CENAM
CENTRO NACIONAL DE METROLOGÍA

NRC·CNRC
Institute for National Measurement Standards

CCL Key Comparison, CCL-K1:2011

Calibration of gauge blocks by Optical Interferometry

Instructions and Technical Protocol

CONTENT

1. Introduction.

2. Organization.
2.1 Requirements for participation.
2.2 Participants.
2.3 Time schedule.
2.4 Transportation.
2.5 Financial aspects and insurance.

3. Description of the standards.

4. Measurement instructions.
4.1 Gauge blocks calibration.
4.2 Reference temperature and standard pressure.
4.3 Optical phase change correction on the reflection of light.
4.4 Mathematical model and measurement uncertainty.

5. Pilot Study on the variation in length.

6. Results report.

7. References.

Annex A1: **Reception of Standards.**
Annex A2: **Shipment of Standards.**
Annex B: **Physical Conditions of the Gauge Blocks upon Reception.**
Annex C1: **Results Report Form – Short Gauge Blocks.**
Annex C2: **Results Report Form – Long Gauge Blocks.**
Annex D: **Mathematical Model and Measurement Uncertainty Form.**
Annex E: **Technical Characteristics of the Measuring System.**
Annex F: **Non-mandatory Variation in Length Report.**

1. Introduction.

At the WGDM meeting held at iNRiM in Torino, Italy, it was decided to start a new comparison on Gauge Blocks (GB) calibration by optical interferometry. It was decided to merge the short GB comparison CCL-K1 (0,5 mm to 100 mm) with the long GB comparison (over 100 mm to 500 mm), previously named CCL-K2. The designated pilot laboratories were CENAM from México for short GB and NRC-INMS from Canada for long GB.

The participants are requested to strictly follow the measurement protocol included in this document, which is consistent with the corresponding GB comparisons of *CCL*. Due to the large number of participants, it is very important that participating *NMIs* perform their measurements during the 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, we recommend to apply the model suggested in this document which was proposed in [3], as we think that most 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 another uncertainty model. Otherwise, participants should review the suggested uncertainty budget and, in case of noticing an omission or error, they should 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, laboratories accept the general instructions and to strictly follow the technical protocol of this document.

2. Organization.

The organization will be coordinated by the pilot laboratories particularly by Dr. Pierre Dubé and Dr. Jennifer Decker from NRC-INMS for long gauge blocks and Dr. Miguel Viliesid and Eng. Carlos Colín from CENAM for short gauge blocks.

2.1 Requirements for participation.

According to the WGDM recommendation No. 2 (document CCDM/WGDM/97-50b), the participating laboratories shall offer these measurements regularly as calibration service to their customers, their participation needs to be voluntary and they should declare a measurement uncertainty (at k=1) below a certain level. These uncertainty levels were reviewed during the sWG on Key Comparisons in June 2010 (Singapore) and it was agreed to fix the standard uncertainty as:

- u = 0,02 μm + 1,3 x 10^{-7} L , for short gauge blocks and
- u = 0,02 μm + 1,6 x 10^{-7} L , for long gauge blocks

Adjusting by regression these limiting uncertainties lines to the usual quadratic notation[1] and expressing it in the usual units posted for the CMCs in the BIPM webpage we obtain that it corresponds approximately to:

- u = Q[21, 0.26L] nm, L in mm, for short gauge blocks and
- u = Q[40, 0.18L] nm, L in mm, for long gauge blocks

[1] $u = Q[a, bL] = \sqrt{a^2 + b^2 \cdot L^2}$

It is otherwise desirable that the metrology regions be adequately represented in the comparison with at least two participants.

