Swedish Metrology and Quality AB

Accred. no. 10436
Proficiency testing
ISO/IEC 17043

To participants

Report on an interlaboratory comparison (ILC pressure 2023:2) on 5000 bar.

The bag carrying the equipment for calibration.

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Content

Abstract

This report is about a calibration inter-comparison of one pressure sensor with 6 participating laboratories.

The pressure sensor was calibrated from zero to 5000 bar for both increasing and decreasing pressure.

The calibration was documented by the error and its uncertainty at all calibrations points. These data were reported in two ways, as an excel-protocol and by sending a calibration certificate. The excel-protocols form the evaluation basis after checking the conformity with the certificate.

The participants calibrated the sensors at all mandatory calibration points except one laboratory that did not calibrate 5000 bar.

For each pressure level the results for increasing and decreasing pressure are presented in two separate tables next to each other.

RISE (Swedish National Metrological Institute) calibrated the sensor prior and after the circulation. Their average serves as assigned inter-comparison reference values and are used together with the stated reference uncertainty to calculate En-values at each measuring point for each participant.

This report covers calibrations made by 6 laboratories in 6 countries. Their calibration certificates were mostly in their local language sometimes completed with English.

Many uncertainty claims are comparable between participants.

All results on increasing pressure gives En values below 1.

Decreasing pressures give En values below I down to 2000 bar.

Decreasing pressure at 1000 bar are 3 of 6 En values above 1.

The point at zero are giving confusing results and and is excluded from the report.

That is in some way related to the hysteresis effect and is probably partly depending on if the laboratories are evaluating the hysteresis effect in their uncertainty evaluations.

Purpose and implementation of the comparison

This interlaboratory comparison serves as a tool to verify results reported 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 pressure 2023:2 intercomparison as well as the choice of calibration points that are defined to be included in the evaluation of the results.

The advisory group consists of Aykurt Altintas Denmark, and Håkan Källgren Swedish Metrology and Quality.

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 pressure 2021:1 published on smquality.se and enclosed to this report in annex 1.

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

Object

The following instrument is included:

Gauge pressure 0-5000 bar

Participating laboratories and measuring scheme for the comparison

Laboratory
RISE, reference laboratory Sweden
IKM laboratorium AS Norway
Trescal NV Netherlands
Nuovo Pignone Tecnologie S.r.l Italy
TRESCAL France
Trescal Ltd UK
Salinger Gruppe GmbH Germany
RISE, reference laboratory Sweden

The circulation ended in week 10 2024.
All participants are accredited by ACCREDIA, NA, COFRAC, DAkkS, UKAS and BELAC.
The reference laboratory RISE, Sweden has the status as a National Metrology Institute, NMI.

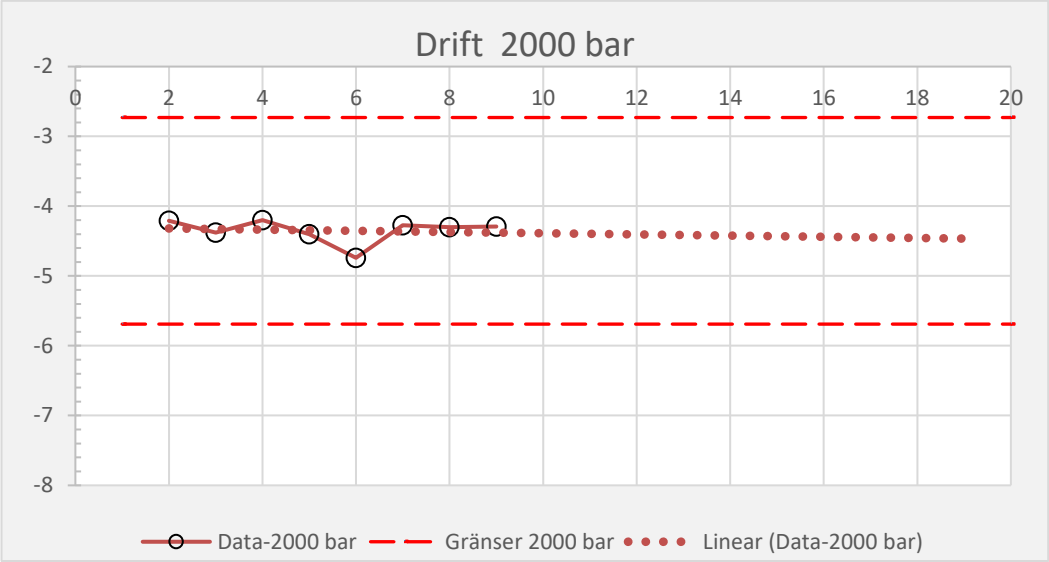
Principles concerning the calibration in general.

The reference laboratory calibrated both sensors at the beginning and after finishing the circulation.

