Supplementary Comparison EURAMET.L-S2.2.n01

Calibration of gauge blocks by mechanical comparison

(EURAMET project 1581)

Technical protocol

AS Metrosert

Central Office of Metrology

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Contents

1 Document control

Version Draft A.1	Issued on 10 February 2023
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2 Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by a set of key and supplementary comparisons chosen and organized by the Consultative Committees of the CIPM or by the regional metrology organizations in collaboration with the Consultative Committees.

In 2022, at the annual EURAMET TC-L meeting it was proposed and agreed upon to have a supplementary comparison on gauge block calibration by mechanical comparison. The purpose of this supplementary comparison is to support new and existing CMC claims for this method.

For this supplementary comparison AS Metrosert is acting as a pilot laboratory and NPL is acting as a co-pilot. AS Metrosert is responsible for providing the travelling standards, monitoring the stability of travelling standards, gathering the measurement data and evaluation and reporting of the measurement results. NPL is responsible for performing additional interferometric measurements to provide a traceability link to gauge block key comparison.

The procedures outlined in this document cover the technical procedure to be followed during the measurements. A goal of the key and supplementary 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). To this end, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

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

3 Organization

3.1 Participants

Table 1. List of participant laboratories and their contacts.

No	Country	Institute	Contact person	Shipping Address
1.	Albania	DPM	Defrim Bulku defrim.bulku@dpm.gov.al Tel. +355 4 2233 174	Autostrada Tirane-Durres Km 8 Tirana
2.	Austria	BEV	Michael Matus michael.matus@bev.gv.at Tel. +43 1 21 110 6540	Arltgasse 35 1160 Wien
3.	Bulgaria	BIM	Denita Tamakyarska d.tamakjarska@bim.government.bg Tel. +359 2 970 27 19	52B, G.M. Dimitrov blvd. 1040 Sofia
4.	Estonia	AS METROSERT	Armin Ansip armin.ansip@metrosert.ee tc-length.contact@metrosert.ee Tel. +372 535 01 887	Teaduspargi 8, 12618 Tallinn
5.	Hungary	BFKH	Gábor Szikszai szikszai.gabor@bfkh.gov.hu Tel. +36 1 4585854	Németvölgyi út 37-39 1534 Budapest
6.	Ireland	NSAI NML	Rory Hanrahan rory.hanrahan@nsai.ie Tel. +351 1 8082611	Claremont Avenue, Glasnevin Dublin 9
7.	Latvia	LATMB	Larisa Svedova larisa.svedova@latmb.lv Tel. +371 67 51 77 27	Kr. Valdemara street 157 1013 Riga
8.	Lithuania	FTMC	Lilija Chaleckiene lilija.chaleckiene@ftmc.lt Tel. +370 61216739	Sauletekio av. 3, LT-10257 Vilnius
9.	Moldova	NMI (MD)	Alexandru Braguta alexandru.braguta@inm.gov.md Tel. +373 79 004 982	Eugen Coca street 28 2064 Chisinau
10.	Montenegro	BMM	Tomo Božović tomo.bozovic@metrologija.gov.me Tel. +382 20 601 360	Arsenija Boljevića bb 81000 Podgorica
11.	Slovenia	MIRS/UM-FS/LTM	Bojan Acko bojan.acko@um.si Tel. +386 2 220 7581	University of Maribor, Faculty of Mechanical Engineering Laboratory for Production Measurement (LTM) Smetanova ulica 17 SI-2000 Maribor
12.	United Kingdom	NPL	Andrew Lewis andrew.lewis@npl.co.uk Tel. +44 (0) 208 943 6074	Hampton Road Teddington, Middlesex TW11 0LW, United Kingdom

3.2 Schedule

Each laboratory has 4 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 laboratory as

soon as possible and, according to whatever it decides, it might eventually be obliged to send the standards directly to the next participant before completing the measurements or even without doing any measurements.

Table 1. Schedule of the comparison.

