Swedish Metrology and Quality AB

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To participants

Report on an interlaboratory comparison (ILC) of the calibration in the length area – part 1 (gauge blocks and control rods)

The case carrying all equipment for calibration.

Weight 20 kg

Author

Håkan Källgren
Swedish Metrology and Quality AB

Calculations

Peter Lau
MNE-Konsult AB

Content

Abstract

The intercomparison ILC length 2021:2 included 4-gauge blocks, 2 control rods, a two-point inside micrometre and one calliper. The results are reported in 2 reports and this report is number 1 covering gauge blocks and control rods.

The number of participating laboratories in this intercomparison was 12, but 13 results were delivered as one laboratory reported results from calibrations made by 2 calibration technicians.

The number of calibration points in total was 47. Two En-values higher than 1 on were found in the calibration of control rod 100 mm.

Purpose and implementation of the comparison

This interlaboratory comparison serves as a tool to verify results from the measurement carried out by calibration laboratories. It is an effective method to demonstrate technical capacity of the participant and serves as a technical base for accreditation as required by ISO/IEC 17025:2017 (SS-EN ISO/IEC 17025:2018) as specified in point 7.7.2.

Advisory group

The intercomparison has followed the recommendations of the advisory group.

The advisory group has defined the set-up of instruments that should be included in the ILC length 2021:2 intercomparison as well as the choice of measuring points that is defined to be included in the evaluation of the results.

The members of the advisory group are Mikael Frennberg, Quality Control in Metrology Sweden, Peter Lau MNE konsult and Håkan Källgren SMQ.

Information about the intercomparison

The information about the intercomparison was given in 3 different media:

- Linkedin
- The data base https://www.eptis.org
- On the web https://smquality.se/interlaboratory-comparisons-ilc

The information on the web was done in 2 steps. General information as ILC Length 2021:1 published on smquality.se annex 1 in this report.

Detailed information as a description of the intercomparison/ILC published on smquality.se.
and enclosed as annex 2 in this report.

List of objects

The following instruments are included:

Gauge blocks

- Gauge block, 2 mm
- Gauge block 50 mm
- Gauge block 200 mm
- Gauge block 600 mm

Control rods

- 100 mm
- 500 mm

All objects above were included in one parcel.

Participants could choose which object(s) they wanted to calibrate.

Participating laboratories and measuring scheme for the comparison

Laboratory	**Delivery address**
MIKES Metrology, VTT Length Metrology Technical Research Centre of Finland	Tekniikantie 1, FI-02150 ESPOO, Finland
Koneteknologiakeskus Turku OY	Lemminkäisenkatu 28, 20520 Turku, Finland
SKF Sverige AB	Kvibergs Broväg 8, SF-Terminal 1/Mätcentrum, 415505 Göteborg, Sweden
Element Metech AB	Flygmotorvägen 1, SE-461 38 Trollhättan Sweden
Element Metech KDK GmbH	In den Ziegelwiesen 25 DE-69186 Wiesloch Germany
TÜV NORD Mobilität GmbH & Co. KG	Frillendorferstrasse 137 45139 Essen, Germany
Hainaut Analyses	4ème Rue, N°13 6040 JUMET Belgique
METROMAT SRL	Str. Ady Endre nr. 44 Sacele jud Brasov 505600 Romania
KIWA CERMET ITALIA SPA	Via Cadriano 23 40057 Granarolo (BO) Italy
MeßTechteknikNord GmbH	Industriestarße 29 22880 Wedel Germany
SC Nuclear NDT Research and services SRL	Soseanua Berceni, Nr 104 Cladirea Laborator Central, Sector 4 Bucharest, Romania
Janz-contagem e Gestao de Fluidos,SA	Av Infante D 288 1950-421 Lisboa Portugal
Elastocon AB	Tvinnargartan 25, 507 30 Brämhult Sweden

There were some challenges and delays during the program as something went wrong in the circulation.

A majority performed a calibration on all equipment others only some objects. During the exercise all together 47 calibrations were performed.

Most of the participants have an accreditation by SWEDAC, DANAK, FINAS, DAkkS. BELAC, ROMANIA RENAR, ACCREDIA or IPAC.

