Bundesamt
für Eich- und
Vermessungswesen

EURAMET Supplementary Comparison
EURAMET.L-S29
Measurement of a 1 mm Stage Micrometer
EURAMET project 1488

Technical protocol

Michael Matus (BEV)

Wien, November 2019

Contents

1 Document control

Version 0.92 Issued on 14 October 2019 for discussion at the TC-L meeting in Braunschweig.
Version 0.93 Distributed for comments.
Version 0.94 List of participants updated, section 8 removed.
Version 0.95 Section 7.2 modified, threshold set from 50 to 10. Registration number added.
Version 0.96 Figure 1 updated

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.

At its meeting in Espoo, 16-17 October 2017, the EURAMET Technical Committee for Length (TC-L) decided to carry out a supplementary comparison on stage micrometer measurements, named EURAMET.L-S29, with BEV (Bundesamt für Eich- und Vermessungswesen) as the pilot laboratory. 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 comparison was registered in November 2019, and artefact circulation is planned to start in June 2020.

The procedures outlined in this document cover the technical procedure to be followed during the measurements. A goal of the EURAMET 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. 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. 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

The participating laboratories are NMIs or DIs fulfilling the following conditions:

- signatory (or applicant) of the CIPM MRA;
- having submitted CMCs for stage micrometer calibration (or intending to do so);
- offering the calibration of stage micrometers for their customers as a regular service (or intending to do so);
- perform stage micrometer calibration with lower uncertainty, with different instrumentation or with smaller interval as compared to the EURAMET.L-K7 measurements;
- being well trained in handling stage micrometers without the risk to damage them;
- being capable to measure all 100 line distances and to report the results in electronic format as stated in section 6.1.

3.1 Participants

Table 1. List of participant laboratories and their contacts.

Laboratory, Country code RMO	**Contact person, Laboratory**	**Phone Email**
BEV (AT) EURAMET Pilot	Michael Matus Bundesamt für Eich- und Vermessungswesen Arltgasse 35, A-1160 Wien Austria	+43 1 21110 826540 michael.matus@bev.gv.at
CEM (ES) EURAMET	Emilio Prieto, Mª Mar Pérez Centro Español de Metrología Alfar 2, ES-28760 Tres Cantos (Madrid) Spain	+34 91 8074 716 / 801 eprieto@cem.es mmperezh@cem.es
INRIM (IT) EURAMET	Alessandro Germak Istituto Nazionale di Ricerca Metrologica Strada delle Cacce 91, 10135 Torino Italy	+39 011 3919 924 a.germak@inrim.it
GUM (PL) EURAMET	Dariusz Czulek Central Office of Measures ul. Elektoralna 2, 00-950 Warszawa Poland	+48 22 581 95 43 d.czulek@gum.gov.pl
INM (RO) EURAMET	Alexandru Duță, Elena Dugheanu National Institute of Metrology Sos. Vitan-Bârzesti 11, 042122 Bucuresti Romania	+40 21 334 5060 alexandru.duta@inm.ro elena.dugheanu@inm.ro
DMDM (RS) EURAMET	Slobodan Zelenika Directorate of Measures and Precious Metals Mike Alasa 14, YU - 11 000 Belgrad Serbia	+381 11 20 24 421 zelenika@dmdm.rs
RISE (SE) EURAMET	Olena Flys, Marianne Äremann RISE Research Institutes of Sweden AB 50115 Borås Sweden	+46 10 516 5492 or 5481 +46 70 280 54 92 olena.flys@ri.se marianne.aremann@ri.se
UME (TR) EURAMET	Bulent Ozgur, Muharrem Asar Ulusal Metroloji Enstitüsü Barış Mah. Dr. Zeki Acar Cad. No:1 41470 Gebze, Kocaeli Turkey	+90 262 679 50 00 ext. 5300 bulent.ozgur@tubitak.gov.tr muharrem.asar@tubitak.gov.tr
NMISA (ZA) AFRIMETS	Pieter Greeff National Metrology Institute of South Africa Building 5 CSIR Campus, Brummeria, Pretoria 0184 South Africa	+27 12 841 4936 pgreeff@nmisa.org
NIM (CN) APMP	Shuanghua Sun National Institute of Metrology No. 18, Bei San Huan Dong Rd. 100029 Beijing China	+86 10 64524911 sunshh@nim.ac.cn
NIMT (TH) APMP	Jariya Buajarern 3/4-5 Moo 3, Klong 5, Klong Luan 12120 Pathumthani Thailand	+66 2 5775100 1216 jariya@nimt.or.th