2.2 Participants.

CCL-K1:2011 Participants					
Country	**Institute**	**Contact person**	**Postal Address**	**Tel. / FAX**	**e-mail**
Brazil	**INMETRO**	Hans Peter H. Grieneisen, Luiz V. Tarelho, & Ricardo dos S. França	Av. Nossa Senhora de Graças, 50 Xerém, Duque de Caxias, RJ, BRASIL, CEP 25250-020	(21) 2679-9077 / Fax (21) 2679-1507	hpgrieneisen@inmetro.gov.br; lvtarelho@inmetro.gov.br rsfranca@inmetro.gov.br
Canada	**NRC-INMS**	Pierre Dubé & Jennifer Decker	1200 Montreal Road, Campus Building M-36 Room 146 Ottawa, Ontario, CANADA, K1A 0R6	+1.613.998-6768 / Fax +1.613.952.1394	pierre.dube@nrc-cnrc.gc.ca ; jennifer.decker@international.gc.ca
China	**NIM**	Sitian Gao	No.18, Bei San Huan Dong Lu, Chaoyang Dist, Beijing, P. R. of CHINA 100013	+86-10-64218565 / Fax +86-10-64218703	Gaost@nim.ac.cn
Finland	**MIKES**	Antti Lassila	Tekniikantie 1 FI-02151 Espoo, P. O. Box 9, FINLAND	+358 10 6054 000 / Fax +358 10 6054 499	antti.lassila@mikes.fi
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Italy	**INRIM**	Alessandro Balsamo & Paola Pedone	Strada delle Cacce 91 IT-10135 Torino, ITALY	+39 011 3919 970 / Fax: +39 011 3919 959	a.balsamo@inrim.it p.pedone@inrim.it
Japan	**NMIJ-AIST**	Toshiyuki Takatsuji	AIST Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, JAPAN	+81-29-861-4361 / Fax +81-29-861-4152	toshiyuki.takatsuji@aist.go.jp
Mexico	**CENAM**	Miguel Viliesid & Carlos Colín	km 4,5 Carretera Los Cués, El Marqués, 76246, Querétaro., MEXICO	+52-442 2110574 / Fax +52-442 2110579	miguel.viliesid@cenam.mx; ccolin@cenam.mx
Singa-pore	**A*STAR-NMC**	Siew-Leng Tan	1 Science Park Drive, SINGAPORE 118221	+65 6279 1900 / Fax +65 6279 1992/1993	tan_siew_leng@nmc.a-star.edu.sg
South Africa	**NMISA**	Oelof Kruger	Private Bag X34 Lynnwood Ridge, Pretoria 0040, SOUTH AFRICA	+27 12 841 4152 / Fax +27 12 841 2131	oakruger@nmisa.org
Switzer-land	**METAS**	Rudolf Thalmann	Lindenweg 50 CH-3003 Bern-Wabern, SWITZERLAND	+41 31 32 33 385 / Fax +41 31 32 33 210	rudolf.thalmann@metas.ch
United States	**NIST**	Jack Stone & John Stoup	100 Bureau Drive, M/S 8210 Gaithersburg, Maryland 20899-8210, USA	301-975-5638 / Fax 301-869-0822	jack.stone@nist.gov john.stoup@nist.gov

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 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 or customs clearance takes too long, the laboratory has to contact the pilot laboratories as soon as possible and, according to whatever they decide, 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 comparison will be carried out with one pilot intermediate measurement check during the circulation. The settled dates are indicated in Table 2.

By accepting this protocol, **the participating laboratories commit to strictly respect the time schedule.**

CCL-K1:2011 Time Schedule				
Region	**Laboratory**	**City**	**Country**	**Date of Reception**
Pilot Laboratory Short GB	**CENAM**	Querétaro	MEXICO	2011-03-14
Pilot Laboratory Long GB	**NRC-INMS**	Ottawa	CANADA	2011-05-01
EURAMET	**METAS**	Bern-Wabern	SWITZERLAND	2011-07-04
	MIKES	Espoo	FINLAND	2011-08-18
	INRIM	Torino	ITALY	2011-10-02
COOMET	**PTB**	Braunschweig	GERMANY	2011-11-16
SIM	**NIST**	Gaithersburg	USA	2011-12-31
	INMETRO	Xerém	BRAZIL	2012-02-14
Pilot Laboratory Long GB[2]	**NRC-INMS**	Ottawa	CANADA	2012-03-30
Pilot Laboratory Short GB[2]	**CENAM**	Querétaro	MEXICO	2012-04-06
APMP	**NMIJ-AIST**	Tsukuba	JAPAN	2012-05-14
	NIM	Beijing	P. R. of CHINA	2012-06-28
	A*STAR-NMC	Singapore	SINGAPORE	2012-08-12
AFRIMETS	**NMISA**	Pretoria	SOUTH AFRICA	2012-09-26
Pilot Laboratory Long GB	**NRC-INMS**	Ottawa	CANADA	2012-11-10
Pilot Laboratory Short GB	**CENAM**	Querétaro	MEXICO	2012-12-25

Table 2. Date of measurement.

2.4 Transportation.

Shipping and insurance costs to the following participating laboratory is the responsibility of each participant.