Principles on the calibration in general

The reference laboratory calibrated all equipment prior to the calibrations by the first participant (in the ILC) and the pilot laboratory performed a second calibration after the last participant calibration .

The organiser made a preliminary follow up after each individual calibration by the participants to find if there were some problems on the objects. The main purpose for doing so was to achieve as equal conditions as possible for all participants and if necessary to do a reference calibration if necessary.

Further it was checked that no significant problem had occurred before the next participant could start its calibration.

Conditions and transport during the measurement period

A special case with special filters and insulation for humidity and vibrations was prepared for the transportation.

Calibration instructions

The laboratories were allowed maximum 10 days for each calibration.

In the call they were advised to use their own calibration procedures with focus on the following points which were important for the inter-comparison outcome. They were not allowed to perform any type of adjustment on the objects.

The laboratories further were encouraged to use their calculated uncertainty values even if those would differ from the CMC values in their accreditation.

Compulsory calibration points

The participant should calibrate according to the following parameters / measuring points on the objects:

- Gauge block 2 mm length in the centre and 4 corner points (see ISO 3650)
- Gauge block 50 mm length in the centre and 4 corner points (see ISO 3650)
- Gauge block 200 mm length in the centre
- Gauge block 600 mm length in the centre
- Control rod 100 mm length in the centre
- Control rod 500 mm length in the centre

The participants were allowed to record other points as described in their method and issue calibration certificates according to their method. However, the comparison was only evaluated and executed in the points (parameters) mentioned above.

Planning and administrative details

The laboratories were asked to send original calibration data in pre-defined protocols (enclosed in annex 3) in digital form as excel files by e-mail before issuing transportation to the next laboratory.

It was possible to provide additional information or supplementary documentation eventually needed to understand the results.

Administrative information

Address to send the required documents:
Swedish Metrology and Quality AB Håkan Källgren Dragspelsgatan 21 SE-504 72 Borås, Sweden e-mail: hakan.kallgren@smquality.se Phone: +46705774931

Summary of the timeline planning in the call:

- A preliminary result should be sent to the organiser before the parcel was sent to the next participant.
- One week after the calibration/measurement the calibration certificate should be send to the evaluator of the intercomparison.
- A draft report should be distributed to the participants two weeks after receiving the last calibration certificate.
- Comments on the draft report to the organiser were asked to be received within one week.
- The final report should be finalized within two weeks after receiving comments from all participants.

Report part 1--Results on gauge blocks and control rods

Analysis of the calibration results

In the draft of this report the correction of these length gages was falsely interpreted partly also due to the various terms used by the participants. In this final report the term deviation from nominal value is used as the calibration result to compare. For length standards like gage blocks and setting rods the deviation calibrated length minus nominal length also is the correction. (This contrasts with measuring instruments presenting values over a measurement range where measured object reading minus

reference value is determined as indication error giving the opposite sign for the correction when using the calibrated instrument).

A second problem arose with the two setting rods. Their nominal value was 100 and 500 mm. But at the same time, they were marked with a correction information by the supplier of these devices which should be interpreted as initial corrections. However, half of the participants used this "improved" value (real nominal + correction) as the actual one. Thus, they determined the deviation between the measured and that improved nominal value and got results that are not comparable with the results of the other half of the participants. In this final report the organizer now has recalculated those data to allow a fair comparison also with respect to the reference laboratory that used the plain nominal values in their calibration.

In the equations below the letter *c* is used as correction and deviation from nominal means the same.

For a faster overview besides the found values $\boldsymbol{fc_i}$ for each participant *i* also the difference from the inter-comparison reference value $\boldsymbol{fc_{ref}}$ is displayed. It is the average between the results from the reference laboratory calibration performed before and after the ILC.

