Accred. no. 10436
Proficiency testing
ISO/IEC 17043

To participants

Report on an interlaboratory comparison (ILC) of the calibration in the length area – part 4 (dial gauge indicator)

The case carrying all equipment for calibration.

Weight 10 kg

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Calculations

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Content

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.

This report is part 4 of a larger inter-comparison also covering gauge blocks, callipers, and micrometres. This part is about the results related to an analogue dial gauge.

Advisory group

The intercomparison has followed the recommendations of the advisory group during several meetings. The advisory group has defined the set-up of instruments that should be included in the ILC length 2021:1 intercomparison as well as the choice of measuring parameters according to ISO 463 that should 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 presented in 2 steps. General information as ILC Length 2021:1 referred to in 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.

Object

Dial gauge indicator (analogue) 0-10 mm (10 revolutions)

Participating laboratories and measuring scheme for the comparison

Laboratory	**Calibration week**	**Address**
RISE reference laboratory	16	Borås, Sweden
Elastocon AB	17	Brämhult, Sweden
SM Kalibrering AB	18	Kulltorp, Sweden
Sandvik Materials Technology kalibreringscentrum	19	Sandviken, Sweden
Mitutoyo Scandinavia AB	20	Upplands Väsby, Sweden
Transport to Germany	21	
Saliger-Gruppe GmbH	22	Gladbeck, Germany
Wocken Industriepartner GmbH & Co.KG	23	Meppen, Germany
QS-Grimm GmbH	24	Gutach, Germany
Reserve Germany if delays		
Melutec Metrology GmbH	26	Allmersbach im Tal, Germany
Testo Industrial Services GmbH	27	Kirchzarten, Germany
Kolb & Baumann GmbH & Co.KG	28	Aschaffenburg, Germany
esz AG	29	Eichenau, Germany
Kyocera-Unimerco Tooling A/S	30	Sunds, Denmark
DSB Vedligehold A/S, Mekanisk Kalibrering	31	Aarhus, Denmark
Koneteknologiakeskus Turku Oy	32	Turku, Finland
Element Metech AB	33	Trollhättan Sweden
RISE-reference laboratory	34	Borås, Sweden

There were some challenges and delays during the program and the last certificates were received during week 50.

Most of the participants have an accreditation by SWEDAC, DANAK, FINAS or DAkkS.

Principles on the calibration in general

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

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 having special filters and insulation for humidity and vibrations was used for the transportation

Calibration instructions

The laboratories were allowed maximum 5 days for each calibration.

In the call the participants were advised to use their own calibration procedures and they were further 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 defined in ISO 463 characterizing the actual dial gauge indicator:

1. Repeatability
2. Hysteresis
3. Maximum indication error per 1/10 revolution
4. Maximum indication error per 1/2 revolution
5. Maximum indication error per 1 revolution

All over the entire measurement range of 10 mm and 10 revolutions of the indicator.

Planning and instruction details

The laboratories were asked to send original calibration data in pre-defined excel-forms (enclosed in annex 3) or as PDF files by e-mail before transporting to next laboratory. The final calibration certificate should then be sent to the organizer within one week.

The evaluator used the principles of the ISO/IEC 17043:2010 in the reporting.

The participants should deliver calibration certificates with a belonging uncertainty for the calibrations stated above.

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:

- The preliminary results should be sent to the organiser when the parcel was sent to next participant.
- One week after the calibration/measurement the calibration certificate should be sent to the evaluator of the intercomparison.
- A draft report should be sent to the participants 2 weeks after receiving the last calibration certificate.
- Comments on the draft report to the organiser were expected within 1 week
- The final report should be finalized within 2 weeks after receiving comments from all participants.

Report Part 4 dial gauge indicator

Considering 15 laboratories from four different countries of which four with several operators performing the calibration work the timeline could be kept quite well. Several values were later replaced in the certificate. Also, several of the calibration certificates arrived extremely late. Thus, even the compilation was delayed, and two certificates are still missing.

Analysis of the calibration results

The above-mentioned parameters are treated in the same way as if they were measuring values that can be compared to corresponding reference values defined by the two calibration measurements of the reference laboratory.

For all five parameters the reference value used is the average from the first and second calibration result from the reference laboratory. If identical results were found the uncertainty of the reference values are identical with the uncertainties specified by the reference laboratory. If the results differed the reference uncertainty was enlarged by linear addition of half of the difference between the first and last parameter result.