INMETRO (BR) SIM	Davi Anders Brasil Av. N. S. das Graças, 50 – Vila Operária - Xerém Duque de Caxias – RJ Brazil	+55 21 2145 3289 dabrasil@inmetro.gov.br
INTI (AR) SIM	Bruno Gastaldi Av. Vélez Sarsfield 1561, Córdoba X5000JKC, Argentina	+54 0351 4684835 gastaldi@inti.gob.ar

3.2 Schedule

The comparison will be carried out in the form of two consecutive circulation loops, to manage the EU versus non-EU customs issues. The artefact will be measured at the beginning and at the end of each circulation by the pilot laboratory in order to monitor the stability.

The participating laboratories were asked to specify a preferred timetable slot for their own measurements of the stage micrometer – the timetable given in table 2 has been drawn up taking these preferences into account. Each laboratory has one calendar month that includes 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. The artefact should arrive at the next participant before starting date of measurement in Table 2. 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 standard directly to the next participant before completing the measurements or even without doing any measurements.

Table 2. Schedule of the comparison. (Order and dates in this table are completely random here)

No.	Laboratory	Country	Starting date of measurement
1	BEV	Austria	1 June 2020
2	CEM	Spain	October/November 2020
3	INRIM	Italy	1 Xxx 2020
4	GUM	Poland	September 2020 or later
5	INM	Romania	October/November 2020
6	RISE	Sweden	1 Xxx 2020
7	BEV	Austria	1 September 2020
8	UME	Turkey	1 February 2021 (preferred)
9	DMDM	Serbia	2021 (March/April 2021 or later – in the part with ATA carnet)
10	NMISA	South Africa	1 Xxx 2021
11	NIM	China	1 April/May 2021
12	NIMT	Thailand	1 Xxx 2021
13	INMETRO	Brazil	1 May 2021
14	INTI	Argentina	1 Xxx 2021
15	BEV	Austria	1 August 2021

3.3 Reception, transportation, insurance, costs

A plastic case containing the stage micrometer is used for the transportation (Figure 1). Upon reception of the package, each laboratory should check that the content is complete and that there is no apparent damage on the box or of the standard. The reception must 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 includes the standard itself, the case and the packaging. The pilot laboratory has no insurance for any loss or damage of the standard during the circulation.