The main plastic case, which contains the short and long GB wooden cases, is accompanied by an ATA Carnet. The carnet shall always accompany the case in a sleeve. It shall not be placed inside of it. **PLEASE BE CERTAIN, THAT WHEN RECEIVING THE PACKAGE, YOU ALSO RECEIVE THE ATA CARNET!**

[2] NRC-INMS will be sending and receiving all the GB to and from the participants and will send the short GB to CENAM for control measurements. CENAM will send them back to NRC-INMS in time for the next participant to receive all the GB from NRC-INMS.

The short GB are packed in a wooden case as shown in Figure 1. Each GB fits into a slot of its size. A data logger is also included inside the short GB case along with its USB cable. The data logger shall remain inside the case at all times while in transport.

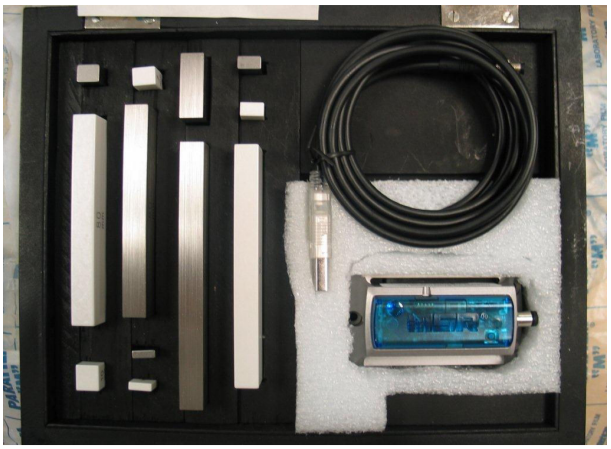

Figure1. Short GB inside case.

The case of the short GB contains the following items:

- 7 steel short gauge blocks
- 6 ceramic short gauges blocks
- Temperature data logger with USB cable

The wooden case for the long GB contains the following items:

- 3 steel long gauge blocks

Along with these two GB cases the following items are included in the main case:

- Handling instructions
- 1 copy of this measurement protocol
- A pair of cotton gloves (if the gloves are in poor condition, please replace them).
- A pair of plastic gloves (if the gloves are torn, please replace them)

Outside the whole package on a sleeve accessible to the customs officer:

- The ATA Carnet

The steel gauge blocks need to be protected against oxidation when not being measured by means of protective oil. Please cover them with this product before packing them for transportation or when stocked for more than three days.

The package should be shipped with a reliable parcel service that provides a service for handling the ATA Carnet[3].

Please inform the pilot laboratories by FAX or on a PDF attached file by e-mail immediately after receiving and visually inspecting the standards by filling the form provided in **Annex A1: Reception of Standards**.

Once the measurements have been completed, the package shall be sent to the following participant. Please inform again the two pilot laboratories and the following participant by

[3] Such as DHL, UPS or other.

FAX or on a PDF attached file by e-mail when the package leaves your installations, by filling the form of **Annex A2**: **Shipment of Standards** 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.

2.5 Financial aspects and insurance.

Each participating laboratory shall cover the costs of shipping, customs formalities and transport insurance against loss or damage. The organization costs will be covered by the pilot laboratories, which include the standards themselves, the data logger included, the cases and packaging and the ATA Carnet. The pilot laboratories have no insurance for any loss or damage of the standards during the circulation.

3. Description of the standards.

The package contains 13 short gauge blocks, 7 of steel and 6 of ceramics; and 3 long gauge blocks of steel. The GB are of rectangular cross section and comply with the Standard [1]. The nominal lengths; identification; Coefficient of Thermal Expansion (CTE) along with its Expanded Uncertainty ($k = 2$); and manufacturer are given in the following tables.

Nominal Length, mm	***Identification Number***	***CTE*** $(10^{-6}\,K^{-1})$	***Manufacturer***
0,5	000774	10,9 ± 1,0	Mitutoyo
3	090771	10,8 ± 0,5	Mitutoyo
5	090772	10,8 ± 0,5	Mitutoyo
7	091740	10,8 ± 0,5	Mitutoyo
25	053292	10,8 ± 0,5	Mitutoyo
80	081305	10,8 ± 0,5	Mitutoyo
100	053178	10,8 ± 0,5	Mitutoyo

Table 3. Steel Short Gauge Blocks.