As for usual measuring data the comparison focus is put on En-values, which are expected to lie between -1 and +1 to be acceptable.

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

For each of the five determined parameters

p_i: Single measurement parameter, index i counts the various participants.

p_{ref}: Reference parameter value for comparison – average provided by reference laboratory.

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

U(p_{ref}): The estimated expanded uncertainty (k=2) of the reference parameter given by the reference laboratory

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 value of 1.

Inter-comparison reference value and uncertainty

To cope with eventual drift, the inter-comparison reference value was chosen as the average from the reference calibration (1) before and (2) after the whole exercise.

If any drift was detected the comparison reference uncertainty was calculated as the uncertainty delivered by the reference laboratory linearly enlarged by half of the difference between the two results.

$$p_{ref} = \frac{p_{ref}(1)+p_{ref}(2)}{2} \qquad U(p_{ref}) = U(p_{ref}(1) + \frac{|p_{ref}(1) - p_{ref}(2|}{2}$$

This also means the comparison reference uncertainty is identical with that of the reference laboratory in case no drift is observed.

Traceability for the reference values R1 and R2 at each point

The traceability for the reference laboratory RISE is established by regular calibrations of the laboratory's standards traceable to the realisation of the metre at RISE in Borås Sweden.

The calibration results by the reference laboratory are documented in the following calibration certificates.

Calibration certificates -- reference laboratory, RISE, Sweden

	Initial calibration	Final calibration
Dial gauge indicator	1050101-139547-K02	1050101-139547-K09

Results of the dial gauge indicator

The following tables and diagrams list the participants with an identity increasing from P1 to P15, which however is not in time order. This participant identity is kept throughout the total intercomparison for the different calibration objects mentioned above and is valid in the four different reports

The following 5 tables and diagram represent the results for each of the five parameters evaluated together with the uncertainties reported. The two reference calibration data denoted R1 and R2 make up the top and bottom line. Below the table the reference values are declared. The En-values shown in the last column are calculated the same way as if these parameters were straight measurement data points.

Table 1. Measurement parameter 1: Repeatability

Partici-pant	Repeatabi-lity error [µm]	Stated uncertainty [µm]	En-value
R1	2,0	3,0	
P1	0,26	1,7	-0,50
P2	0,40	1,7	-0,46
P3	0,35	3,1	-0,38
P4	0,0	0,8	-0,64
P5	0,5	6,9	-0,20
P6	0,2	6,0	-0,27
P7	0,5	3,1	-0,35
P8			
P9	0,25	2,1	-0,48
P10	0,6	1,3	-0,43
P11	0,7	3,1	-0,30
P12	0,3	3,5	-0,37
P13	0,3	1,5	-0,51
P14	0,5	3,1	-0,35
P15	0,4	0,7	-0,52
R2	2,0	3,0	
R1&R2	2,0	3,0	

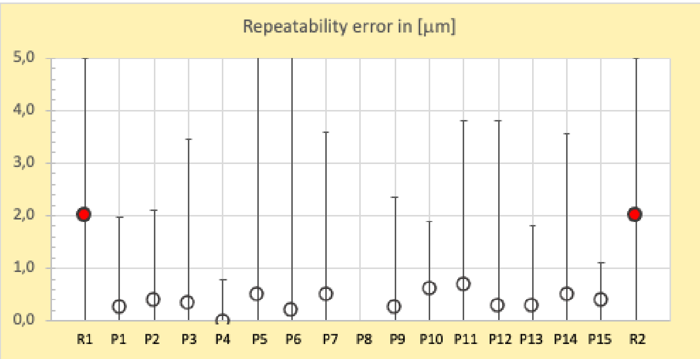

Diagram 1. Stated repeatability values with uncertainty.

Comment:
The detected repeatability value is displayed in column 2. Normally the repetitions are performed at the point of the largest hysteresis. All participants reported the same number of repetitions 5.