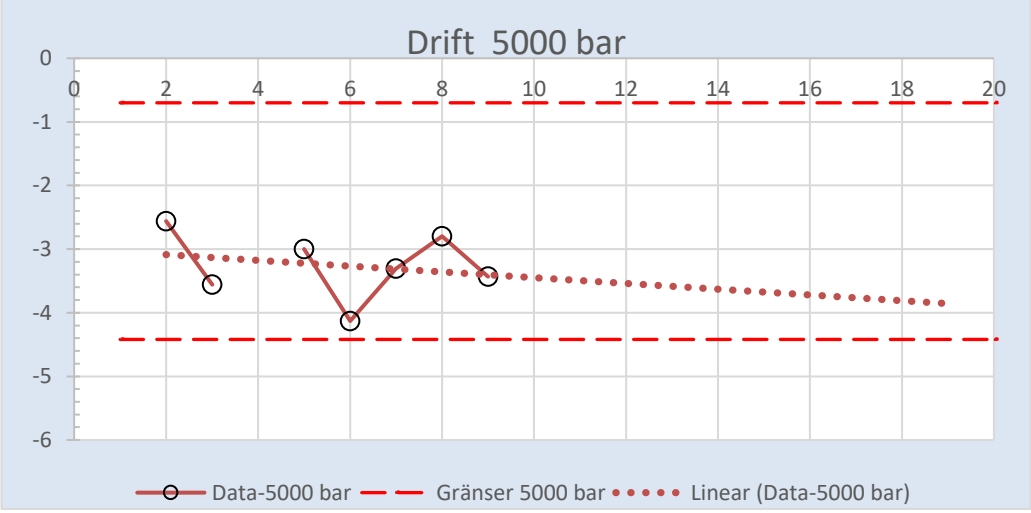
During the whole exercise the preliminary reported results were used for checking possible drift behaviour of the sensors. The purpose was to maintain equal conditions for all participants over the total measurement period. In doubt the sensors were planned to be called back for a new reference calibration, which however was not necessary.

Stability diagrams during the circulation

Example of a stability diagram at 2000 bar at increasing pressure



Example of a stability diagram at 5000 bar increasing pressure.



Conditions and transport during the measurement period

A special case having special filters and insulation for humidity and vibrations was used for transport.

Compulsory calibration points

The participants were asked to calibrate at the following points both at increasing and decreasing pressure:

Range: 0-5000 bar,
Calibration points: 0, 1000, 2000, 3000, 4000 and 5000 bar.

Calibration instructions

The laboratories were allowed maximum 5 days for each calibration. In the call they were advised to use their own calibration procedures with focus on the predefined pressure points. They weren't allowed to perform any type of adjustment on the object.

Using own procedures also meant it was up to the laboratories which measurement points over the compulsory ones they would include and further if they would report values both for in- and decreasing pressure or only the average on the calibration certificate.

The prepared excel sheets documented the results for both increasing and decreasing pressures and those results are used in this report.

Planning and administrative details

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: +46 705 774 931

Summary of the timeline planning in the call:

- The preliminary results (excel-protocol) 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 dispatched to the participants 2 weeks after receiving the last calibration certificate. The organiser was not able to deliver according to this rule.
- Comments or feed-back on the draft report to the organiser were expected within 1 week.
- Final report should be finalized within 2 weeks after receiving all comments or feed-back from the participants.

Analysis of the calibration results

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

As an easy-to-understand measure to judge each participant result its distance to the assigned reference value is used, normalized with respect to the uncertainty in this difference. This measure the En-value is calculated for every calibration point according to equation 1).

$$E_{n,j} = \frac{x_{i,j} - x_{ref,j}}{\sqrt{U_{i,j}^2 + U_{ref,j}^2}} \qquad \text{(eq. 1)}$$

$x_{i,j}$: Single measurement result (error of indication); index *i* and *j* count the various participants and calibration points respectively.

$x_{ref,j}$: Assigned inter-comparison reference value for calibration point *j*.

$U_{i,j}$: The estimated expanded uncertainty (k=2) stated by each laboratory *i* for respective calibration point *j*.

$U_{ref,j}$: The estimated expanded uncertainty (k=2) of the assigned reference value for the same calibration point *j*.

$E_{n,j}$: The calculated En value at each pressure point *j*.

Inter-comparison reference value and its uncertainty

The reference values $x_{ref,j}$ are calculated as the average from the first and last calibration provided by the reference laboratory.

$$x_{ref,j} = \frac{R_{1,j} + R_{2,j}}{2} \qquad \text{(eq. 2)}$$

$x_{ref,j}$: The calculated inter-comparison reference value for pressure level *j*.

j: Counting pressure points 1 to 6 at increasing and decreasing pressure.

$R_{1,j}$ & $R_{2,j}$: The assigned comparison reference values provided by the reference laboratory at start and end. In the result tables only the symbol R1&R2, in the diagrams *R* is used for identifying the assigned reference.

At some calibration points the reported uncertainties differed slightly between the calibration at the beginning and the end. Thus, the measurement uncertainty for each calibration level was calculated as the uncertainty of the mean (equation 3).

$$U_j = \frac{\sqrt{U_{1,j}^2 + U_{2,j}^2}}{\sqrt{2}} \qquad \text{(eq. 3)}$$

U_j: The combined uncertainty from two calibrations (at different pressure levels *j*).
Index 1: Refers to the calibration prior the circulation.
Index 2: Refers to the calibration at the end of circulation.

Given the same uncertainty for a pressure level at start and at the end the uncertainty of the reference value is identical with that stated by the laboratory in one of the calibrations. Otherwise, the reference uncertainty lies close to the middle of both.