Nominal Length, mm	***Identification Number***	***CTE*** $(10^{-6}\,K^{-1})$	***Manufacturer***
3	090486	9,3 ± 0,5	Mitutoyo
5	090662	9,3 ± 0,5	Mitutoyo
7	090343	9,3 ± 0,5	Mitutoyo
10	090721	9,3 ± 0,5	Mitutoyo
80	080099	9,3 ± 0,5	Mitutoyo
90	080173	9,3 ± 0,5	Mitutoyo

Table 4. Ceramic Short Gauge Blocks.

Nominal Length, mm (inches)	***Identification Number***	***CTE*** $(10^{-6}\,K^{-1})$	***Manufacturer***
152,4 (6)	36686	10,5 ± 0,6	Hommel Werke
254,0 (10)	36686	10,5 ± 0,6	Hommel Werke
508,0 (20)	36686	10,5 ± 0,6	Hommel Werke

Table 5. Steel Long Gauge Blocks.

Long gauge blocks were chosen in Imperial Units because of technical reasons regarding their quality and quality of wringing. The present exercise does not by these means encourage the use of Imperial units. The nominal length is stated in SI equivalent length and their deviations shall also be stated in SI units.

4. Measurement instructions.

The GB shall be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers. Before making the measurements, the GB 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. The condition of the blocks before measurement should be registered in the form provided in **Annex B (Annex B1** for Short GB and **Annex B2** for Long GB). The "A" surface is the one marked with nominal length; identification number and manufacturer for GB with nominal length < 6 mm and the surface on the right-hand side of the inscriptions for GB with a nominal length ≥ 6 mm (see Figures 2 and 3).

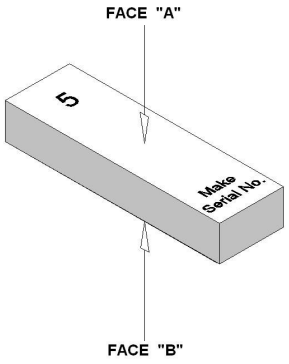

Figure 2. Gauge Block with nominal length < 6 mm.

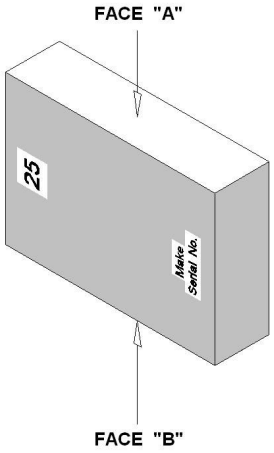

Figure 3. Gauge block with nominal length ≥ 6 mm.

4.1 Gauge block calibration.

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

Short gauge block calibration by optical interferometry should be performed with the GB in vertical position wrung to a platen as indicated in [1]. The gauge block central length, l_c, is the perpendicular distance between the central point of the free measurement surface of the gauge block and the surface of the platen.

Long gauge block (over 100 mm) length is defined in horizontal position supported at two points at a distance of 0,211 of its length from the ends according to [1]. If measured in this position the weight of the platen wrung to one end should be compensated. Otherwise, if they are measured vertically the deformation due to compression should be corrected.

The mesurands that shall be reported are the deviations from nominal length (l_n) determined at the center for both measuring faces "A" and "B", $e_{cX} = l_c - l_n$, (where X = "A" or "B"); the average of both values, e_{avg}; the so called phase change correction, Δl_ϕ that is described in section 4.3; and the corrected average deviation after having applied phase change correction, e_c. The measurement results shall be reported in the form of **Annex C1** for short GB and in the form of **Annex C2** for long GB.

4.2 Reference temperature and standard pressure

Measurement results should be reported at the reference temperature of 20 °C and standard pressure of 101 325 Pa. For corrections the CTE provided in this document should be applied. Additional corrections may be applied according to the specific procedure of each laboratory.

4.3 Optical phase change correction on the reflection of light

The position of the plane where light is reflected on a surface differs from the position of mechanical contact of the surface. This difference varies depending mainly on the material and surface finish of the surface. As the free measuring face of the GB under measurement and the platen where it is wrung are in general different in both characteristics, this difference varies and a correction has to be applied. It is called the phase change correction, Δl_ϕ. This correction, if considered, should be reported in **Annex C** as an individual value for each short GB material, and, eventually, for the long GB. If reported, It shall be estimated or determined by each laboratory according to its calibration procedure as it usually does it for its customers.