Along with each result $\boldsymbol{fc_i}$ the tables also list the reported measurement U($\boldsymbol{fc_i}$) uncertainties stated by the participants and so did as well the reference laboratory VTT MIKES. Together with the reference value $\boldsymbol{fc_{ref}}$ and its uncertainty U($\boldsymbol{fc_{ref}}$) found at the bottom line in the tables (R1&R2) the En-value is calculated.

$$En = \frac{|fc_i - fc_{ref}|}{\sqrt{U^2(fc_i) + U^2(fc_{ref})}}$$

Equation 1

For each calibrated point

fc_i: Single measurement result, index i counts the various participants.

fc_{ref}: Corresponding reference value for comparison – average from reference laboratory.

U(fc_i): The estimated expanded uncertainty (k=2) stated by each laboratory

U(fc_{ref}): The estimated expanded uncertainty (k=2) of the reference value

The expression in the denominator is a measure for the uncertainty in the difference in the nominator.

For an acceptable result the En-value should not exceed the absolute value of 1.

Inter-comparison reference value and uncertainty

For all four gage blocks the difference between the final and first reference calibration was clearly less than the reported uncertainty. The same is true for the two micrometer setting rods. For all six objects the respective reference value was decided as the mean of the first (1) and last (2) calibration.

$$fc_{ref} = \frac{fc_{ref}(1) + fc_{ref}(2)}{2}$$

Equation 2

For a given gage block the reference laboratory provided the same uncertainty in both calibrations. Half of the found drift between both results, however, was added to these uncertainties to represent the uncertainty of the average necessary due to the drift.

$$U_{ref} = \frac{\sqrt{U^2(1) + U^2(2)}}{\sqrt{2}} + \left|\frac{c_{ref}(1) - c_{ref}(2)}{2}\right|$$

Equation 3

Traceability for the reference values R1 and R2 at each point

The traceability for the reference laboratory VTT (National reference laboratory) in Finland is established by regular calibrations of the laboratory's standards traceable to the realisation of the metre at VTT in Finland.

The results from calibration of the equipment at the reference laboratory are documented in the following calibration certificates at the primary and final calibration respectively.

- Gauge blocks: M-22L190, M-23L081
- Control rods M22L188, M22L189, M-23L084, M-23L083

Results gauge blocks

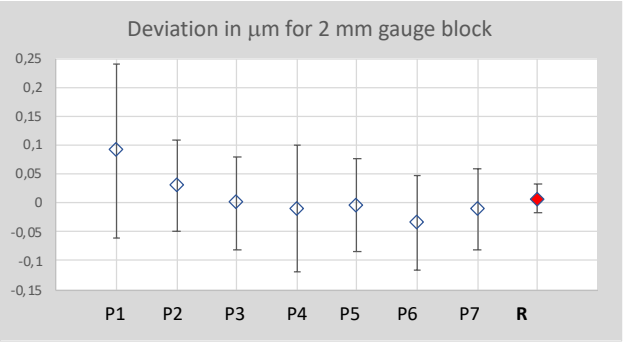
The following tables and diagrams list the participants with an identity increasing from P1 to P13, which however is not in time order. This identity is kept the same for the different calibration objects and in the two different reports. Column 2 shows the measured length and column 3 the found (deviation) correction f_{ci}. Column 4 displays the claimed uncertainties. The bottom line represents the corresponding reference values (R1&R2). They are used to calculate the various En-values in the last column.

Result gauge block 2 mm

Table 1. Deviation of centre from nominal value

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[µm]	[µm]	[µm]	
P1	2000,13	0,09	0,15	0,54
P2	2000,03	0,03	0,08	0,27
P3	2,00001	0,00	0,08	-0,09
P4	1999,99	-0,01	0,11	-0,15
P5	1999,996	-0,004	0,081	-0,14
P6	2000,035	-0,035	0,082	-0,49
P7	1999,99	-0,01	0,07	-0,23
R1&R2	2000,0075	0,008	0,026	

Diagram 1. Correction with uncertainty stables



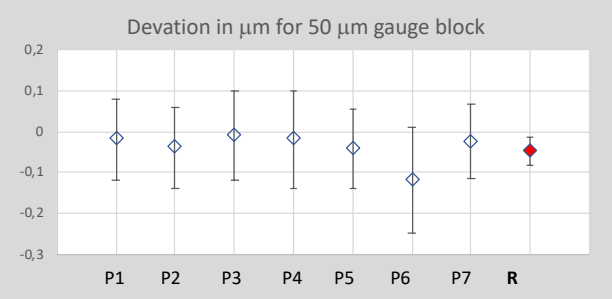
Comment: The measured values were given in both µm and mm but adjusted by the evaluator to µm. The measured length in column 2 is always taken from the excel- protocol. Often the calibration certificate does not contain this information. This rises the problem that sometimes the calculated deviation in the excel-protocol and the deviation specified in the certificate does not match. In this case the certificate value is used for calculating the En-value.