Table 2. Measurement parameter 2: hysteresis

Partici-pant	Hysteresis error [µm]	Stated uncertainty [µm]	En-value
R1	1,3	4,2	
P1	1,54	1,7	**0,03**
P2	1,00	1,7	**-0,09**
P3	2,74	3,1	**0,25**
P4	3,7	0,8	**0,53**
P5	1,6	6,9	**0,02**
P6	1,8	6,0	**0,05**
P7	1,6	3,1	**0,04**
P8			
P9	1,39	2,1	**0,00**
P10	1,7	1,3	**0,07**
P11	1,4	3,1	**0,00**
P12	0,8	3,5	**-0,11**
P13	1,8	1,5	**0,09**
P14	1,2	4,3	**-0,03**
P15	3,2	0,7	**0,41**
R2	1,5	4,2	
R1&R2	**1,4**	**4,3**	

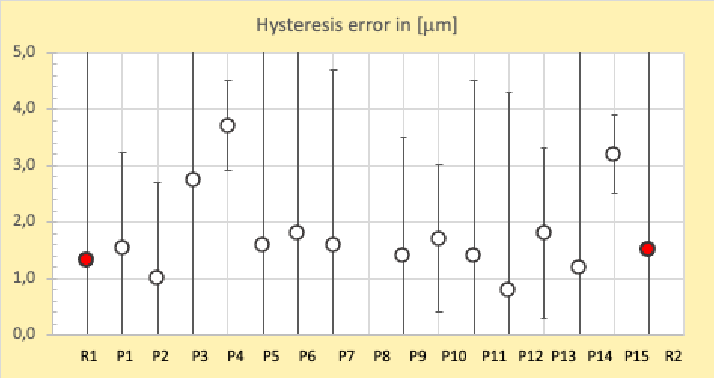

Diagram 2. Varying hysteresis values with belonging uncertainties.

Comment:
The step size in measurement varied between the laboratories which most probably influenced the reported hysteresis values. Due to the relatively high reference uncertainty all En-values in column 4 are rather low.

The maximum indication error is an important characterization for the usage of an analogue dial gauge. It measures the range of non-linearity within defined length intervals expected in one revolution corresponding to 1 mm on the dial scale (analogue to half a revolution covering 0,5 mm or to one tenth of a revolution covering 0,1 mm somewhere within the total measuring range of 10 mm. Depending on the step size in calibration participants can find the maximum range at different length intervals. However, only the largest range found in one of these intervals is reported and compared.

Table 3. Measurement parameter 3: max indication error per 1/10 revolution

Partici-pant	Max indication error [µm]	Stated uncertainty [µm]	En-value	Step size [mm]
R1	2,0	4,2		
P1	2,24	1,7	**0,05**	0,1
P2	1,70	1,7	**-0,07**	0,01
P3	1,60	3,1	**-0,08**	0,01
P4	3,2	0,8	**0,28**	0,1
P5	2,2	6,9	**0,02**	0,1
P6	2,3	6,0	**0,04**	0,01
P7	1,9	3,1	**-0,02**	0,01
P8				
P9	2,88	2,1	**0,19**	0,01
P10	1,4	1,3	**-0,14**	0,1
P11	2,8	3,1	**0,15**	0,01
P12	2,5	3,5	**0,09**	0,01
P13	2,3	1,5	**0,07**	
P14	1,4	3,0	**-0,11**	0,1
P15	1,4	1,4	**-0,14**	0,1
R2	2,0	4,2		
R1&R2	**2,0**	**4,2**		

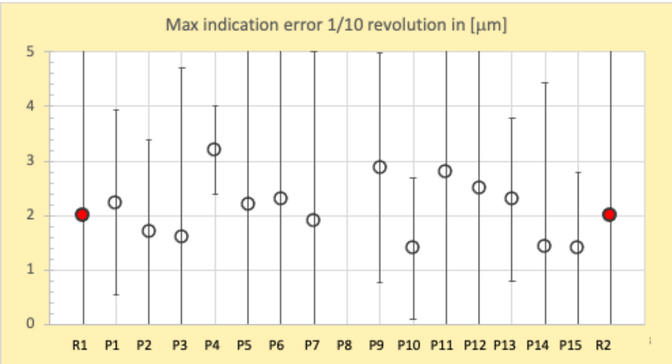

Diagram 3.

Comment:
The last column indicates the step size in measurement. In practice this also means the max. indication error was found in different measurement intervals. One participant could only measure up to 7 mm. And participant P8 did not take part in this dial gauge calibration.