A method usually applied to determine Δl_ϕ is the stack method where three or more GB are measured individually and then measured wrung together into a stack as shown in Figure 4. From these measurements the global phase change correction for this set of GB may be obtained as follows:

$$\Delta l_\phi = \frac{l_{O_S} - \sum_{i=1}^{N} l_{O_i}}{N-1}$$

Where*:*

l_{OS} – Optical central length of the stack.
l_{Oi} – Optical central length of the i^{th} individual GB, $i = 1,2,...,N,$ of the stack.
N – Number of gauge blocks comprising the stack.

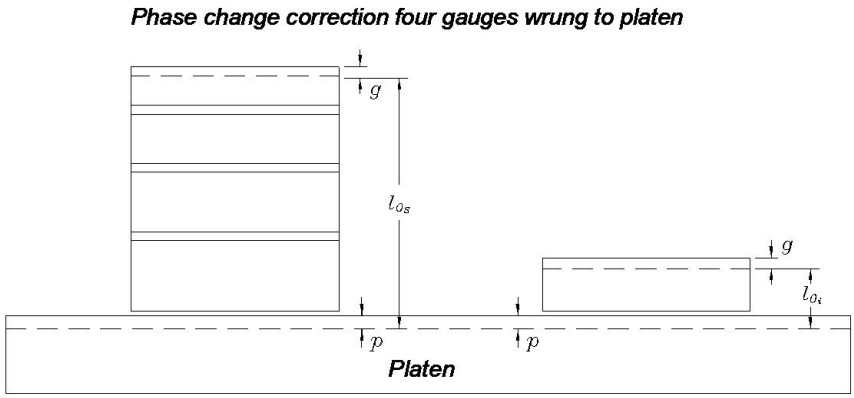

Figure 4. Stack method measurements to derive Δl_ϕ. g represents the difference between the optical plane and the mechanical plane for the GB free surface, and p represents this difference between planes for the platen.

4.4 Mathematical model and measurement uncertainty

All participating laboratories shall state the mathematical model they apply and their uncertainty budget established according to [2] and to their current calibration procedure.

The mathematical model for the central length deviation, e_c, proposed in [3] is the following, but may vary depending on the specific method, equipment and considerations used by each laboratory:

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

Where:

- l_n – nominal length of the gauge block
- q – number of wavelengths used 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 – i^{th} vacuum wavelength of the q set of wavelengths used to measure.
- n – refractive index of air.
- θ = $(T_G - 20)$ temperature difference of gauge block during the measurement with respect to the reference temperature of 20 °C.
- α – linear coefficient of thermal expansion, CTE,
- δl_w – wringing (expectation value equals zero),
- 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.

The laboratories shall apply the mathematical model they use according to their measurement method and shall state the uncertainty sources they consider in their

procedure. They shall submit the mathematical model as an equation and shall define each of the variables included in it in a similar way as the above equation. According to the submitted model they should fill an uncertainty budget chart. Both, mathematical model as well as the uncertainty budget chart shall be reported as indicated in **Annex D**.

5. Pilot Study on the Variation in Length

For those laboratories able to measure variation in length and willing to participate in a pilot study of it, please proceed to measure it for each gauge block and complete **Annex F** with your results. These results will be included in a pilot study report separate from the present comparison report. For the purpose of this study, the variation in length, v, as defined in [1], is the difference between the largest value of l, l_{max}, and the smallest value of l, $l_{\min}$ registered throughout the free measuring face. Participants will indicate if they measure maximum length and minimum length anywhere on the gauge block surface, or if only the four corners and center are inspected as described in Section 8.4.4 of [1].

6. Reporting Results.

The results for the short GB shall be sent out to CENAM, the pilot laboratory for short GB, and the results for the long GB shall be sent out to NRC-INMS[4], the pilot laboratory for long GB. The forms for reporting the measurement results are included in **Annex C**. **Annex C1** for short GB and **Annex C2** for long GB.

The results of **Annex C1** sent out to CENAM shall be **accompanied by other Annexes**[5]:

- **Annex B,** stating the detailed condition of the GBs upon reception by the laboratory;
- **Annex D**, containing the mathematical model and the uncertainty budget;
- **Annex E**, describing the technical features of the measurement system; and,
- if willing to participate in the variation in length pilot study, **Annex F**.

This information should be sent-out properly filled and signed **within the four weeks following the completion of the measurements either by FAX or in a PDF attached file by e-mail; as well as by postal service** to be received afterwards by the pilot laboratories. The original signed document serves as the official submission from the lab.

