University of Maribor
Faculty of Mechanical Engineering

MIRS

EURAMET Supplementary Comparison
EURAMET.L–S31
(EURAMET Project 1513)

Calibration of a transducer 60 mm

Technical protocol

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Contents

1 Document control

Version 1 Issued on 7 December 2020

Version 2 Issued on 17 February 2021

Version 3 Issued on 4 March 2021

Version 4 Issued on 11 March 2021 (final)

Version 5 Issued on 26 November 2021 (final amended)

2 Introduction

The metrological equivalence of national measurement standards and of calibration certificates issued by national metrology institutes is established by set of key and supplementary comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).

At its meeting in October 2020 (organised and hosted online by DFM Denmark), the TC for Length (TC-L) decided to perform a supplementary comparison on precise linear transducers, named EURAMET.L-SXX. The results of this international comparison will support the Calibration and Measurement Capabilities (CMCs) declared by the NMIs in the CIPM Mutual Recognition Arrangement (MRA).

The interest of participation was initially expressed by eight NMIs/DIs, EURAMET members.

The transfer standard for the comparison was proposed by MIRS/UM-FS/LTM at the TC-L meeting in October 2020. Since no alternative was proposed by other potential participants, it was decided to perform the comparison on a transducer with a measuring range up to 60 mm and with resolution of 10 nm.

The pilot laboratory is MIRS/UM-FS/LTM (Slovenia).

The procedures outlined in this document cover the technical procedure to be followed during measurement of the transducer. The procedures are principally intended to allow a clear description of the required measurements, handling and transportation of the circulating standard, and to complete the comparison in the defined time scale.

A goal of the EUROMET key and supplementary comparisons for topics in dimensional metrology is to demonstrate the equivalence of routine calibration services offered by NMIs/DIs to clients. Therefore, participants in this comparison agree to use the same apparatus and methods as routinely applied to client artefacts.

3 Organisation

3.1 Participants

Table 1. List of participant laboratories and their contacts.

Laboratory	Address	Contact person/phone/e-mail
BEV	Bundesamt für Eich – und Vermessungswesen Arltgasse 35 AT-1160 Wien Austria	Michael Matus +43 1 21 110 6540 michael.matus@bev.gv.at
CEM	Centro Espanol de Metrologia C/del Alfar 2 ES-28760 Tres Cantos (Madrid) Spain	Emilio Prieto +34 91 807 47 16 eprieto@cem.es Mar Pérez +34 91 807 48 01 mmperezh@cem.es
DFM	Danish Fundamental Metrology (DFM) Kogle Allé 5 DK-2970 Hørsholm Denmark	Jan Hald +45 2545 9019 jha@dfm.dk
DTI	Teknologisk Institut (DTI) Gregersensvej 8H 2630 Taastrup Denmark	Jens Bo Toftegaard +45 7220 3034 jbt@teknologisk.dk
JV	Justervesenet - Norwegian Metrology Service Fetveien 99 NO-2007 Kjeller Norway	Helge Karlsson +47 64 84 84 84 hka@justervesenet.no
METAS	Federal Institute of Metrology METAS Lindenweg 50 CH-3003 Bern-Wabern Switzerland	Felix Meli +41 58 387 03 46 felix.meli@metas.ch
MIRS/UM-FS/LTM	University of Maribor Faculty of Mechancal Engineering Smetanova 17 SI-2000 Maribor Slovenia	Bojan Acko +386 2 220 7581 bojan.acko@um.si
VSL	VSL Thijsseweg 11 P.O.Box 654 NL-2600 AR Delft The Netherlands	Richard Koops +31 15 2691 642 rkoops@vsl.nl
VTT MIKES	VTT Technical Research Centre of Finland Ltd, Centre for Metrology MIKES Tekniikantie 1 FI-02150 Espoo Finland	Antti Lassila +358 40 7678584 antti.lassila@vtt.fi

3.2 Form of comparison and time-schedule

The comparison will be performed in a 'circular' form. The transfer standard will be measured at the beginning and at the end of the circulation by the pilot laboratory in order to monitor the stability of the transducer.

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

The participating laboratories were asked to specify a preferred timetable slot for their measurements of the artefact - the timetable given below have been drawn up taking these preferences into account.