Table 4. Measurement parameter 4: max indication error per 1/2 revolution

Partici-pant	Max indication error	Stated uncertainty	En-value	Step size
	[µm]	[µm]		[mm]
R1	3,0	4,2		
P1	3,42	1,7	**0,09**	0,1
P2	3,60	1,7	**0,13**	0,05
P3	1,15	3,1	**-0,35**	0,05
P4	1,0	0,8	**-0,47**	0,1
P5	4,5	6,9	**0,19**	0,50
P6	3,0	6,0	**0,00**	0,05
P7	4,0	3,1	**0,19**	0,05
P8				
P9	4,27	2,1	**0,27**	0,02
P10	3,0	1,3	**0,00**	0,1
P11	3,5	3,1	**0,10**	0,05
P12	4,4	3,5	**0,26**	0,05
P13	5,9	1,5	**0,65**	
P14	5,4	3,1	**0,45**	1,0
P15	2,6	1,4	**-0,09**	0,1
R2	3,0	4,2		
R1&R2	**3,0**	**4,2**		

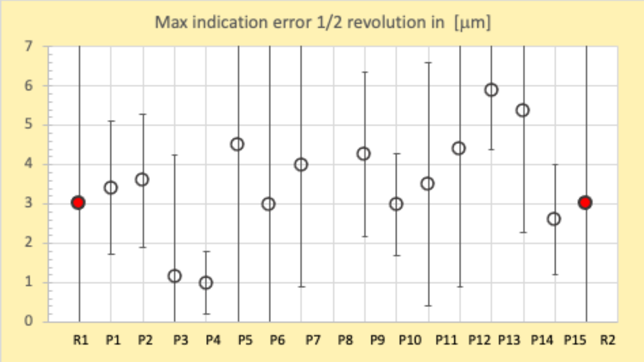

Diagram 4. Maximum difference in indication error within various 0,5 mm length intervals.

Comment:
One participant reported a negative value in table 4 and 5. This was changed to a positive one by the organizer. One participants data differed between the delivered excel-protocol data and the calibration certificate. The data from the certificate were used.

Before collecting all data in the above tables and diagrams the preliminary excel-protocol data were compared with the later given data in the calibration certificates. In most cases they were identical. However, in two cases it was not self-evident to identify and compare protocol and certificate unambiguously partly due to language difficulties. In that case the protocol data were used. In one case the data differed, and the certificate data were preferred.

Table 5. Measurement parameter 5: max indication error per 1 revolution

Partici-pant	Max indication error	Stated uncertainty	En-value
	[µm]	[µm]	
R1	3,0	4,2	
P1	3,18	1,7	**-0,15**
P2	4,50	1,7	**0,09**
P3	3,45	3,1	**-0,09**
P4	1,0	0,8	**-0,57**
P5	4,1	6,9	**0,01**
P6	2,7	6,0	**-0,16**
P7	2,7	3,1	**-0,21**
P8			
P9	5,09	2,1	**0,19**
P10	2,8	1,3	**-0,22**
P11	4,0	3,1	**0,00**
P12	5,1	3,5	**0,18**
P13	2,6	1,5	**-0,26**
P14	5,6	3,1	**0,26**
P15	1,8	1,4	**-0,41**
R2	5,0	4,2	
R1&R2	**4,0**	**5,2**	

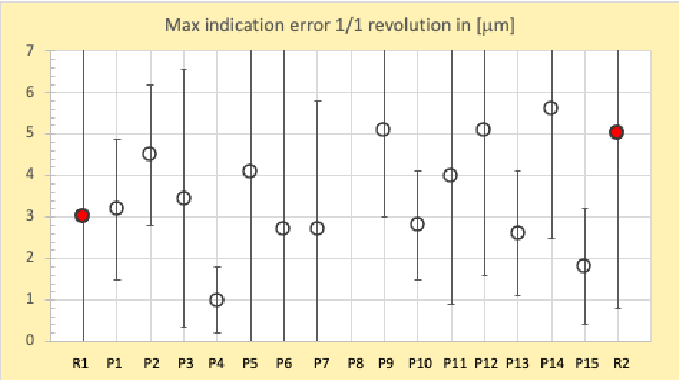

Diagram 5. Largest found range in indication error over 10 intervals of 1 mm each.

Comment:
Due to the relatively large uncertainty of the reference value all En-values are in good agreement.

Comment:

The stated uncertainties are roughly the same for all five examined parameters. Especially the maximum indication errors, building on two measurements somewhat higher uncertainties perhaps could be expected. The uncertainties range from 0,8 to 6,9 µm, which corresponds to a factor of almost 9. Had the reference uncertainty been half the one stated in the tables, which could be possible, then several En-values would have exceeded the border of 1.