The data supplied by the reference laboratory indicated a drift that was taken into account. The uncertainty of the inter-comparison reference value was then composed by adding half of the detected drift over the time for the total exercise, see equation 4.

$$U_{ref,j} = U_j + \frac{1}{2} abs\left(R_{2,j} - R_{1,j}\right) \qquad \text{(eq. 4)}$$

The principle of the intercomparison

An absolute value of E_n of less than |1| is often used as a criterion for an acceptable measurement quality, according to ISO/IEC 17043:2010, B.4.1.1. It means a reported indication error x_i from a participant does not deviate more from the assigned reference comparison value x_{ref} than what can be expected from the calculated uncertainty in this difference.

$$E_n < 1: \quad \left|x_i - x_{ref}\right| < \sqrt{U_i^2 + U_{ref}^2} \qquad \text{(eq. 5)}$$

However, to make this measure a reliable one for an inter-comparison the reference U_{ref} must be small enough not to contribute significantly to the right side of equation 5.

Due to the quadratic combination ideally U_{ref} should be in the range of 1/3 of U_i, but that was not possible in this intercomparison as the drift increased the uncertainty value coming from the reference laboratory.

Measuring results on calibration in the ILC

The following tables and graphs present the error of indication along with the stated measurement uncertainty for each calibration point. This presentation is chosen to allow the participants to compare the tabled data in this report with their own documentation.

It was the ambition of the organizer to directly incorporate the participants excel-protocols into the evaluation calculations for reporting the outcome of the comparison measurements after first having checked all data against those in the calibration certificates delivered in a separate calibration certificate. This worked mostly very well.

The following tables are built with increasing participant identity numbers that is not following the logistic scheme. The participants will be informed separately about their identification. Together with the estimated uncertainty $U_{ref,j}$ these two values are used for calculating each participants E_n-value displayed in the last column.

The sensor was new and not used before the ILC.

Calibration certificates by the reference laboratory

Before circulation 105102-1195534-K01

After circulation 105102-1212535-K01

Zero-point before increasing pressure Table 1

Lab no.	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	**0,000**	**0,220**	**0,00**	**0,01**	**0,00**
2	**0,000**	**0,300**	**0,00**	**0,01**	**0,00**
3	**0,000**	**0,900**	**0,00**	**0,01**	**0,00**
4	**0,000**	**0,060**	**0,00**	**0,01**	**0,00**
5	**-0,100**	**1,230**	**0,00**	**0,01**	**-0,08**
6	**0,000**	**0,058**	**0,00**	**0,01**	**0,00**

Different pressure levels

Table 2 Calibration at 1000 bar increasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-2,920	0,150	-2,925	0,183	0,02
2	-3,000	0,400	-2,925	0,183	-0,17
3	-2,900	0,900	-2,925	0,183	0,03
4	-3,200	0,260	-2,925	0,183	-0,86
5	-3,070	1,260	-2,925	0,183	-0,11
6	-2,843	0,170	-2,925	0,183	0,33