Result gauge block 50 mm

Table 2.

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[µm]	[µm]	[µm]	
P1	49999,75	-0,02	0,1	0,26
P2	49999,96	-0,04	0,10	0,07
P3	49999,99	-0,01	0,11	0,33
P4	49999,98	-0,02	0,12	0,22
P5	49999,958	-0,042	0,096	0,05
P6	49999,88	-0,12	0,13	-0,54
P7	49999,975	-0,025	0,09	0,23
R1&R2	49999,953	-0,048	0,035	

Diagram 2.



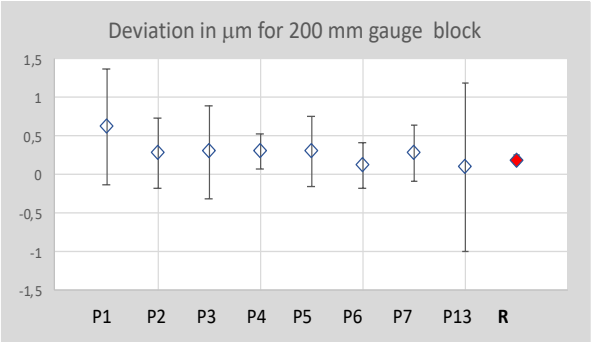
Comment: The reference uncertainty is roughly 1/3 of that of the participants. This means it will not influence the denominator in the En-calculation, thus leading to reliable values. A further observation is that all participant uncertainties are equal and there is good consensus between all results. With increasing length, the uncertainties differ more between the participants.

Result gauge block 200 mm

Table 3.

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[µm]	[µm]	[µm]	
P1	199999,62	0,62	0,74	0,57
P2	200000,28	0,28	0,46	0,17
P3	200000,2	0,30	0,6	0,17
P4	200000,3	0,3	0,23	0,42
P5	200000,31	0,31	0,45	0,24
P6	200000,12	0,12	0,3	-0,26
P7	200000,28	0,28	0,37	0,21
P13	200000,1	0,10	1,1	-0,09
R1&R2	200000,20	0,20	0,059	

Diagram 3.

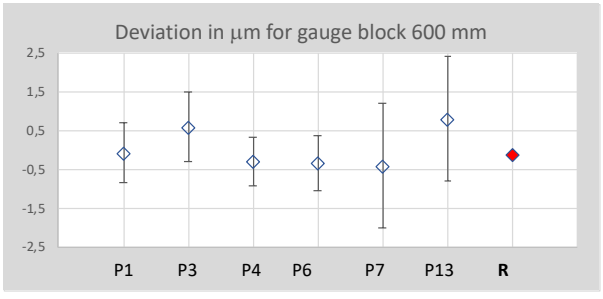


Result gauge block 600 mm

Table 4.

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[µm]	[µm]	[µm]	
P1	599999,92	-0,08	0,77	0,06
P3	600000,7	0,6	0,90	0,80
P4	599999,71	-0,29	0,61	-0,26
P6	599999,66	-0,34	0,7	-0,30
P7	599999,6	-0,4	1,6	-0,17
P13	600000,8	0,8	1,6	0,58
R1&R2	599999,87	-0,127	0,099	

Diagram 4



Comment: The reference uncertainty for the 200 and 600 mm gage blocks is so small that it cannot be resolved in diagram 3 and 4.