Table 2. Comparison timetable

Laboratory	Country	Starting date
MIRS/UM-FS/LTM	Slovenia	1 March 2021
~~BEV*~~	~~Austria~~	~~1 April 2021~~
DTI	Denmark	1 June 2021
~~VSL*~~	~~The Netherlands~~	~~1 July 2021~~
DFM	Denmark	1 September 2021
CEM	Spain	1 October 2021
JV	Norway	1 November 2021
METAS	Switzerland	1 December 2021
MIRS/UM-FS/LTM	Slovenia	15 January 2022
BEV**	Austria	1 March 2022
VSL**	The Netherlands	1 April 2022
VTT MIKES	Finland	1 May 2021
MIRS/UM-FS/LTM	Slovenia	1 June 2022

* measurements withdrawn due to technical issues
** rescheduled measurements

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 artefact arrives in the country of the next participant at the beginning of the next month.

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 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.

3.3 Transport of the artefact

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

Packaging for the artefact is suitably robust to protect the artefact from being deformed or damaged during transit. The transducer and the display unit are packed in a suitcase (See Fig. 1).

Figure 1: Transducer container

The package shall be marked as 'Fragile'.

Transportation to the next participant is each participant'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 final measurements and the processing of results are covered by the pilot laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during transportation.

The package should be shipped with a reliable parcel service of the participant's choice.

Due to customs issues, all export outside and into the European Union will be handled by MIRS/UM-FS/LTM as sender or recipient. Participants outside EU must ensure that they fulfil the respective customs requirements for the "temporary import" of the artefact.

3.4 Receipt and handling of the artefact

The artefact shall be examined immediately after receipt. The condition of the artefact shall be noted (a photo or a drawing) and all discrepancies communicated to the pilot laboratory per e-mail. The form in Appendix A.3 should be used for this purpose.

The artefact should only be handled by authorized persons and stored in a proper way in order to prevent damages. No special instructions on handling in the laboratory is necessary. The artefact is robust and need no special care like oiling etc. Prevent mechanical and thermal shocks, keep it in the laboratory conditions all the time.

The artefact shall be examined before dispatch and any change in condition during the measurement shall be communicated to the pilot laboratory.

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

The artefact shall be packed according to the instructions in the package. Ensure that the content of the package is complete before shipment. Always use the original packaging.

4 The artefact

4.1 Description of the artefact

At the Euramet TCL meeting in October 2020 it has been decided to measure a transducer with the measurement range (0 to 60) mm and the resolution of 10 nm. The artefact is shown in Fig. 2.

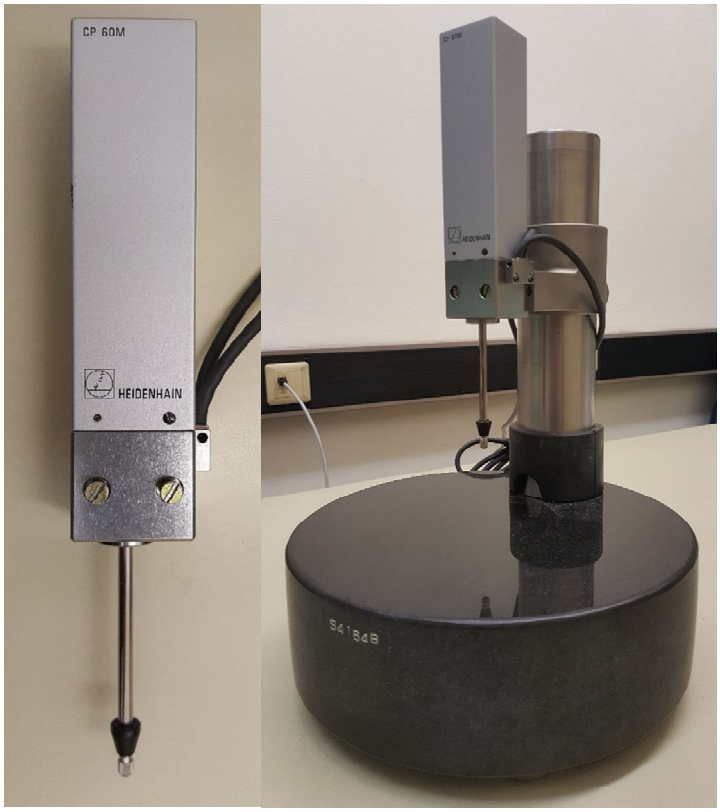


Figure 2: Heidenhain transducer Certo CP 60M

Producer's specifications:

Measuring range:	(0 to 60) mm
Resolution:	10 nm (by using the supplied display unit)
Repeatability:	< 0.03 µm
System accuracy:	±0.1 µm (with linear error compensation up to ±0.03 µm)
Scale material:	Zerodur (thermal expansion α not specified; assumed to be negligible in the specified measuring range at temperatures 19 °C to 21 °C)
Material of the components in the measuring loop:	Invar; $\alpha = 1 \times 10^{-6}$ K^{-1}
Guides:	Ball-bearing guide with low friction
Plunger (probe) actuation:	By gravity (chosen for the transducer in comparison)

Dimensions of the artefact are presented in Fig. 3.

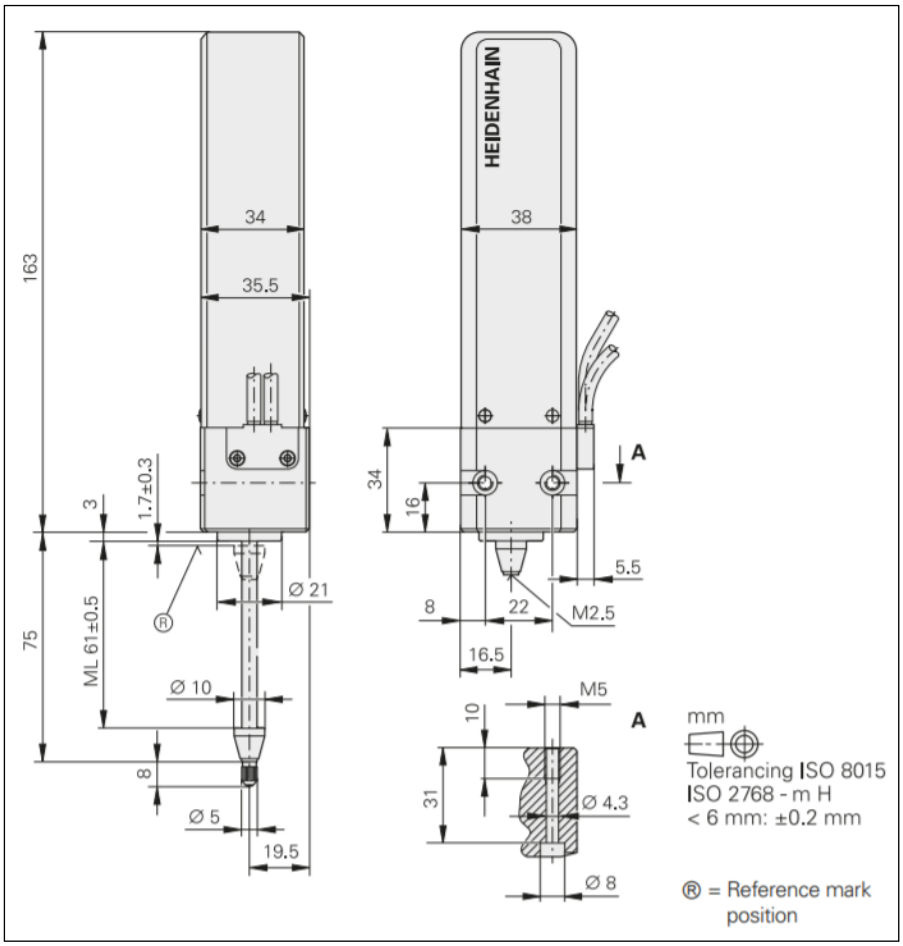


Figure 3: Dimensions of the artefact [1]

Display unit

The transducer is equipped with an easy to use display unit shown in Fig. 4. The transducer cable shall be attached to the input socket X1.

Important: Don't change the display settings in the menu!