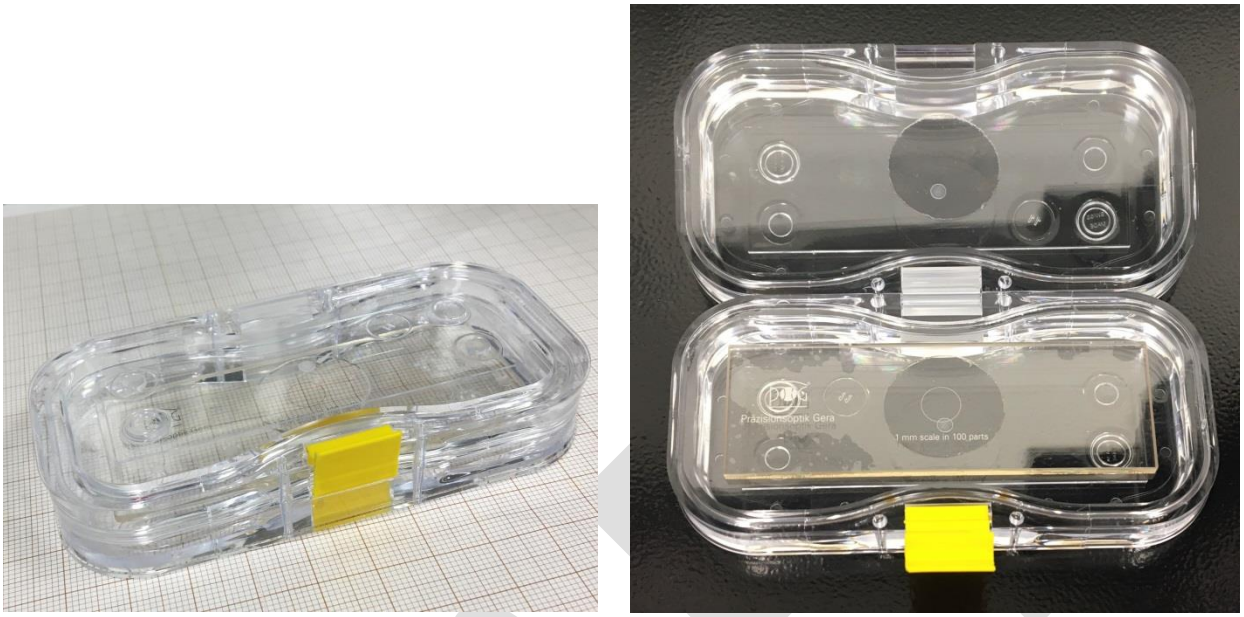


Figure 1 – Transporting case. Left properly closed, right demonstrating the placement of the artefact

In order to prevent any damage, the artifacts should only be handled by authorized persons and stored in a proper way. The standard needs to be protected from dust and fingerprints when not being measured by means of using suitable gloves. The stage micrometer shall be put in the plastic case whenever not in use.

Figure 1 shows the special plastic case designed for the used artefact. When properly closed with the yellow clip, the stage micrometer is securely fixed between two rubber membranes. Both membranes have a circular hole in the center. The stage micrometer can be placed in a way so that the scale does not touch any other object.

When opening the case (by pulling the yellow clip), care has to be taken not to drop the stage micrometer. It may stick to either of the two membranes! You should check on which one before completely open the case!

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, the package shall be sent to the following participant. Please inform the pilot laboratory and the following participant when the package leaves your installations 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.

The artifact will be accompanied by a suitable customs carnet (where appropriate) and documentation identifying the contents. The ATA 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! Every time the carnet is used, it is stamped twice – on exit from one country and on entry into the next. Please examine the carnet and assure that the transportation company used has arranged for correct stamping of the carnet. Failure to ensure both stamps (exit, entry) subjects the carnet holder to a penalty.

In general participants must ensure that they fulfil the respective customs requirements for the export of the standards into the recipient country.

4 Artefact

4.1 Description of artefact

The artefact is a typical stage micrometer with fairly well-defined graduation lines (Figure 2). The scale length is 1 mm divided in 100 parts. The graduation lines have a width of approximately 3 µm and are of unequal length. 11 lines are numerical labelled in multiples of 0.1 mm (Figure 3). The graduation is not covered.

Substrate dimensions: 75.7 mm × 25.8 mm × 2.2 mm
Substrate material: Nextrema® 724-3[1]
Linear thermal expansion coefficient: $(-0.1 \pm 0.7) \cdot 10^{-6}\ K^{-1}$
Lines: vacuum deposited chromium