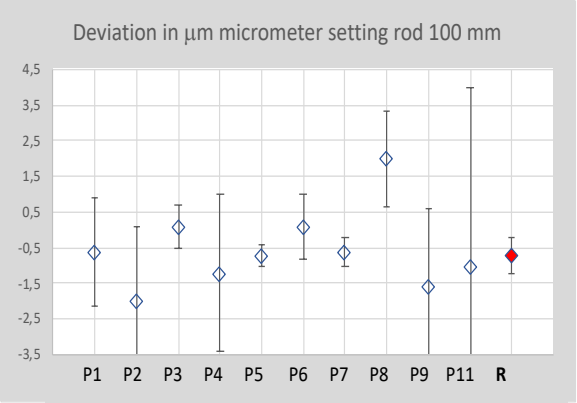
Results control rods

Result control rod 100 mm

Table 5.

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[mm]	[µm]	[µm]	
P1	99,99938	-0,62	1,5	0,05
P2	99,998	-2,0	2,1	-0,60
P3	100,0001	0,1	0,6	1,03
P4	99,9988	-1,2	2,2	-0,22
P5	99,9993	-0,7	0,3	0,01
P6	100,0001	0,1	0,9	0,78
P7	99,9994	-0,6	0,4	0,16
P8	100,002	2	1,34	1,89
P9	99,9984	-1,6	2,2	-0,40
P11	99,999	-1	5,0	-0,06
R1&R2	99,99930	-0,70	0,51	

Diagram 5.



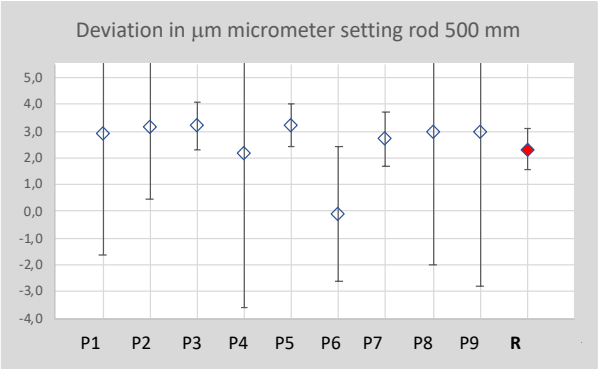
Comment: The rows with grey numbers indicate those participants that had used the improved length indication of the rods as their nominal value. This is here changed compared to the draft report. Some had only specified values in the certificate. These values are here added as interpreted by the organizer.

Result control rod 500 mm

Table 6.

Partici-pant	Measured value	Deviation from nominal	Uncertainty	En-value
	[mm]	[µm]	[µm]	
P1	500,00289	2,89	4,5	0,12
P2	500,00317	3,17	2,7	0,30
P3	500,0032	3,2	0,9	0,74
P4	500,0022	2,2	5,8	-0,02
P5	500,0032	3,2	0,8	0,79
P6	500,0019	-0,11	2,51	-0,93
P7	500,0027	2,7	1,0	0,30
P8	500,003	3	5,0	0,13
P9	500,003	3,0	5,8	0,12
R1&R2	500,0023	2,32	0,77	

Diagram 6.

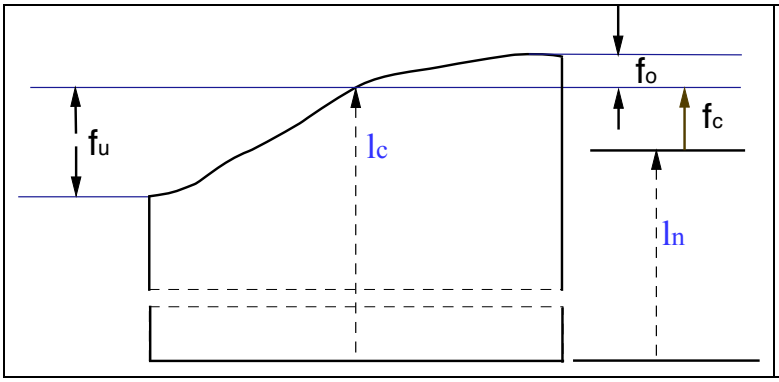


Comment: Due to the recalculation with respect to the real nominal value half of the En-values are exchanged compared to the draft report.