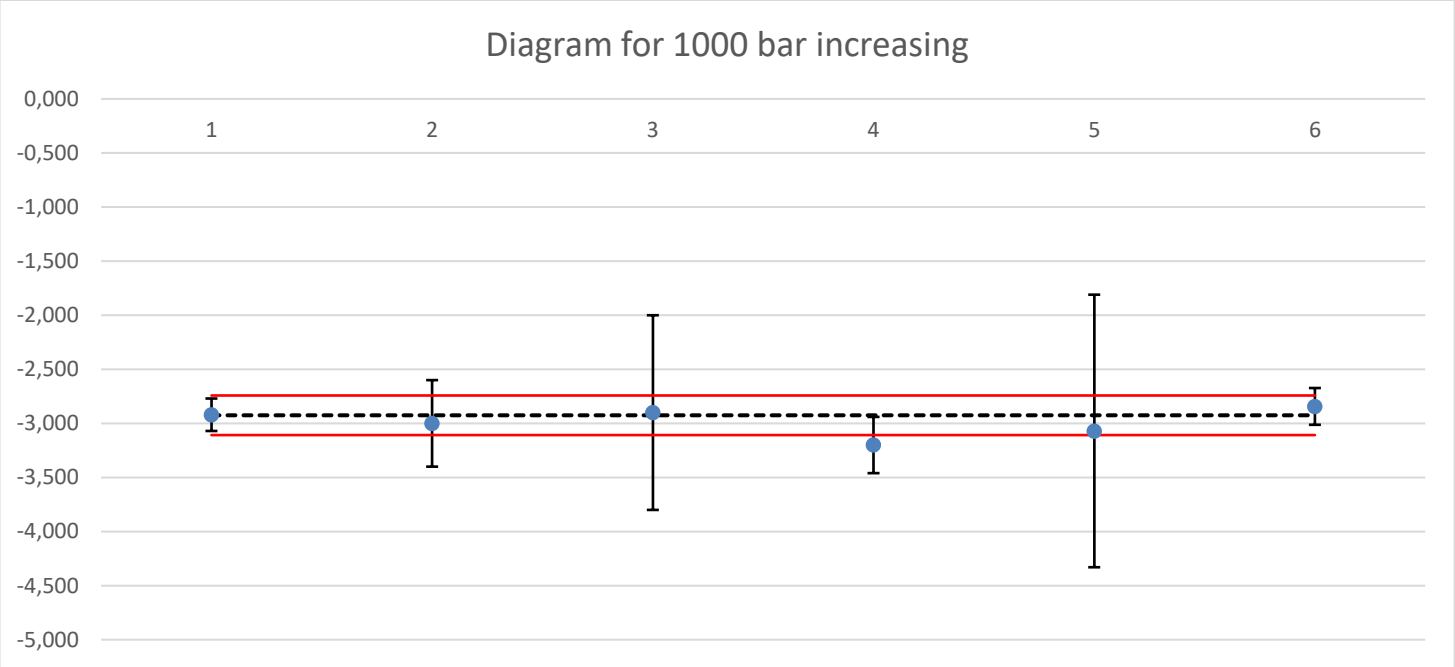


Table 3 Calibration at 1000 bar decreasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-3,720	0,150	-3,395	0,242	-1,14
2	-3,800	0,400	-3,395	0,242	-0,87
3	-4,100	0,900	-3,395	0,242	-0,76
4	-4,060	0,380	-3,395	0,242	-1,48
5	-3,470	1,260	-3,395	0,242	-0,06
6	-3,943	0,170	-3,395	0,242	-1,85

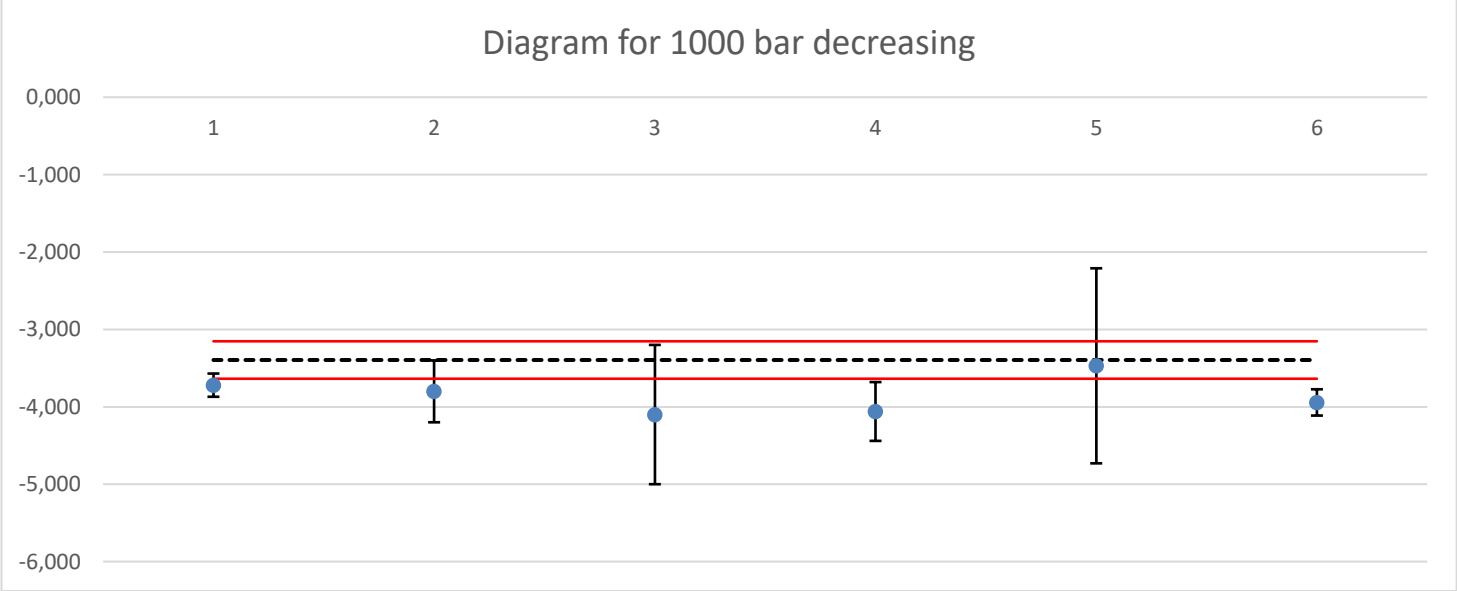


Table 4 Calibration at 2000 bar increasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-4,380	0,230	-4,250	0,260	-0,37
2	-4,400	0,500	-4,250	0,260	-0,27
3	-4,300	0,900	-4,250	0,260	-0,05
4	-4,740	0,480	-4,250	0,260	-0,90
5	-4,200	1,330	-4,250	0,260	0,04
6	-4,273	0,255	-4,250	0,260	-0,06

