 5 made of tungsten carbide. The gauge blocks (GBs) have a rectangular cross section according to the International Standard ISO 3650. The thermal expansion coefficient supplied by the manufacturer will be used and their technical description is found in the next tables.

Nominal Length (mm)	***Identification Number***	***Thermal Expansion Coefficient (10^{-6} K^{-1})***	***Manufacturer***
2	110371	10,8 ± 0,5	Mitutoyo
5	182156	10,8 ± 0,5	Mitutoyo
8	181157	10,8 ± 0,5	Mitutoyo
10	183255	10,8 ± 0,5	Mitutoyo
25	110366	10,8 ± 0,5	Mitutoyo
100	173809	10,8 ± 0,5	Mitutoyo

Table 3: Steel Short Gauge Blocks.

Nominal Length (mm)	***Identification Number***	***Thermal Expansion Coefficient (10^{-6} K^{-1})***	***Manufacturer***
2	13248U	9,7	Opus
5	13174Y	9,7	Opus
7	13168Y	9,7	Opus
10	16732V	9,7	Opus
25	13012V	9,7	Opus
50	10559X	9,7	Opus

Table 4: Ceramic Short Gauge Blocks.

Nominal Length (mm)	***Identification Number***	***Thermal Expansion Coefficient (10^{-6} K^{-1})***	***Manufacturer***
2	07074W	4,23	Opus
5	06706W	4,23	Opus
8	22819Y	4,23	Opus
10	22784Y	4,23	Opus
25	07609W	4,23	Opus

Table 5: Tungsten Carbirde Short Gauge Blocks

4. Measurement instructions.

The GBs will be measured based on the procedure the laboratory normally uses offering this calibration service. Before making the measurements, the GBs need to be checked to verify that the surface is not damaged, has severe scratches and/or rust that may affect the measurement result. The condition in which the blocks are received will be reported in the form in the annex B. The “A” surface is the marked one with nominal length; identification number and manufacturer for GBs with nominal length < 6 mm and the surface on the right side for gauge blocks with a nominal length ≥ 6 mm, looking on the front side of the marked lateral surface (see Images 1 and 2).

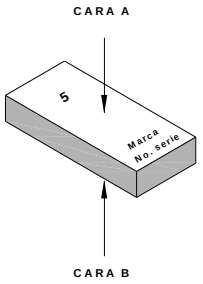


Image 1: Gauge block with nominal length < 6 mm

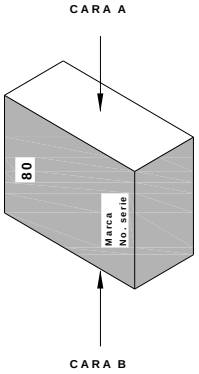


Image 2: Gauge block with nominal lenth ≥ 6 mm

4.1 Gauge blocks calibration.

The GBs are to be measured wrung to the platens that the laboratory habitually uses to offer their gauge block calibration service.

Short gauge blocks calibration by optical interferometry should be performed with the gauge blocks in a vertical position, each wrung to a platen as defined in the international ISO 3650

Gauge Block Standard. The gauge block central length is the perpendicular distance between the central point of the free measurement surface of the gauge block and the plain surface of the platen.

The result that will be reported is central length, reported as the deviation from the nominal length from measuring faces (Δl_{right} and Δl_{left}) and their average, $\Delta l = l - L$, and the phase change correction, Δl_{Φ}. The measurement results should be reported in the form of the annex C.

Measurement results should be corrected to the reference temperature of 20 °C, using the thermal expansion coefficient given in this document. Additional corrections may be applied according to the procedure in each laboratory. The only correction that has to be reported like an additional value, is the phase change correction, estimated by every laboratory according to its calibration procedure.

4.2 Measurement uncertainty.

Every one of the participating laboratories should send their uncertainty budget according to ISO Guide for the Expression of Uncertainty in Measurement together with the measurement results.

The mathematical model for the determination of uncertainty in the measurement of gauge blocks is the following:

$$\Delta l = \frac{1}{q}\sum_{i=1}^{q}\left(K_i + F_i\right)\frac{\lambda_i}{2n} - L + \theta\alpha L + \delta l_w + \delta l_A + \delta l_\Omega + \delta l_s + \delta l_G + \Delta l_\phi$$

Where:

L – nominal length of gauge block
q – number of used wavelengths to determine length, based on the method of exact fractions.
K_i – integer number of fringes in length of the gauge block (fringe order).
F_i – fractional part of the fringe order.
λ_i – wavelength in gap between different used light sources.
n – air refraction index.
θ = (Tg – 20) temperature difference of gauge block (Tg in °C) during the measurement regarding the reference temperature (20 °C).
α – linear coefficient of thermal expansion,
δl_w – wringing,
δl_A – wave-front aberrations,
δl_Ω – obliquity correction – alignment of the entrance aperture,
Δl_s – obliquity correction – size of the source aperture,
δl_G – departure from perfect prismatic geometry of the gauge block,
Δl_Φ – phase change correction.