Figure 2 – Stage micrometer

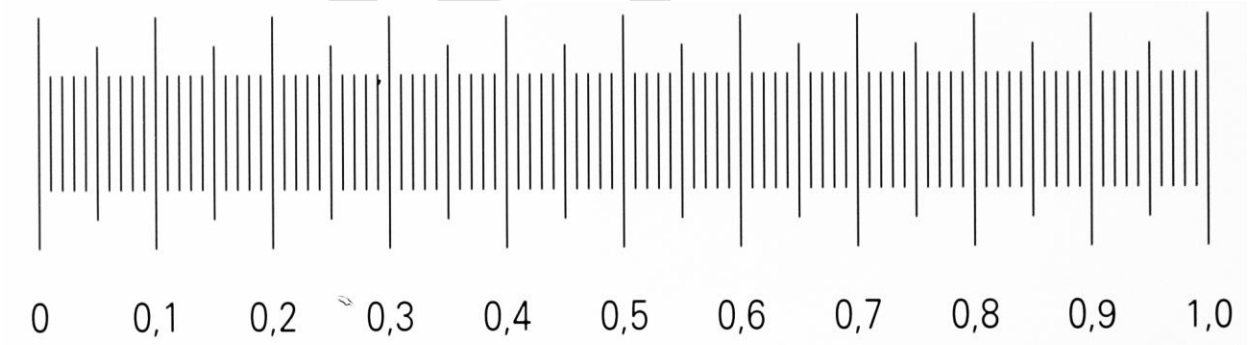


Figure 3 – Microphotography of the scale

5 Measuring instructions

5.1 Handling the artefact

The stage micrometer shall only be handled by authorized persons wearing appropriate gloves. It should be stored in such a way as to prevent damage. The side bearing the graduation should not came in

[1] Information by manufacturer at: www.schott.com/nextrema

contact with other objects; the transportation box is constructed in a way to avoid any contact with its walls.

Before making the measurements, the stage micrometer needs to be checked to verify that the measuring surface is not damaged. Micrographic images are the most appropriate way for this check. The condition of the graduation should be registered in the form provided in Appendix B.

No other measurements are to be attempted by the participants and the stage micrometer should not be used for any purpose other than described in this document. The stage micrometer may not be given to any party other than the participants in the comparison. When not in use, place the scale back into its container to avoid dust or dirt deposits.

The stage micrometer should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory. Ensure that the content of the package is complete before shipment. Always use the original packaging.

5.2 Cleaning

The principle rule is not to clean the artefact at all! No cleaning of the scale should be tried besides blowing away dust particles using dry, clean air or other clean gases. Especially, rubbing the surface with soft tissues or any other firm physical contact will possibly damage the line structures of the standards. Application of solvents such as acetone or alcohol is strictly forbidden.

If it is necessary to clean the scale before the measurement, please get in contact with the pilot.

5.3 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).

5.4 Measurands

The stage micrometer shall be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers.

The measurand e_i is the deviation of the distance d_i between the reference line to the measured line from the nominal distance L_i:

$$e_i = d_i - L_i$$

The distance d_i has to be determined between the center line position of the reference line (zero line, labelled "0") and the center line position of the measured line. All measurements should be performed over the section of 50 µm width. That is, it should be tried to apply an effective slit height or CCD image window height of 50 µm for the analysis of measurements (Figure 4). This 50 µm window should be positioned symmetrical with respect to the graduation. Since the artefact does not have any guiding structures, there is some arbitrariness in the alignment. This fact and any deviation from the given measurand definition should be recognized by appropriate uncertainty contributions. This decision must be made by the participant (not the pilot).

The measurement results shall be corrected for the reference conditions as stated in section 5.6.

All 100 values e_1 to e_{100} as defined above have to be measured and reported.

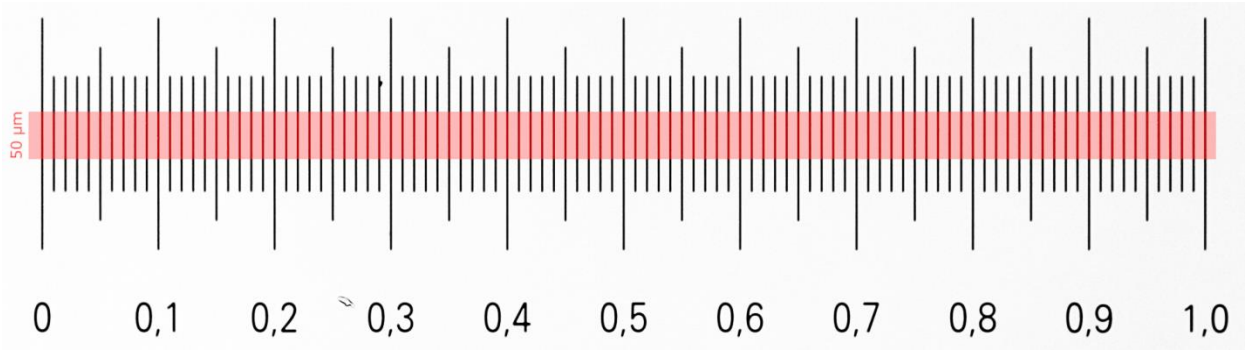


Figure 4 – The 50 µm region (in pink) over which the line centers are to be evaluateds.