After collecting the results from all participants, the pilot laboratories will prepare a Draft A report to be circulated among the participants for them to review their submitted results and overall development of the comparison exercise. This Draft A report will contain no data analysis. Once this report is accepted by all participants, a Draft B containing the comparison data analysis will be prepared by the pilot laboratories and circulated again to all participants. The results will be analyzed according to [4] or further more recent recommendations issued by the Consultative Committee for Length (CCL) at the end of the circulation of the artifacts. Recommendations on the eventual linking of this comparison and the corresponding regional comparisons according to the latest recommendations of CCL at the time of preparation of the report will also be included. The Final Report will be the Draft B

[4] As the two pilot laboratories are also participants, they shall not have access to others results before submitting theirs. CENAM will be the last participant for long GB, therefore long GB results shall be sent out to INMS-NRC.

[5] CENAM will then share the information of **Annexes**, **B**, **D**, **E** and **F** with INMS-NRC, the other pilot laboratory.

version agreed by the participants. At this point, a publication of the results of the comparison will be prepared by the pilot laboratories to be included in the Technical Supplement of *Metrologia*.

7. References.

1. ISO 3650:1998(E), *Geometrical Product Specification (GPS) – Length Standards – Gauge Blocks*, International Organization for Standardization, Geneva, Switzerland.
2. *Guide to the Expression of Uncertainty in Measurement,* International Organization for Standardization, 1995, 110p., Geneva, Switzerland.
3. Decker J. E., Pekelsky J. R. *Uncertainty evaluation for the measurement of gauge blocks by optical interferometry*, *Metrologia*, **34**, 479-493 (1997).
4. Decker J.E., Brown N. *et al.*, *Recent recommendations of Consultative Committee for Length (CCL) regarding strategies for evaluating key comparison data. Metrologia* **43** (2006) L51-L55.

Annex A1: Reception of Standards.

To: Pierre Dubé
National Research Council NRC
1200 Montreal Road Campus
Bldg M-36, Room 146
Ottawa, Ontario, CANADA K1A 0R6
Fax +1.613.952.1394
e-mail: pierre.dube@nrc-cnrc.gc.ca

Carlos Colín
Centro Nacional de Metrología CENAM
División de Metrología Dimensional- Edif. D
km 4,5 Carretera a los Cués, El Marqués
CP 76241, Querétaro, México
Fax: +52 (442) 211 0577
ccolin@cenam.mx

From: (*Participating laboratory*)

We confirm having received the gauge blocks for the CCL-K:2011 comparison of Gauge Blocks by interferometry on *(indicate reception date)*

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.*

_____
_____
_____
_____
_____
_____
_____
_____

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

_____ _____ _____

Annex A2: Shipment of Standards.

To: Pierre Dubé
National Research Council NRC
1200 Montreal Road Campus
Bldg M-36, Room 146
Ottawa, Ontario, CANADA K1A 0R6
Fax +1.613.952.1394
e-mail: pierre.dube@nrc-cnrc.gc.ca

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División de Metrología Dimensional- Edif. D
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CP 76241, Querétaro, México
Fax: +52 (442) 211 0577
ccolin@cenam.mx

From: (*Participating laboratory*)

We confirm having sent the gauge blocks to *(name of the laboratory)* _____ **on** _____ *(indicate date of shipment)* _____ **having used the following transport method** *(please indicate parcel service, tracking number and other details that could be important)* _____

_____

_____

_____

_____

_____

_____

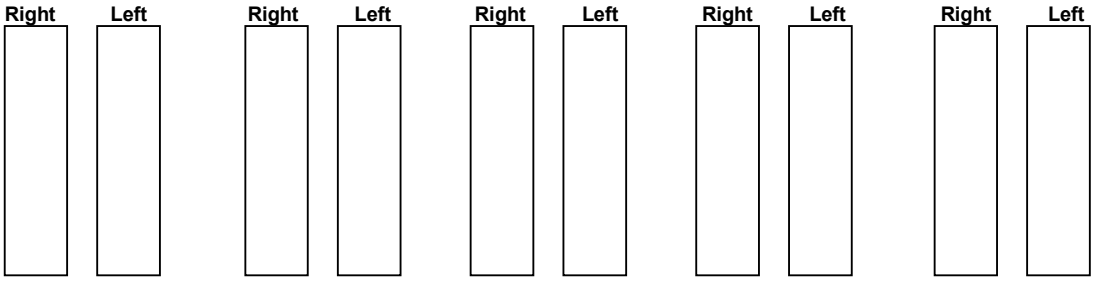
Date: **Name:** **Signature:**

_____ _____ _____

Annex B: Physical Conditions of the Gauge Blocks upon Reception.