Characteristic of the 2 mm and 50 mm gauge blocks concerning the deviation of the four corners from the centre measure.

The information asked for comparison was the length in the centre and the difference to the corner points (1 to 4) defined by a drawing. The excel protocol was aimed to report the five measured lengths, the difference to the nominal value (correction) and the estimated uncertainties.

The comparison thus is focused on mainly three measures (see drawing below). This is ***fc*** the difference between the calibrated centre length ***lc*** and its nominal value ***ln***. If ***lc*** > ***ln*** then ***fc*** is positive, otherwise ***fc*** is negative. In this context ***fc,*** the deviation from the gage blocks nominal value is also the correction which should be applied to the nominal value when using it as a length standard. In the tables and diagrams below ***fc*** is the main calibration result compared. Instead of four corner deviations from the centre length ***lc*** only the distance ***fo*** to the corner with the largest length and ***fu*** the distance to the shortest length is listed; both are absolute values.



Definition of measures

ln: nominal length (1,26; 50 and 80 mm)
lc: actual calibrated centre length
fc: deviation of centre length from nominal length
fo: height difference from highest corner to centre
fu: height difference from lowest corner to centre

The following tables present a comparison on the relation between the center length and the distance to the corner with the largest length ***fo*** and to the shortest length ***fu***. Table 7 is valid for the 2 mm gauge block and table 8 for the 50 mm gauge block. The left half in each table specifies ***fo*** with a one color from ***fu*** in the right half with a different one.

Partici-pant	f_o [µm]	Corner no.	f_u [µm]	Corner no.
P1	0,045	1 & 4	0	2 & 3 & C
P2	0,0	2 & 3 & C	0,05	1
P3	0,02	2	0,04	1 & 4
P4	0,0	C	0,08	1 & 4
P5	0,012	2	0,058	1
P6	0,0	3 & C	0,035	1
P7	0,0	C	0,03	1 & 4
R	0,016	4	0,035	3

Partici-pant	f_o [µm]	Corner no.	f_u [µm]	Corner no.
P1	0,09	2	0,0	C
P2	0,0	1 & C	0,02	2
P3	0,013	2 & 4	0,057	2
P4	0,01	1 & 3	0,01	4
P5	0,002	4	0,04	2
P6	0,01	2 & 4	0,045	3
P7	0,0	C	0,035	3
R	0	C	0,023	4

The calculated length difference in µm together with the corner number is listed. Almost half of the results do not show any difference ***fo***, which means the center also is the maximum length, which is indicated with a C. In half of the results the center is pointed out as the maximum length, several times together with one or two of the corners. One can state that the reported differences all lie within the uncertainties claimed in table 1 and 2 for the 2 and 50 mm gauge blocks. Thus, there is a reasonable consensus in this respect too.

Comments on calibration certificates

-not a part of the intercomparison

General

Calibration certificates are issued in the local language and in some cases in English as well. Some laboratories refer their calibration methods to national and international standards and documents while other laboratories refer to methods they have evaluated locally.

All laboratories have an accreditation from the national accreditation institute.

The German laboratories use the same design of the calibration certificates.

Most of the laboratories document the status of the object at arrival. Description about visual check and cleaning of the objects are good in many cases.

Description of traceability for calibrations are clear in all certificates.

Most of the laboratories refer to the MRA.

All laboratories indicate the reference temperature to 20°C and some give the range of temperature to be ±0,5°C up to ±1,5°C. Some laboratories indicate the actual temperature during calibration very clear (e.g., ±0,6 per hour). Some laboratories are describing the time they use for temperature stabilization (e.g., 6 hours). Length expansion component is sometimes documented as well as the surface temperature.

Many laboratories use the term deviation/abweichung to describe error or correction.

Uncertainty is sometimes described as a fixed value and sometimes as a formula using a fixed term and a part related to the length. This gives some complications for clients.

Comments on the calibration certificates on gauge blocks

Several laboratories refer to and describe tolerances according to ISO 3650.

Pictures of situation for different corners of the gauge blocks are defined in some cases in the certificates but it is not clear in other cases.

Some laboratories give the absolute value in µm and others the difference from the nominal value for the corners.