Institute	Country	Starting date	Time for measurement and transportation
AS METROSERT	Estonia	17.07.2023	28 days
BEV	Austria	14.08.2023	28 days
NSAI NML	Ireland	11.09.2023	28 days
BIM	Bulgaria	09.10.2023	28 days
FTMC	Lithuania	06.11.2023	28 days
BMM	Montenegro	04.12.2023	28 days
AS METROSERT	Estonia	01.01.2024	28 days
MIRS/UM-FS/LTM	Slovenia	29.01.2024	28 days
NMI (MD)	Moldova	26.02.2024	28 days
DPM	Albania	25.03.2024	28 days
LATMB	Latvia	22.04.2024	28 days
NPL	United Kingdom	20.05.2024	28 days
BFKH	Hungary	17.06.2024	28 days
AS METROSERT	Estonia	15.07.2024	28 days

3.3 Reception, transportation, insurance, costs

A wooden case containing 6 short gauge blocks is used for transportation of the artefacts (Figure 1). Wooden case is sealed with hooks and tape and is transported in a larger carton box filled with padding. Upon reception of the package, each laboratory has to check that the content is complete and that there is no apparent damage on the box or any of the standards. The receipt has to be confirmed immediately to the pilot with a copy to the former participant (sender), preferably using the form of Appendix A.

The organization costs will be covered by the pilot laboratory, which include the standards themselves, the case and packaging, and the shipping costs to the next laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during the circulation.

Figure 1 – Transporting case

Once the measurements have been completed, the package shall be sent to the following participant. The steel gauge blocks need to be protected against corrosion 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.

Each participating laboratory shall cover the costs of shipping and transport insurance against loss or damage. The package should be shipped with a reliable parcel service of its choice. Once the measurements have been completed, please inform the pilot laboratory and the following participant when the package leaves your organization 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.

For shipment outside the EU the package is accompanied by an ATA carnet. Outside EU the carnet 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!** For shipment inside the EU the ATA carnet may be shipped inside the box.

4 Artefacts

4.1 Description of artefacts

The package contains 6 gauge blocks. The gauge blocks are of rectangular cross section and comply with the calibration grade K of the standard ISO 3650. Gauge blocks are made of steel and have following nominal values: 0.5 mm, 4 mm, 10 mm, 25 mm, 50 mm, 100 mm.

Table 2. List of artefacts.

Identification	Nominal length /mm	Manufacturer
218004	0.5	Mitutoyo
217026	4	Mitutoyo
222541	10	Mitutoyo
221877	25	Mitutoyo
221469	50	Mitutoyo
221625	100	Mitutoyo

5 Measuring instructions

5.1 Handling the artefact

The gauge blocks should only be handled by authorized persons and stored in such a way as to prevent damage. Before making the measurements, the gauge blocks 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 appendix B. Laboratories should attempt to measure all gauge blocks unless doing so would damage their equipment. No participant shall try to re-finish measuring faces by burring, lapping, stoning, or whatsoever. The measurement of the face concerned or the complete gauge block shall be omitted.

Measurements may only be performed using equipment normally used to offer the relevant CMC service. In case of multiple CMC services in this area, only the service/equipment with the smallest uncertainty should be used, unless the pilot and other participants agree to allow additional instruments to be used; in which case, only the results of the instrument/service with the smallest uncertainty may contribute to the reference value. For clarity – this is a supplementary comparison based on calibration using

mechanical comparison – laboratories with both mechanical gauge block comparators and gauge block interferometers should only make measurements using the comparator service. No other measurements are to be attempted by the participants and the gauge blocks should not be used for any purpose other than described in this document. The gauge blocks may not be given to any party other than the participants in the comparison.

The gauge blocks should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory. After the measurements, the gauge blocks must be cleaned and greased. Ensure that the content of the package is complete before shipment. Always use the original packaging.

5.2 Traceability

Length measurements should be traceable to the latest realisation of the metre as set out in the current "*Mise en Pratique*". Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90).