Phase change correction $$\Delta l_{\phi} = \frac{Oc - Oi}{N - 1}$$

Where*:*

O_c – Deviation in central length of the pack (or stack)

O_i – Sum of deviation in central length of the *n* individual GBs of the pack

N – Number of gauge blocks comprising the pack (stack)

5. Result report.

The forms for the report of the measurement results are in the annex C of this document and should be sending properly filled out and signed by the metrologist and the responsible person for revision, **within the four weeks following the completion of the measurements**. The uncertainty estimation will be reported in the form in the annex D.

In the form of the annex E, the technical features of the used instrument should be indicated.

Once the results are collected, the pilot laboratories will prepare a preliminary report to be analyzed and commented on by the participants, afterwards a meeting will be called to adjust the last details and to proceed to the publication of the results in the Technical Supplement of *Metrologia*.

Annex A: Reception form and shipment of gauge blocks.

To: National Metrology Institute of South Africa
Mr. Patrick Masina
Private Bag X34
Lynnwood Ridge
Pretoria
0040
Tel +27 12 841 3057
Fax +27 12 841 2131
e-mail:pmasina@nmisa.org

From: (*Participating laboratory*)

Mark the option with an X:

- ☐ **We confirm having received the gauge blocks for the AFRIMETS comparison of Gauge Blocks by interferometry and by mechanical comparison on** *(indicate reception date)*

- ☐ **We confirm having sent the gauge blocks to** *(name of the laboratory)* **the** *(indicate date of shipment)* **having used the following transport method** *(please indicate carrier, identification number and other details you consider important)*

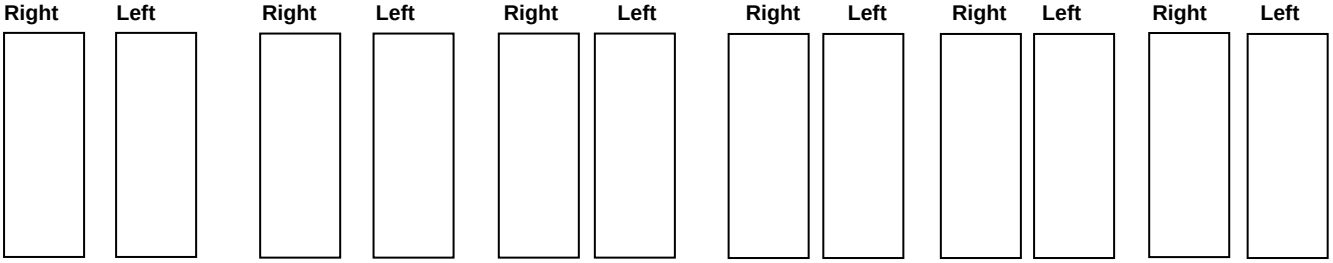
After a visual inspection:

- ϒ **There are no considerable damages; their general state will be reported in the form from the annex B, together with the measurement results.**
- ϒ **There are severe damages putting at risk the measurement result.** *Please indicate the damages, specifying every detail and if it is possible sending photos. If it is necessary use additional sheets for your report.*

Date: **Name:** **Signature:**

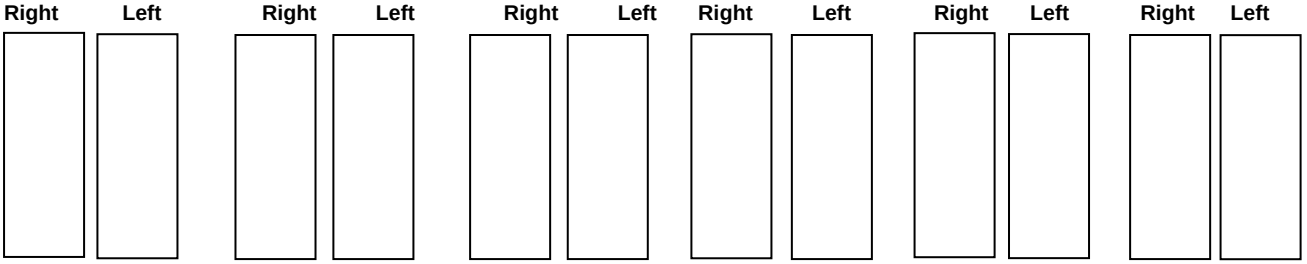
Annex B. Form for reception conditions of the gauge blocks.
After a detailed inspection of the measurement surfaces of the gauge blocks these are the results:

STEEL SHORT GAUGE BLOCKS



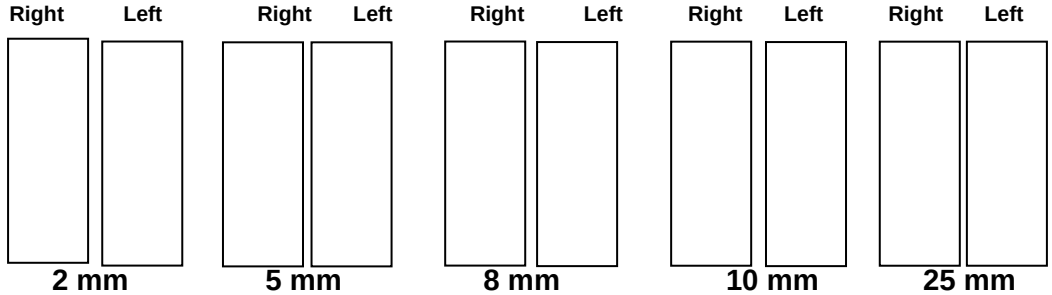
2 mm	5 mm	8 mm	10 mm	25 mm	100 mm
Id. 110371	Id. 182156	Id. 181157	Id. 183255	Id. 110366	Id. 173808

CERAMIC SHORT GAUGE BLOCKS



2 mm	5 mm	7 mm	10 mm	25 mm	50 mm
Id. 13248U	Id. 13174Y	Id. 13168Y	Id. 16732V	Id. 13012V	Id. 10559X

TUNGSTEN CARBIDE SHORT GAUGE BLOCKS



2 mm	5 mm	8 mm	10 mm	25 mm
Id. 07074W	Id.06706W	Id. 22819Y	Id. 22784Y	Id. 07609W

Observations:

_____
_____
_____
_____
_____
_____

Laboratory:_____

Date:_____ **Name and Signature**_____

Annex C: Result Report Forms.
Laboratory:_____

Material of the short gauge blocks__STEEL_
Material of the used platen:_____**Identification:**_____

Nominal Length mm	Identification	Deviation in the central point nm			Phase correction nm	Measurement uncertainty (k = 1) ± nm
		Surface "A"	Surface "B"	Average		
2	110371					
5	182156					
8	181157					
10	183255					
25	110366					
100	173809					

Material of the short gauge blocks:__CERAMIC_____
Material of the used platen:_____**Identification:**_____

Nominal Length mm	Identification	Deviation in the central point nm			Phase correction nm	Measurement uncertainty (k = 1) ± nm
		Surface "A"	Surface "B"	Average		
2	13248U					
5	13174Y					
7	13168Y					
10	16732V					
25	13012V					
50	10559X					

Material of the long gauge blocks:__TUNGSTEN CARBIDE_____
Material of the used platen:_____**Identification:**_____

Nominal Length mm	Identification	Deviation in the central point nm			Phase correction nm	Measurement uncertainty (k = 1) ± nm
		Surface "A"	Surface "B"	Average		
2	07074W					
5	06706W					
8	22819Y					
10	22784Y					
25	07609W					

Date: **Name:** **Signature:**

_____ _____ _____

Annex D. Form of uncertainty estimation.

Source of uncertainty x_i	Standard uncertainty $u(x_i)$	Sensitivity Coefficient. $\|c_i\| \equiv \partial I / \partial x_i$	Combined Standard Uncertainty. $u_i \equiv \|c_i\| \, u(x_i)$
λ_1			
λ_2			
F_i (i = 1,2)			
n			
t_g			
α			
δI_Ω			
s (as a part of ΔI_s*)*			
δI_A			
δI_G			
δI_W			
ΔI_Φ			
COMBINED STANDARD UNCERTAINTY (k = 1)			

Laboratory:_____

Date:_____**Name and Signature**_____

Annex E. Form of technical characteristics of the used instrument.

Type.	Model.	Serial number.	Measurement range mm	Date of last calibration

Instrument description.

Type of instrument (for interferometry number of light sources and their wavelengths, method to determine fringe fraction and refraction index of air, etc.):
_____
_____
_____
_____
_____
_____

Traceability: _____
_____
_____
_____
_____
_____

Calibration method of your reference (just mechanical comparison):
_____
_____
_____
_____
_____

Interval of temperature during measurements: _____
_____
_____
_____
_____
_____

Laboratory:_____

Date:_____**Name and Signature**_____