Some laboratories also specify a lower uncertainty for the difference of to the corners to the center.

Some laboratories describe the principles for conformity decision or by giving a diagram based on ILAC-G8:09/2019.

Final conclusions

In this inter comparison all the participants could demonstrate a convincing capacity to calibrate the various gauge blocks that are involved in this ILC. Most of the laboratories took part in the comparison of all equipment, that will be reported separately.

The number of calibration points in total was 47 and En-values higher than 1 occurred two times in the calibration of control rod 100 mm.

The ability of different laboratories to prove the correctness of their CMC values is not a part of an intercomparison of this type. It is up to the various laboratories to evaluate their results according to the requirements in ISO/IEC 17025:2017 as specified in point 7.7.3.

Acknowledgement

We gratefully thank the member of the advisory board and expert in length calibrations Mikael Frennberg Quality Control in Metrology Sweden as well as the main evaluator of the results Peter Lau MNE konsult.

We also acknowledge the primary calibrations by VTT Finland that supported the ILC with reference calibrations.

Annex 1 ILC Length 2021:1 published on www.smquality.se

Annex 2 Revised description of the intercomparison/ILC published on www.smquality.se

Annex 3 reporting form for preliminary calibration results.

Observe that only the left part could be seen by the participants.

Inter-comparison ILC length 2021:2 Code for opening the transportation case: 504

Reporting form for preliminary calibration results

Laboratory:	
Name:	
e-mail:	
Reporting date:	

Comparison ID

OBSERVE that no adjustments are allowed except zeroing

4 Gage blocks small and large size — **Date of calibration**

Utvärderingsdel

Denna del bestäms när båda sidor är klara
Mellandelen förvandlas till tabelle och diagram

Gauge block 1 — **Serial no.** 215272

Calibration point	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	Determind correction for comparison	Determined uncertainty	From certificate: Stated correction	From certificate: Expanded uncertainty
	[mm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
Center	2							
Corner point 1	2							
Corner point 2	2							
Corner point 3	2							
Corner point 4	2							

Gauge block 2 — **Serial no.** 213099

Calibration point	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	Determind correction for comparison	Determined uncertainty	From certificate: Stated correction	From certificate: Expanded uncertainty
[mm]	[mm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
Center	50							
Point 1	50							
Point 2	50							
Point 3	50							
Point 4	50							

Gauge block 3 **200 mm** — **Serial no.** 210512

Calibration point	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	correction for comparison	Determined uncertainty	From certificate: Stated correction	From certificate: Expanded uncertainty
[mm]	[mm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
Center								

Gauge block 4 **600 mm** — **Serial no.** 220006

Calibration point	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	Determind correction for	Determined uncertainty	From certificate: Stated correction	From certificate: Expanded uncertainty
[mm]	[mm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]	[µm]
Center								

Micrometer setting rod 1 — **Serial no.** 2000184

Calibration point	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	Determind correction for comparison	Determined uncertainty	Stated correction	Expanded uncertainty
[mm]	[mm]	[mm]	[µm]	[µm]	[µm]	[µm]	[mm]	[mm]
100								

Micrometer setting rod 2 — **Serial no.** 2022215

Calibration points	Nominal length	Measured length	Error (deviation from nominal)	Stated measure-ment uncertainty	Determind correction for	Determined uncertainty	Stated correction	Expanded uncertainty
[mm]	[mm]	[mm]	[µm]	[µm]	[µm]	[µm]	[mm]	[mm]
500								

References:

- ISO/IEC 17043:2010 Conformity assessment – General requirements for proficiency testing
- ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories
- ISO 13528 Statistical methods for use in proficiency testing by interlaboratory comparison
- Evaluation of measurement data – Guide to the expression of uncertainty in measurement, GUM (JCGM 100:2008)
- EA-4/02 M:2013 Evaluation of Uncertainty of Measurement in Calibration
- International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)
- ISO 3650:1998 Geometrical product specifications (GPS)-Length Standards-Gauge blocks
- ILAC-G8:09/2019 Guidelines on Decision Rules and Statements of Conformity