- *Encoder compensation shall remain "COMP. OFF" (menu P40)*
- *Linear error compensation shall remain 0 (default setting in menu P41)*

Figure 4: Display unit

4.2 Fixing the artefact

The artefact will be shipped without any special mounting fixtures. As it can be seen form Fig. 2 and Fig. 3, it shall be fixed on a flat surface by using two M4 screws (attached in the package). This surface shall be parallel to the axis of measurement. If necessary, additional fixing interface should be produced. For illustration, original fixture on the Heidenhain-Certo CS-200 gauge stand is shown in Fig. 5.

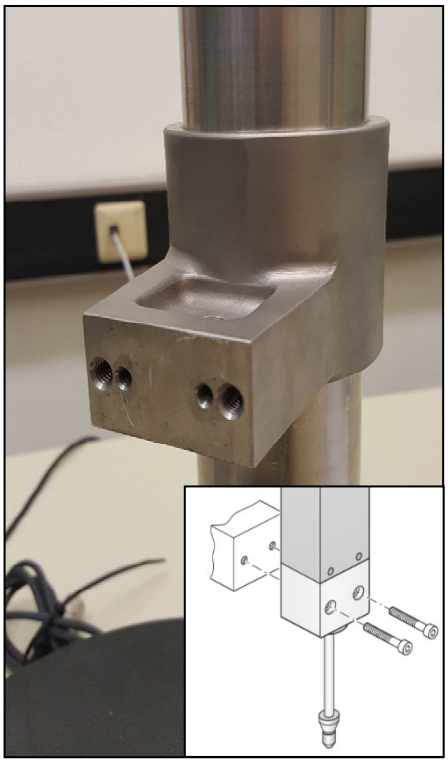


Figure 5: Fixture on the Heidenhain-Certo CS-200 gauge stand

5 Measurement instructions

5.1 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).

5.2 Measurand

Measurand is a displacement error (bias) of the transducer in defined measurement points in the measurement direction perpendicular to the lower housing surface.

The origin (reference point, "0") shall be defined in respect to the internal reference mark (see 3.2.1).

Table 1: Measurement points

Nominal lengths from defined origin in mm									
2	4	6	8	10	12	14	16	18	20
22	24	26	28	30	32	34	36	38	40
42	44	46	48	50	52	54	56	58	

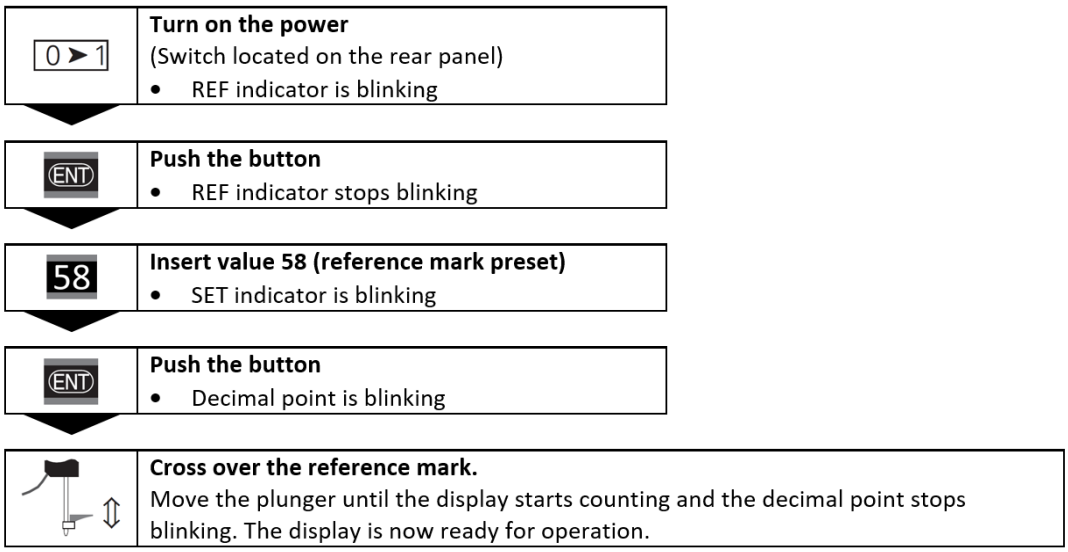
3.2.1 Setting the reference point (origin)

The origin for the measurements shall be set in respect to the transducer's internal reference mark, which is reached by pushing the probe in the upper (inner) position as indicated in Fig. 6.