After a detailed inspection of the measurement surfaces of the gauge blocks these are the results:

STEEL SHORT GAUGE BLOCKS



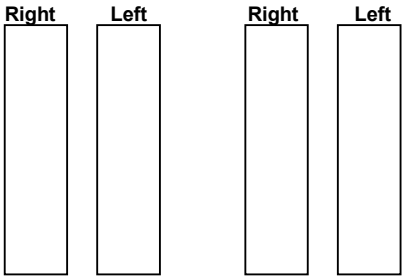
0,5 mm
Id. 000774

3 mm
Id. 090771

5 mm
Id. 090772

7 mm
Id. 091740

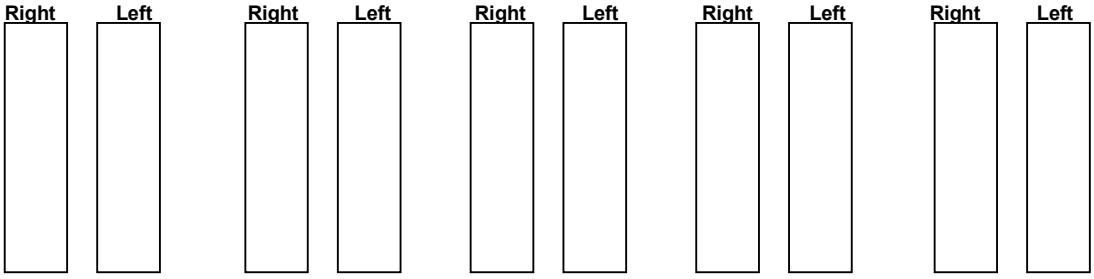
25 mm
Id. 053292



80 mm
Id. 081305

100 mm
Id. 053178

CERAMICS SHORT GAUGE BLOCKS



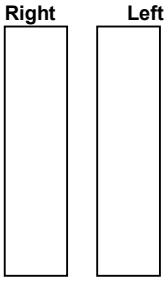
3 mm
Id. 090486

5 mm
Id. 090662

7 mm
Id. 090343

10 mm
Id. 090721

80 mm
Id. 080099

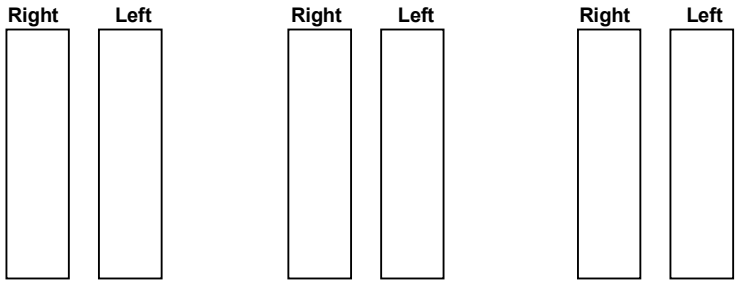


90 mm
Id. 080173

Laboratory:_____

Date:_____ **Name and Signature** _____ Page 1/2

STEEL LONG GAUGE BLOCKS



152,4 mm (6 inch)
Id. 36686

254,0 mm (10 inch)
Id. 36686

508,0 (20 inch)
Id. 36686

Observations:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Laboratory:_____

Date:_____ **Name and Signature**_____

Annex C1: Results Report Form – Short Gauge Blocks

To: *Carlos Colín*
Centro Nacional de Metrología CENAM
División de Metrología Dimensional- Edificio D
km 4,5 Carretera a los Cués, El Marqués
CP 76241, Querétaro, México
Fax: +52 (442) 211 0577
e-mail: *colin@cenam.mx*

Laboratory:_____

Short gauge blocks material: STEEL **Platen material:**_____

Method to obtain Δl_ϕ: _____

Nominal Length in mm	GB Id.	Platen Id.	Deviation from nominal length at the central point without phase change correction in nm			Deviation from nominal length, e_c in mm	Phase change correction Δl_ϕ in nm	Measure-ment uncertain-ty (k = 1) in nm	Effective degrees of freedom ν_{eff}
			Face A, e_A	Face B, e_B	Average, e_{Avg}				
0,5	000774								
3	090771								
5	090772								
7	091740								
25	053292								
80	081305								
100	053178								