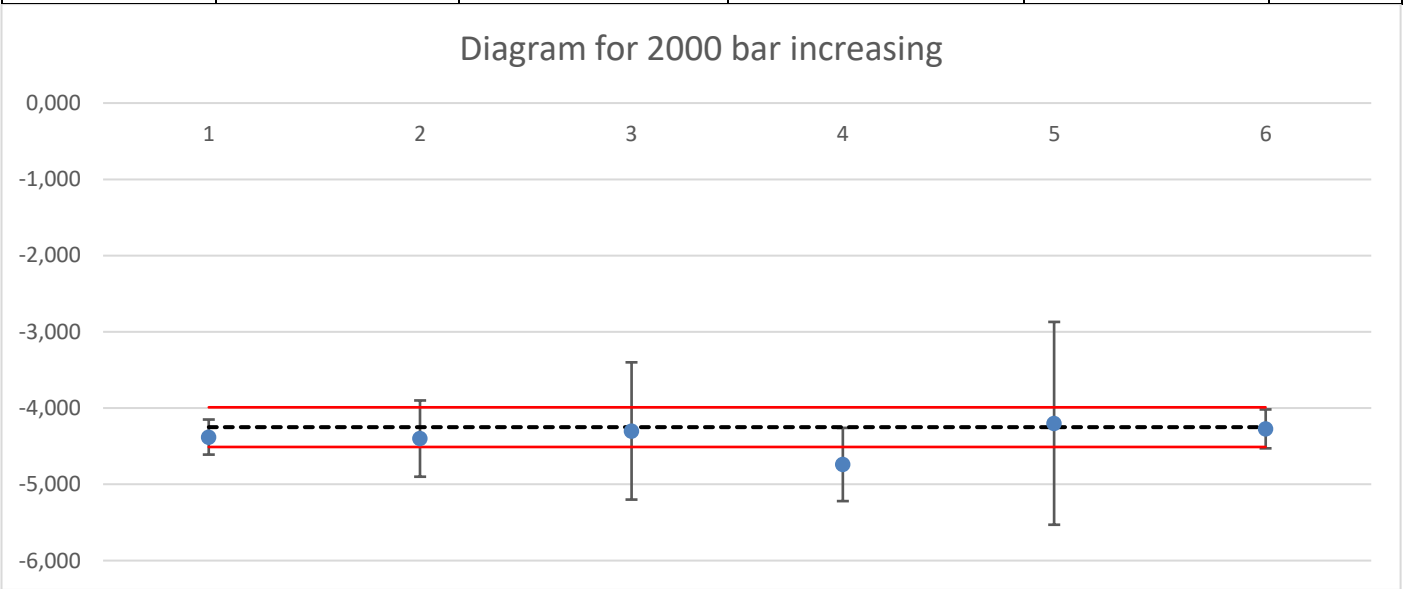


Table 5 Calibration at 2000 bar decreasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-5,580	0,230	-5,545	0,620	-0,05
2	-5,800	0,500	-5,545	0,620	-0,32
3	-6,000	0,900	-5,545	0,620	-0,42
4	-6,210	0,450	-5,545	0,620	-0,87
5	-5,000	1,330	-5,545	0,620	0,37
6	-5,898	0,255	-5,545	0,620	-0,53

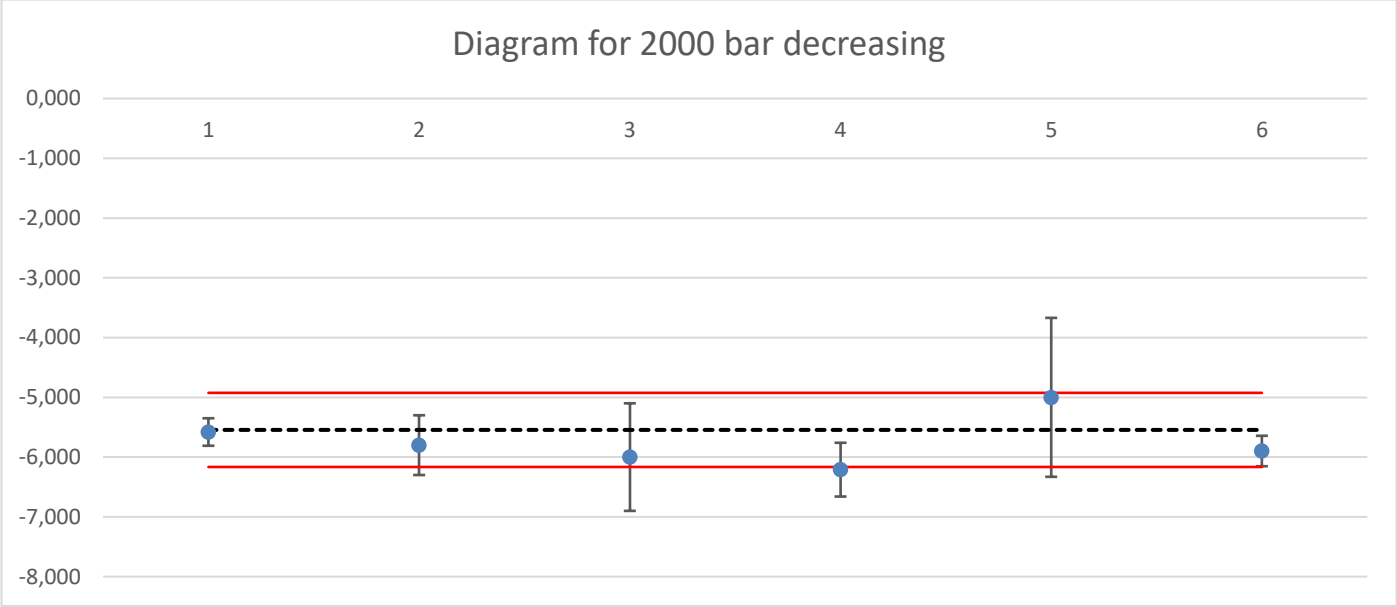


Table 6 Calibration at 3000 bar increasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-4,970	0,350	-4,765	0,470	-0,35
2	-4,900	0,700	-4,765	0,470	-0,16
3	-4,700	1,000	-4,765	0,470	0,06
4	-5,510	0,720	-4,765	0,470	-0,87
5	-4,500	1,440	-4,765	0,470	0,17
6	-4,499	0,354	-4,765	0,470	0,45