Additional calibration results

Fourteen of altogether fifteen participating laboratories in the total calibration exercise also took part in the dial gauge indicator comparison. Of those fifteen laboratories three wanted to take the chance to involve an extra person to this calibration task and sent in a separate excel-protocol and calibration certificate. One laboratory took part with four extra results. Their data were not included in the above tables to keep these straight. Instead, their additional data are evaluated and compared in the same way below against the same reference values. By using the same numbering of the tables, they can be directly compared to the results above.

Table 1a. Measurement parameter 1: Repeatability

Partici-pant	Repeatabi-lity error	Stated uncertainty	En-value
	[mm]	[µm]	
R1	2,0	3,0	
P6-2	0,3	6,0	**-0,25**
P7-2	0,4	3,1	**-0,37**
P7-3	0,3	3,1	**-0,39**
P7-4	0,2	3,1	**-0,42**
P15-2	0,2	0,7	**-0,58**
P10-2	0,5	1,3	**-0,46**
P12-2			
R2	2,0	3,0	
R1&R2	2,0	3,0	

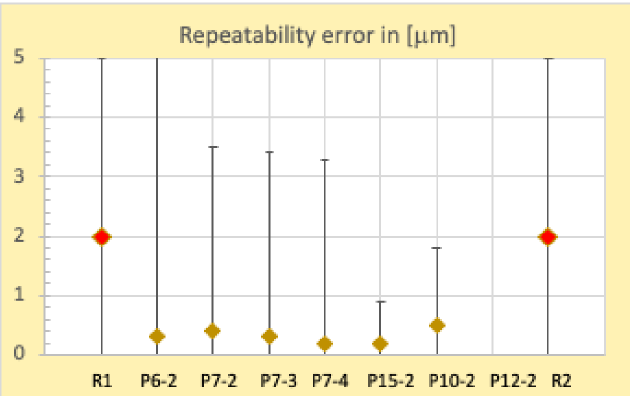

Diagram 1b.

Table 2a. Measurement parameter 2: Hysteresis

Partici-pant	Hysteresis error	Stated uncertainty	En-value
	[mm]	[µm]	
R1	1,3	4,2	
P6-2	1,6	6,0	**0,03**
P7-2	1,7	3,1	**0,06**
P7-3	2,3	3,1	**0,17**
P7-4	2,2	3,1	**0,15**
P15-2	3,7	0,7	**0,53**
P10-2	2,2	1,3	**0,18**
P12-2			
R2	1,5	4,2	
R1&R2	1,4	4,3	

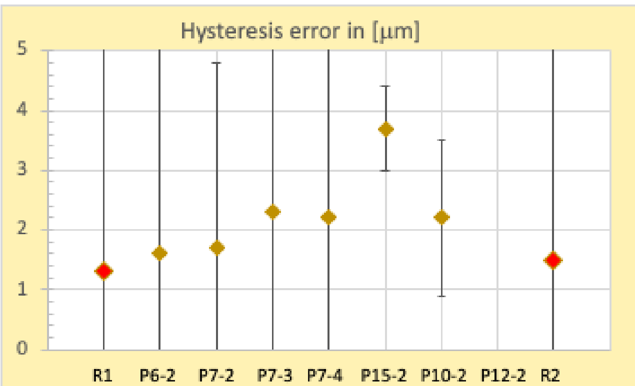

Diagram 2b.

Table 3a. Measurement parameter 3: Maximum indication error per 1/10 revolution

Partici-pant	Max indica-tion error	Stated uncertainty	En-value
	[mm]	[µm]	
R1	2,0	4,2	
P6-2	2,5	6,0	**0,07**
P7-2	1,0	3,1	**-0,19**
P7-3	0,6	3,1	**-0,27**
P7-4	1,3	3,1	**-0,13**
P15-2	1,5	1,4	**-0,11**
P10-2	3,0	1,3	**0,23**
P12-2			
R2	2,0	4,2	
R1&R2	2,0	4,2	

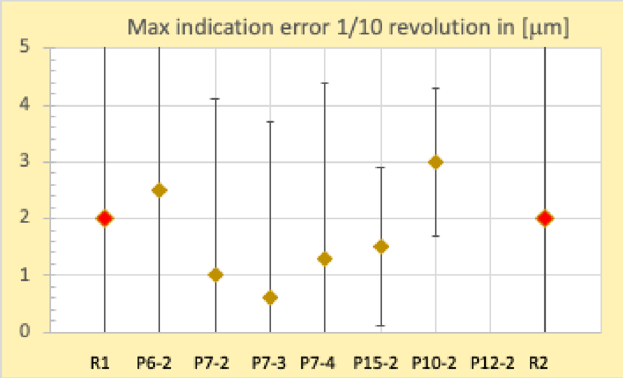

Diagram 3b.