Short gauge blocks material: CERAMICS **Platen material:**_____

Method to obtain Δl_Φ: _____

Nominal Length in mm	GB Id.	Platen Id.	Deviation from nominal length at the central point without phase change correction in nm			Deviation from nominal length, e_c in mm	Phase change correction Δl_ϕ in nm	Measure-ment uncertain-ty (k = 1) in nm	Effective degrees of freedom ν_{eff}
			Face A, e_A	Face B, e_B	Average, e_{Avg}				
3	090486								
5	090662								
7	090343								
10	090721								
80	080099								
90	080173								

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

_____ _____ _____

Annex C2: Results Report Form – Long Gauge Blocks

To: Pierre Dubé
National Research Council NRC
1200 Montreal Road Campus
Bldg M-36, Room 146
Ottawa, Ontario, CANADA K1A 0R6
Fax +1.613.952.1394
e-mail: pierre.dube@nrc-cnrc.gc.ca

Laboratory:_____

Long gauge blocks material: **STEEL** **Platen material:**_____

Method to obtain Δl_Φ: _____

Nominal Length in mm	GB Id.	Platen Id.	Deviation from nominal length at the central point without phase change correction in nm			Deviation from nominal length, e_c in mm	Phase change correction Δl_ϕ in nm	Measure-ment uncertain-ty (k = 1) in nm	Effective degrees of freedom ν_{eff}
			Face A, e_A	Face B, e_B	Average, e_{Avg}				
152,4 (6)	36686								
254 (10)	36686								
508 (20)	36686								

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

_____ _____ _____

Annex D: Mathematical Model and Measurement Uncertainty Form.

Laboratory:_____

Mathematical Model[6] (equation)**:**

Definition of variables in the model:

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

[6] In case a different kind of interferometer or optical arrangement from the usual gauge block interferometer set-ups is used, please include a drawing to specify the variables in the equation or give the reference to a publication describing the instrument additional to Annex E.

Uncertainty Budget

Source of uncertainty x_i	Standard uncertainty $u(x_i)$	Sensitivity Coefficient. $\|c_i\| \equiv \partial I / \partial x_i$	Combined Standard Uncertainty. $u_i \equiv \|c_i\| u(x_i)$
COMBINED STANDARD UNCERTAINTY (k = 1)			

Laboratory:_____

Date:_____ Name and Signature_____

Annex E: Technical Characteristics and Description of the Measuring System.

Make and Type of interferometer (Include a drawing or a reference to a paper if necessary):

_____

_____

_____

_____

Light sources/Wavelengths used:

_____

_____

_____

_____

Method of fringe fraction determination:

_____

_____

_____

_____

Method used for determination of refractive index of the air:

_____

_____

_____

_____

_____

Temperature variation during measurements:

_____

_____

_____

_____

Laboratory:_____

Date:_____ **Name and Signature**_____

Annex F: Non-mandatory Variation in Length Report Form

Laboratory:_____

For those laboratories who want to participate: additional variation in length measurements.

Give measured variation in length value for gauge blocks according to ISO 3650:1998 (see Figure f.1).

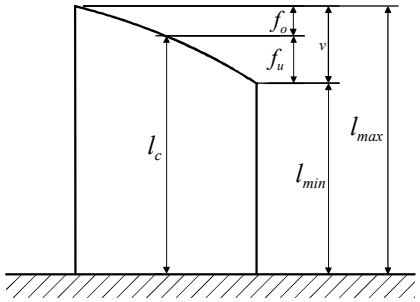


Figure f.1. Variation in length v, according to ISO3650 is equal to l_{max} - l_{min} and f_o+f_u.

Short gauge blocks, steel

Nominal Length in mm	Identification	Variation in length v in nm	Measurement uncertainty (k = 1) in nm	Effective degrees of freedom v_{eff}
0,5	000774			
3	090771			
5	090772			
7	091740			
25	053292			
80	081305			
100	053178			

Short gauge blocks, ceramics

Nominal Length in mm	Identification	Variation in length v in nm	Measurement uncertainty (k = 1) in nm	Effective degrees of freedom v_{eff}
3	090486			
5	090662			
7	090343			
10	090721			
80	080099			
90	080173			

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

_____ _____ _____

Annex F: Non-mandatory Variation in Length Report Form

Laboratory:_____

Long gauge blocks

Nominal Length in mm	Identification	Variation in length v in nm	Measurement uncertainty (k = 1) in nm	Effective degrees of freedom v_{eff}
152,4	36686 (6)			
254,0	36686 (10)			
508,0	36686 (20)			

Explain method for variation in length measurement:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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

_____ _____ _____

Page 2/2