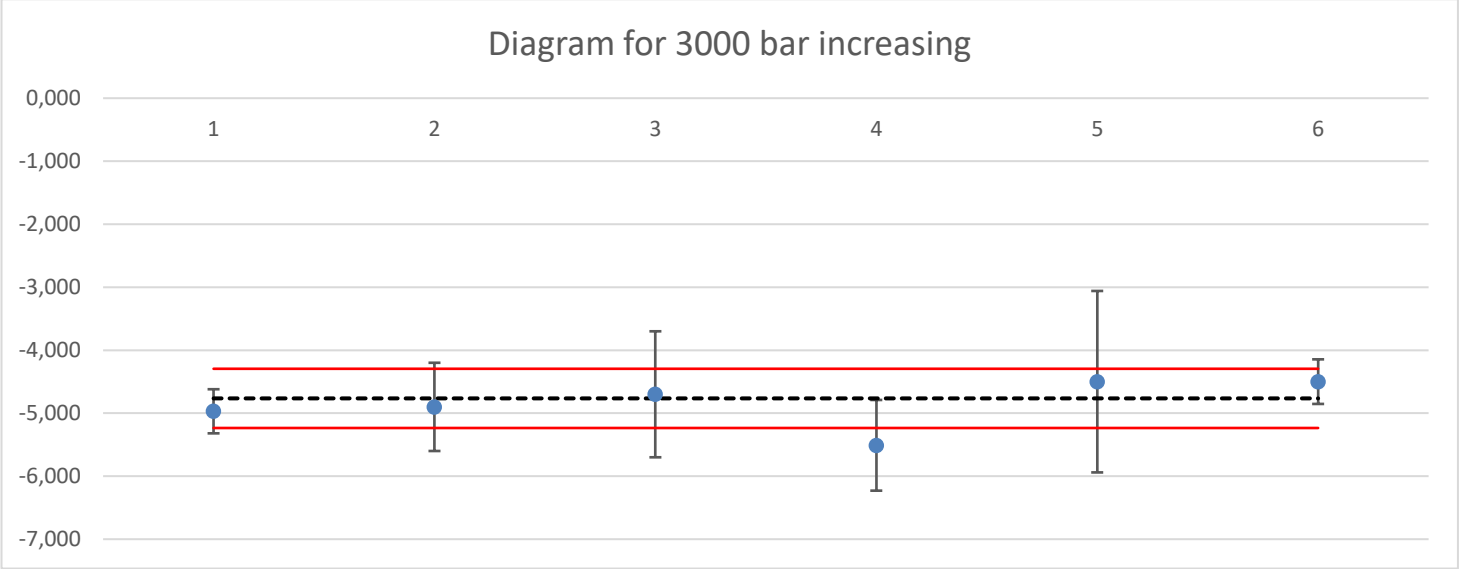


Table 7 Calibration at 3000 bar decreasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-6,370	0,350	-6,260	0,786	-0,13
2	-6,600	0,700	-6,260	0,786	-0,32
3	-6,500	1,000	-6,260	0,786	-0,19
4	-7,110	0,660	-6,260	0,786	-0,83
5	-5,000	1,440	-6,260	0,786	0,77
6	-6,494	0,354	-6,260	0,786	-0,27