5.3 Measurands

The gauge blocks shall be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers. The "A" surface is the marked measuring face for gauge blocks with nominal length < 6 mm and the right hand measuring face for gauge blocks with a nominal length ≥ 6 mm, respectively (see Figure 2).

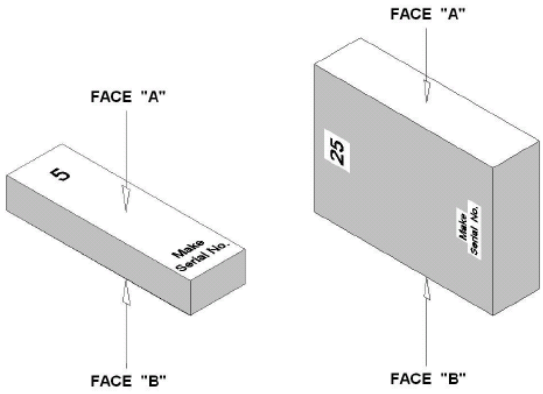


Figure 2 – Nomenclature of faces

The mechanical calibration should be performed as a five point measurement (see Figure 3) and the measurands are as stated in ISO 3650. There are two measurands: the deviation of the central length, l_c, from the nominal length, l_n, thus $\Delta l_c = l_c - l_n$. And the second measurand is variation in length, v (see also Figure 4). Measurements must be done only in one orientation with face "A" surface uppermost.

Figure 3 – Measurement points

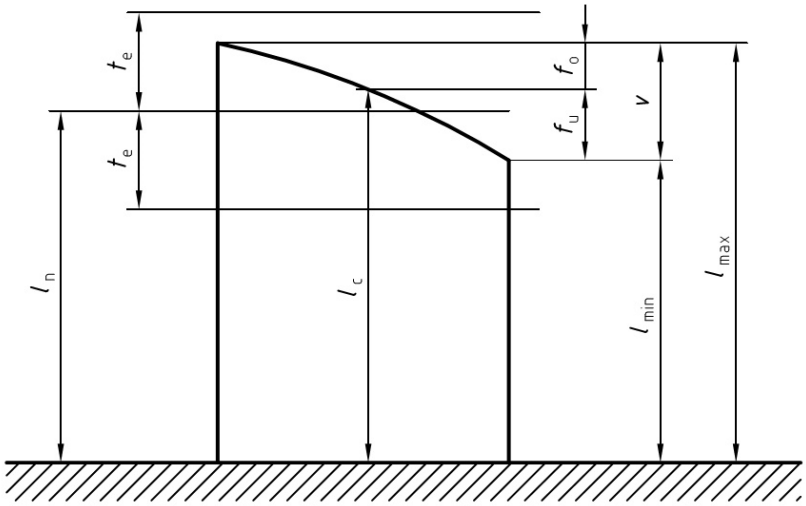


Figure 4 – nominal length (l_n), central length (l_c), variation (v), (f_o), (f_u)

5.4 Measurement uncertainty

The uncertainty of measurement shall be estimated according to the ISO *Guide to the Expression of Uncertainty in Measurement*. The participating laboratories are encouraged to use their usual model for the uncertainty calculation.

The participants are asked to report the standard uncertainty for each central length deviation $u(\Delta l_c)$ and standard uncertainty for each variation in length $u(v)$. Also, uncertainty budget of each participant with indication of the resulting combined uncertainty is required.

In case of relevant CMC-s expanded measurement uncertainty for central length deviation from the nominal length $U(\Delta l_c)$ has to be expressed in the usual length-dependent form:

$$U(\Delta l_c) = Q[a, b \times l_n] = \sqrt{a^2 + (b \times l_n)^2} \quad (1)$$

5.5 Reference condition

Measurement results should be reported for the reference conditions as set down in the standard ISO 3650.

6 Reporting of results

6.1 Results and standard uncertainties as reported by participants

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

The measurement report forms in appendix C 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 pilot. In any case, the signed report must also be sent in paper form by mail or electronically as a scanned pdf document. In case of any differences, the signed forms are considered to be the definitive version.