5.5 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 $u(e_i)$ (or u_i for short) for each of the 100 individual measurement values in the report file. Moreover, the expanded measurement uncertainty U has to be expressed in the usual length-dependent form:

$$U = Q[a, b \cdot L] \equiv \sqrt{a^2 + (b \cdot L)^2}$$

using a coverage factor of $k = 2$.

5.6 Reference condition

Measurement results should be reported for the reference temperature of 20 °C. For corrections, the linear thermal expansion coefficient indicated in section 4.1 should be used. The reference orientation is horizontal with the graduation facing upwards.

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 stated in appendix C of this document will be sent by e-mail (Excel 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.

All values should be given in µm with at least one and at most three decimal digits. Care has to be taken to use the correct sign.

6.2 File name convention

The name of the file send to the pilot should be in the format `XXX_EURAMET.L-S29.xls`. Where `XXX` is to be substituted by the acronym of the participant's NMI (can be more or less than three letters). The participants are asked to include only the intended information as numerical or literal values in the Excel sheets (i.e. do not enter formulas or formats specifications in the cells).

Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare within 3 months 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 (here denoted as SCRV) is calculated for each nominal length separately 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 and each line with respect to the SCRV will be evaluated using E_n values. If necessary, artefact instability and correlations between institutes will be taken into account.

7.2 Handling of inconsistent results

If the Birge criterion is not fulfilled for a given e_i the participant´s result with the highest E_n value will be excluded from the SCRV calculation for this measurement point. This step is iterated until the Birge criterion is eventually passed.

In case a participant shows an exceptional large numbers of inconsistent results, all values will be considered inconsistent and not a single value will contribute to the SCRV. The threshold for "exceptional large" is set to 10[2] values.

In any case the E_n values for all participants and all points will be reported. Values not contributing to the SCRV are identified as such in the reports.

7.3 Artefact instability

A dimensional instability of the artefact is not expected considering the limited length and measurement uncertainty. For this check the measurements of the pilot laboratory are used exclusively, and not those of any of the other participants.

7.4 Correlation between laboratories

Significant correlations between the results of different NMIs are unlikely. Thus, correlations are normally not considered in the analysis of this comparison. For an actual decision on this matter, the participants are asked to state the traceability route (by a calibrated stage micrometer) and the measurement uncertainty of this reference standard.

7.5 Linking to other comparisons

It is not intended to link this comparison to other SC or KC. Specifically it is not intended to link to the concurrent EURAMET.L-K7. For a possible follow-up SC the pilot will provide all necessary data in electronic form.

[2] In the previous drafts this number was set arbitrarily to 50. Even for completely "correct" measurements, one would expect up to 9 inconsistent results with a probability exceeding 97 %. This estimation is based on a binomial distribution under usual constrains.

Appendix A – Reception of Standards

To:	Michael Matus, Bundesamt für Eich- und Vermessungswesen (BEV) Arltgasse 35, 1160 Wien, Austria Fax: +43-1-21110 826000 E-mail: michael.matus@bev.gv.at	
From:	NMI: ……	Name: ……
	Signature: ……	Date: ……

We confirm having received the stage micrometer 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 artefact

To:	Michael Matus, Bundesamt für Eich- und Vermessungswesen (BEV) Arltgasse 35, 1160 Wien, Austria Fax: +43-1-21110 826000 E-mail: michael.matus@bev.gv.at	
From:	NMI: ……	Name: ……
	Signature: ……	Date: ……