Figure 6: Approximate probe position when the internal reference mark is traversed

Since the origin for measurements (0) is normally in the lower probe position (in order to measure in positive direction), the transducer shall be preset to 58 mm, when traversing the internal reference mark (full 60 mm range is not available in case of using the internal reference mark for defining the origin).

The following procedure shall be used for traversing the internal reference mark and defining the origin for measurements:



5.3 Measurement conditions

Since the measurement force is produced by gravity, it is strongly recommended to orient the transducer vertically. Such orientation is also proposed by the producer.

However, it is also allowed to perform the measurements in horizontal orientation if a proper connection of the transducer with the standard instrument is assured. In this case, the results shall be properly corrected (measurement force, shaft bending, …).

The measured values have to be referred to the following reference conditions:

- temperature of 20 °C (ITS-90),

If necessary, corrections have to be applied based upon the thermal expansion, stated in Chapter 4.1.

5.4 Measurement instructions

The calibration should be carried out as for a normal customer. The participants are free to choose their own method of measurement**. It is recommended to measure in both directions: inwards (+) and outwards (-). However, the quantity for the comparison is only the average detected bias ($\overline{B}$), because some laboratories might choose to measure only in one direction (e. g. only outwards if gauge block are used).**

Before calibration, the transducer shall be inspected for damages. Any scratches or other damages have to be documented.

The measurements have to be reported for the measuring conditions, given in 5.3.

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.

5.5 Measurement uncertainty

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

The participants are requested to report a detailed measurement uncertainty budget using the table of the Appendix A.2

6 Reporting the 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**.

The measurement results (appropriately corrected to the reference conditions) have to be reported using the table in Appendix A.1.

The report shall also contain a description of the equipment used for calibration, as well as the method of alignment (horizontal/vertical position of the transducer; measurement direction - perpendicular to the lower housing surface/parallel to the plunger axis/… , …).

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 or electronically as a scanned pdf document.** In case of any differences, the paper forms are considered to be the definitive version.

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

7 Analysis of results

The comparison reference value will be calculated 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 the Birge ratio, the degrees of equivalence for each laboratory with respect to the reference value will be evaluated by E_n values. If necessary, artefact instability will be taken into account.

8 References

[1] Heidenhain: Length gauges. https://www.heidenhain.de/fileadmin/pdb/media/img/208945-2G_Length_Gauges_en.pdf (accessed November 25, 2020).

A.1 Measurement results

I. Short description of the instrument and the measurement method/procedure

(Use more sheets if necessary, enclose photo(s) and/or sketch(es) of the instrument, describe the alignment of the transducer)

II. Measurement results

Nominal length	Inwards (+)			Outwards (-)			Average
	Transducer indication	Reference indication	Bias $B_+ = L_T - L_R$	Transducer indication	Reference indication	Bias $B_+ = L_T - L_R$	Bias
L (mm)	L_T (mm)	L_R (mm)	B_+ (nm)	L (mm)	L (mm)	B_+ (nm)	$\bar{B}$ (nm)
2							
4							
6							
8							
10							
12							
14							
16							
18							
20							
22							
24							
26							
28							
30							
32							
34							
36							
38							
40							
42							
44							
46							
48							
50							
52							
54							
56							
58							

Laboratory:

Date: Signature:

A.2 Uncertainty of measurement

Quantity X_i	*Quantity estimate* x_i	*Standard uncertainty* $u(x_i)$	*Sensitivity coefficient* $c_i = \partial f/\partial x_i$	*Uncertainty contribution* $u_i(B)$

Combined standard uncertainty: $u_c(B)$ =

Expanded uncertainty (*95 %*): $U(B)$ =

Laboratory:

Date: Signature:

A.3 Receipt confirmation

To:	Bojan Acko, University of Maribor – Faculty of Mechanical Engineering Smetanova 17 SI – 2000 Maribor, Slovenia Fax: +386 2 220 7586 E-mail: bojan.acko@uni-mb.si
From:	NMI: Name: Signature: Date:

We confirm the receipt of the artefact for the *EURAMET key comparison on transducers* on .....(date).

After visual inspection

o no damage has been noticed;

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