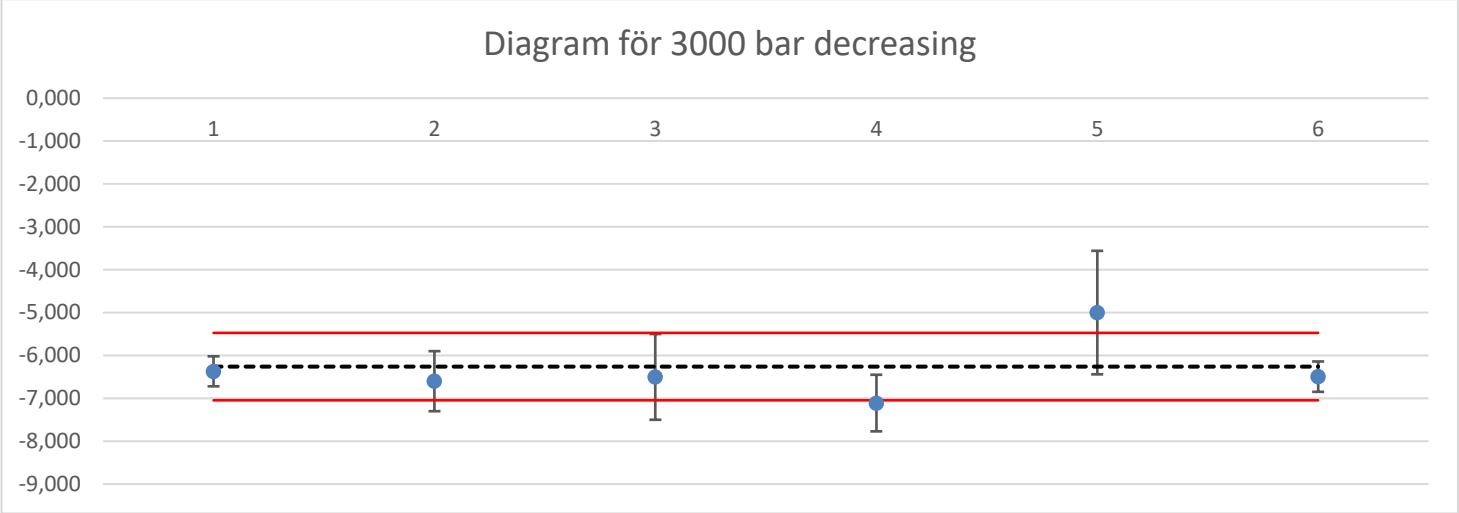


Table 8 Calibration at 4000 bar increasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-4,600	0,420	-4,270	0,850	-0,35
2	-4,500	0,900	-4,270	0,850	-0,19
3	-4,100	1,100	-4,270	0,850	0,12
4	-5,260	0,890	-4,270	0,850	-0,80
5	-12,100	1,590	-4,270	0,850	-4,34
6	-3,997	0,459	-4,270	0,850	0,28

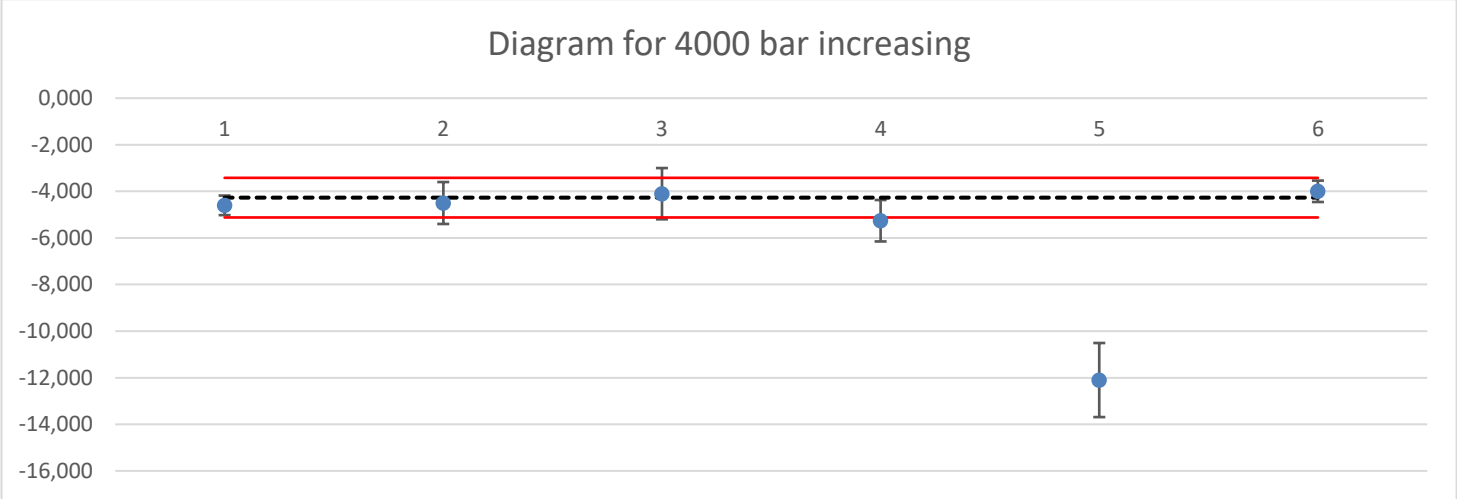


Table 9 Calibration at 4000 bar decreasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-5,700	0,420	-5,420	0,995	-0,26
2	-5,700	0,900	-5,420	0,995	-0,21
3	-5,600	1,100	-5,420	0,995	-0,12
4	-6,490	0,870	-5,420	0,995	-0,81
5	-7,100	1,590	-5,420	0,995	-0,90
6	-5,412	0,459	-5,420	0,995	0,01