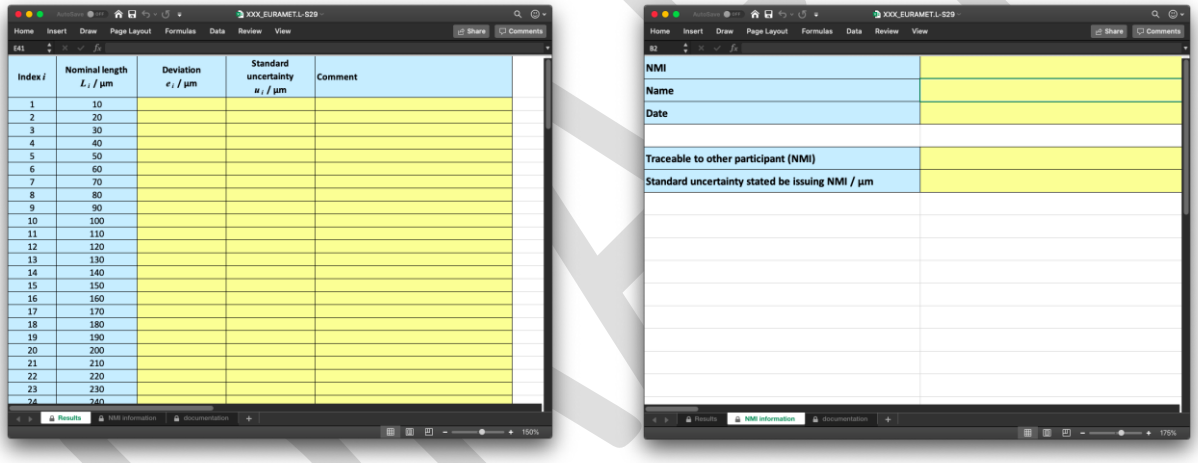
After detailed inspection of the stage micrometer these are the results. Please mark significant faults (scratches, finger prints, particles, etc.) in a drawing and/or provide microphotographs.

Appendix C – Results Report Form

To:	Michael Matus, Bundesamt für Eich- und Vermessungswesen (BEV) Arltgasse 35, 1160 Wien, Austria Fax: +43-1-21110 826000 E-mail: michael.matus@bev.gv.at
From:	NMI: …… Name: …… Signature: …… Date: ……

Results

For all measured points include the value e_i and its associated standard uncertainty $u(e_i)$ in the provided Excel file. The name of this file should be in the form `XXX_EURAMET.L-S29.xls`. Here `XXX` should be substituted by the acronym of you NMI. All values should be given in µm with at least one decimal digit. A screen shot of this sheet is shown below together with one for general laboratory information.



Index i	Nominal length L_i / µm	Deviation e_i / µm	Standard uncertainty u_i / µm	Comment
1	10			
2	20			
3	30			
4	40			
5	50			
6	60			
7	70			
8	80			
9	90			
10	100			
11	110			
12	120			
13	130			
14	140			
15	150			
16	160			
17	170			
18	180			
19	190			
20	200			
21	210			
22	220			
23	230			

NMI	
Name	
Date	
Traceable to other participant (NMI)	
Standard uncertainty stated be issuing NMI / µm	

Uncertainty claim

Please state the length dependent expanded uncertainty U for $k = 2$ according to section 5.5

For this comparison:

a	
b	

Published CMC:

a	
b	

Appendix D – Description of the measurement instrument

To:	Michael Matus, Bundesamt für Eich- und Vermessungswesen (BEV) Arltgasse 35, 1160 Wien, Austria Fax: +43-1-21110 826000 E-mail: michael.matus@bev.gv.at
From:	NMI: …… Name: …… Signature: …… Date: ……

Short description of measurement instrument (Illumination type, incl. photo)

<To be completed by participant>

Traceability route
(comparison with reference stage micrometer, laser interferometer, ...?)

<To be completed by participant>

Principle of line center detection

<To be completed by participant>

Temperature range during measurements

XX.XX °C to XX.XX °C

Additional remarks

<To be completed by participant>