When reporting the results of the comparison, each participant should also report the identifier, range and uncertainty of any existing CMC related to the comparison. This will be used by the pilot when checking whether or not CMC claims are supported by the comparison results.

In the case that the measurement uncertainty reported by a participant in a comparison is significantly higher than the relevant CMC claim, this should be explained at the time of submitting the results (e.g. air conditioning failure at time of measurements, damage on artefacts affecting measurements).

Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare within 1 month a first draft A.1 report on the comparison. This will be circulated to the participants for comments, additions and corrections.

7 Analysis of results

7.1 Calculation of the reference value

The reference value is calculated on a gauge-per-gauge basis as the weighted mean of the participant results. The check for consistency of the comparison results with their associated uncertainties will be made based on Birge ratio, the degrees of equivalence for each laboratory and each gauge block with respect to the reference value will be evaluated using E_n values, along the lines of the *WG-MRA-KC-report-template*. If necessary, artefact instability, correlations between institutes, and the necessity for linking to another comparison will be taken into account.

7.2 Artefact instability

Steel gauge blocks occasionally show a growing or a shrinkage the rate of which is approximately linear with time. Since the artefacts used here are new and with no history, the instability of the blocks must be determined in course of the comparison. For this check the measurements of the pilot laboratory are used exclusively, not that of the other participants. Using these data a linear regression line is fitted and the slope together with its uncertainty is determined (per gauge block).

Three cases can be foreseen:

a) The linear regression line is an acceptable drift model and the absolute drift is smaller than its uncertainty. The gauge block is considered stable and no modification to the standard evaluation procedure will be applied. In fact the results of the pilot's stability measurements will not influence the numerical results in any way.
b) The linear regression line is an acceptable drift model and the absolute drift is larger than its uncertainty, i.e. there is a significant drift for the gauge block. In this case an analysis similar to [Nien F Z *et al.* 2004, Statistical analysis of key comparisons with linear trends, *Metrologia* **41,**

231] will be followed. The pilot influences the reference value by the slope of the drift only, not by the measured absolute lengths.

c) The data are not compatible at all with a linear drift, regarding the uncertainties of the pilot's measurements. In this case the artefact is unpredictably unstable or the pilot has problems with its measurements. TC-L has to determine the further approach.

7.3 Correlation between laboratories

Significant correlation between results of laboratories may occur if two or more participating laboratories have same source of traceability for interferometric calibration of reference gauge blocks. For that reason, source of traceability for reference gauge blocks is asked from the participants.

7.4 Linking of result to other comparisons

The CCL task group on linking CCL TG-L will set guidelines for linking this comparison to any other key comparison within CCL for the same measurement quantity. To provide traceability to gauge block key comparison NPL will perform additional interferometric measurements.

Appendix A – Reception of Standards

To:	AS Metrosert Teaduspargi 8, 12618 Tallinn, Estonia e-mail: armin.ansip@metrosert.ee tc-length.contact@metrosert.ee	
From:	NMI: ……	Name: ……
	Signature: ……	Date: ……

We confirm having received the gauge blocks for the comparison on the date given above.

After a visual inspection:

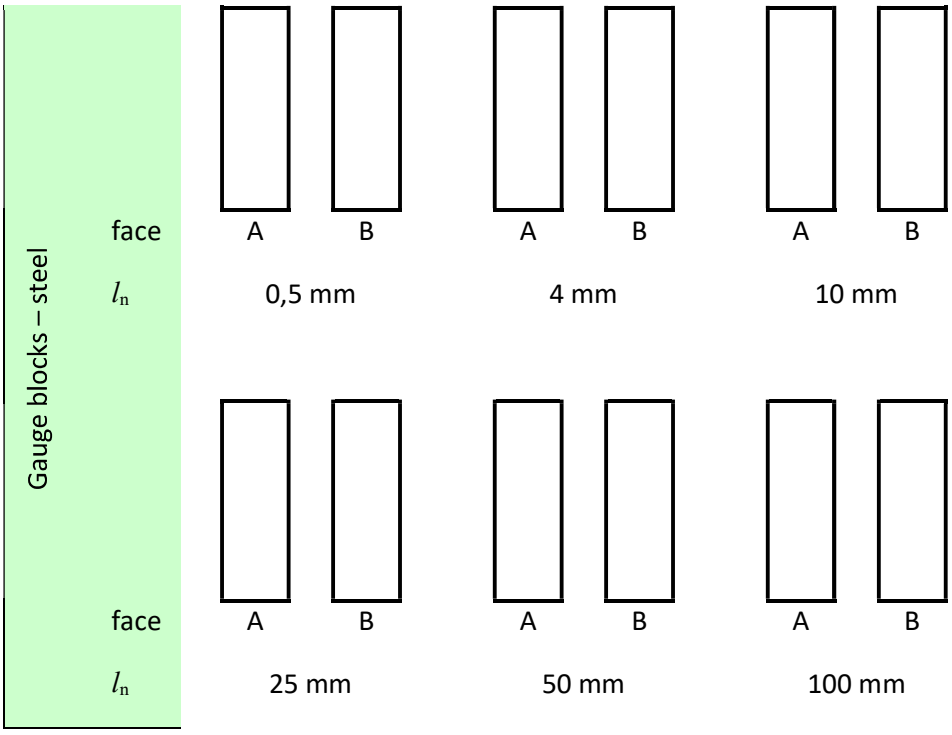
☐ There are no apparent damages; their precise state will be reported in the form provided in Annex B/C once inspected in the laboratory along with the measurement results.

☐ 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.

Appendix B – Conditions of Measuring Faces

To:	AS Metrosert Teaduspargi 8, 12618 Tallinn, Estonia e-mail: armin.ansip@metrosert.ee tc-length.contact@metrosert.ee
From:	NMI: …… Name: …… Signature: …… Date: ……

After detailed inspection of the measuring faces of the gauge blocks these are the results. Please mark significant surface faults (scratches, indentations, corrosion, etc.).



Appendix C – Results Report Form

To:	AS Metrosert Teaduspargi 8, 12618 Tallinn, Estonia e-mail: armin.ansip@metrosert.ee tc-length.contact@metrosert.ee
From:	NMI: …… Name: …… Signature: …… Date: ……

	Short gauge blocks, steel					
l_n / mm	Ident. number	l_c / mm	Δl_c / µm	$u(\Delta l_c)$ / µm	v/ μm	$u(v)$ / µm
0,5						
4						
10						
25						
50						
100						

If your laboratory has a corresponding CMC entry, please fill in the table below.

Measurands level of range		Expanded uncertainty $U(\Delta l_c) = Q[a, b \times l_n] = \sqrt{a^2 + (b \times l_n)^2}$		
Max value (mm)	Min value (mm)	Value (µm)	Coverage factor	Level of confidence
Gauge blocks		a / nm	b / 1	Comment
Short, steel				

Please state source of traceability:

Source of Traceability for reference gauge blocks	Comments

If the reported uncertainty is significantly higher than that of the related CMC, explanation for the increased uncertainty .....

.....

Service(s) related to this comparison topic (if existing) and identifier of the CMC.....

.....

.....

Detailed uncertainty budget

Description	Quantity x_i	Standard uncertainty $u(x_i)$	Sensitivity coefficient c_i	Standard uncertainty $u_i(y)$ / μm

Combined standard uncertainty u_c: ……

Expanded uncertainty U (k=2): ……

Appendix D – Description of the measurement instrument

To:	AS Metrosert Teaduspargi 8, 12618 Tallinn, Estonia e-mail: armin.ansip@metrosert.ee tc-length.contact@metrosert.ee
From:	NMI: …… Name: …… Signature: …… Date: ……

Make and type of instrument(s) .....

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Range of gauge block temperature during measurements & description of temperature measurement method:.....

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