Table 4a. Measurement parameter 4: Maximum indication error per 1/2 revolution

Partici-pant	Max indica-tion error	Stated uncertainty	En-value
	[mm]	[µm]	
R1	3,0	4,2	
P6-2	3,5	6,0	**0,07**
P7-2	2,9	3,1	**-0,02**
P7-3	2,4	3,1	**-0,11**
P7-4	2,1	3,1	**-0,17**
P15-2	2,8	1,4	**-0,05**
P10-2	2,7	1,3	**-0,07**
P12-2			
R2	3,0	4,2	
R1&R2	3,0	4,2	

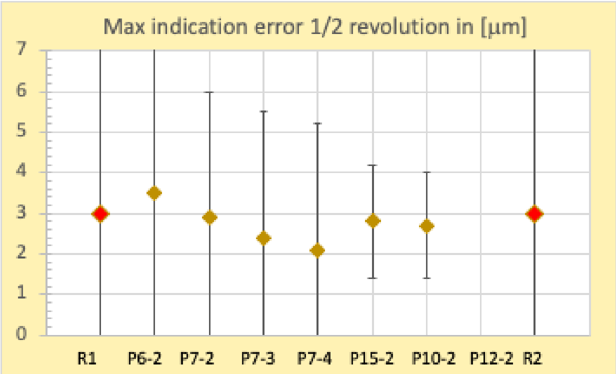

Diagram 4b

Table 5a. Measurement parameter 5: Maximum indication error per 1/1 revolution

Partici-pant	Max indica-tion error	Stated uncertainty	En-value
	[mm]	[µm]	
R1	3,0	4,2	
0	3,1	6,0	**0,01**
P7-2	3,0	3,1	**0,00**
P7-3	3,2	3,1	**0,04**
P7-4	2,2	3,1	**-0,15**
P15-2	2,5	1,4	**-0,11**
P10-2	2,3	1,3	**-0,16**
P12-2			
R2	5,0	4,2	
R1&R2	4,0	5,2	

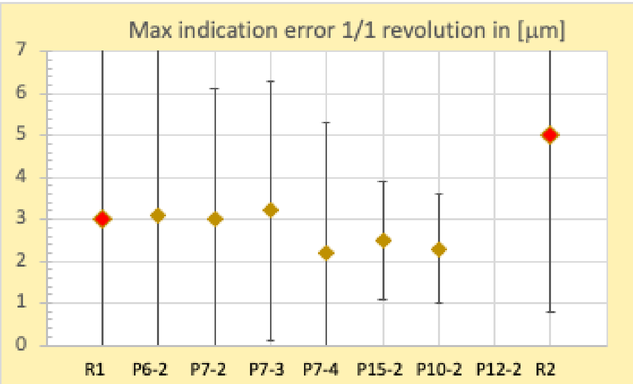

Diagram 5b

Comment: Comparing the same diagrams above with those extra ones it can be stated that these extra calibrations are fully comparable with the first ones and would qualify the personnel in question.

Comments on calibration certificates

-not a part of the intercomparison

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.

Most of the laboratories have an accreditation from the local accreditation institutes.

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 normally very clear.

Description about visual check and cleaning of the objects are good in many cases.

Most of the laboratories refer to the MRA.

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 may give some complications for clients.

The laboratories are documenting the calibration results by a table or a diagram or both.

Final conclusions

In this inter comparison all the participants could demonstrate a convincing capacity to calibrate the dial gauge indicator that are involved in this ILC.

Of the 100 calculated En-values non exceeded the value of $|1|$.

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 as well as the main evaluator of the results Peter Lau.

We also acknowledge the primary calibrations by RISE Sweden 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.

Reporting form for preliminary calibration results			
Laboratory:			Comparison ID
Name:			
e-mail:			
Reporting date:			

Dial gauge indicator		**OBSERVE that no adjustments are allowed**		
		Date of calibration		
	Dial gauge indicator	**0 to 10 mm**		
Ccalibration parameters	Result	Stated measure-ment uncertainty	Number of repetitions	Step size
	[∝m]	[∝m]		
Repeatability error				
Hysteresis error				
Max indication error				
1 /10 revolution				
1 /2 revolution				
1/1 revolution				
Comments?	Space for diagram			

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