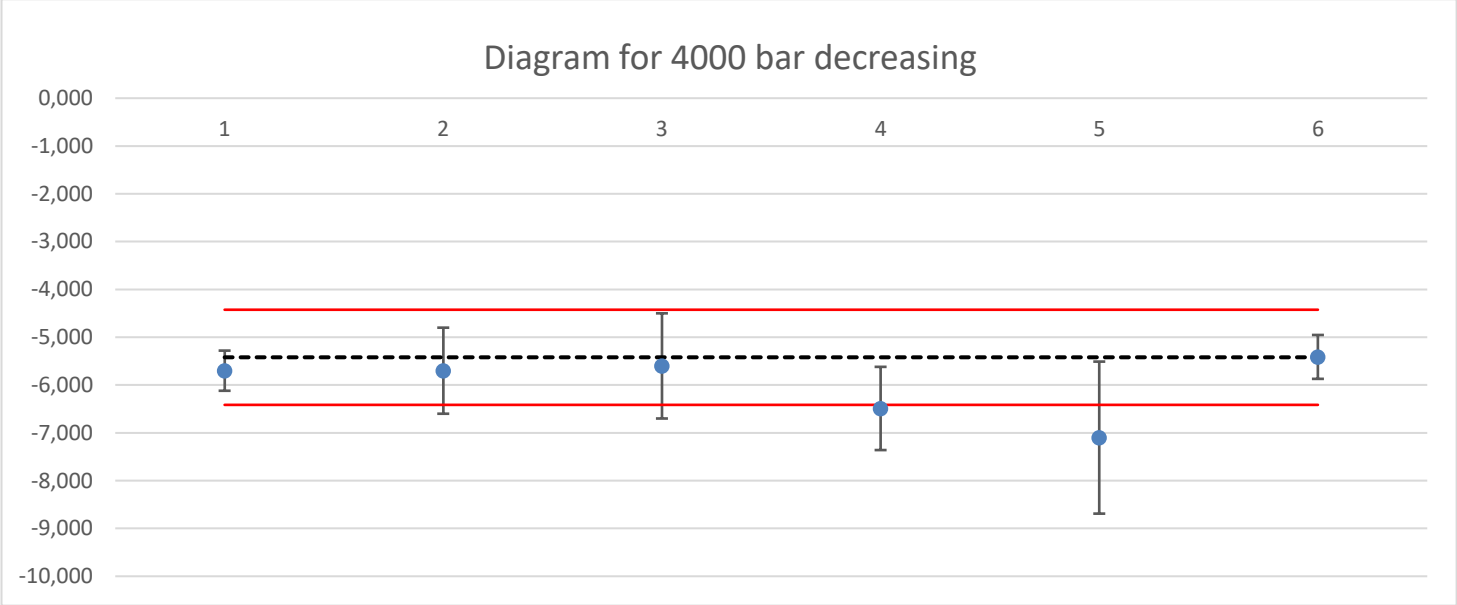


Table 10 Calibration at 5000 bar increasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-3,560	0,510	-2,995	1,355	-0,39
2	-3,000	1,000	-2,995	1,355	0,00
3	-2,800	1,100	-2,995	1,355	0,11
4	-4,130	1,090	-2,995	1,355	-0,65
5					
6	-3,305	0,565	-2,995	1,355	-0,21

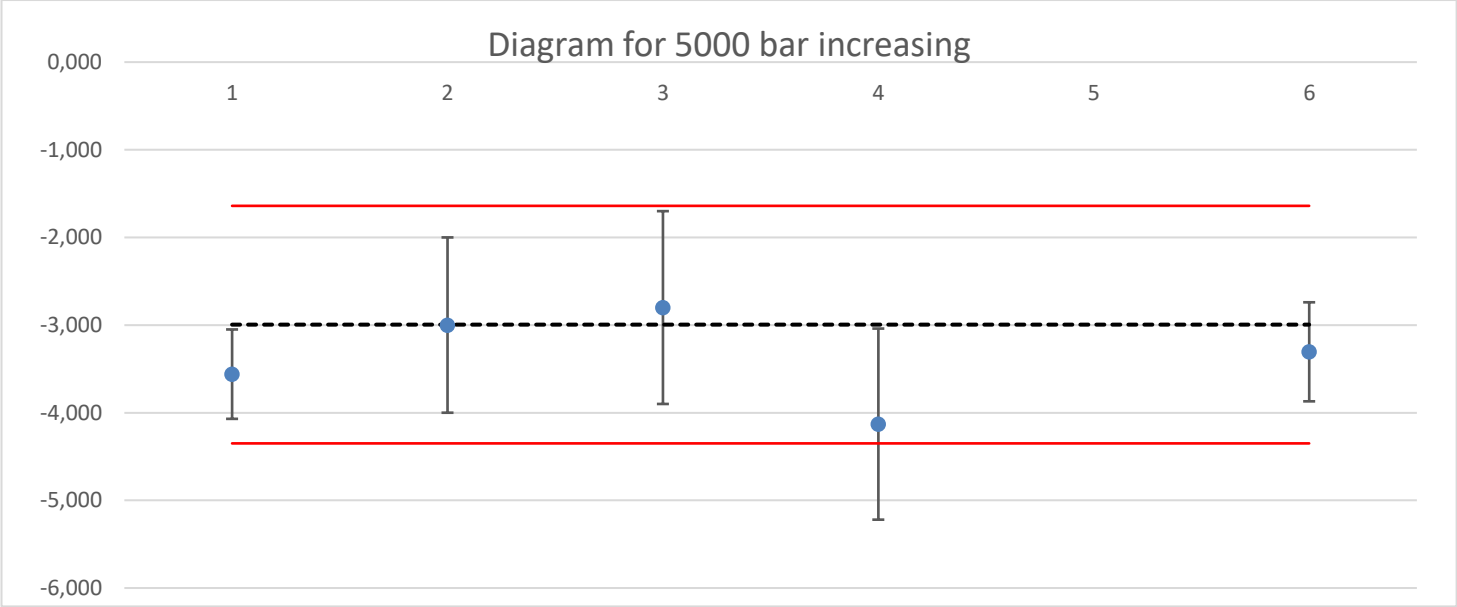
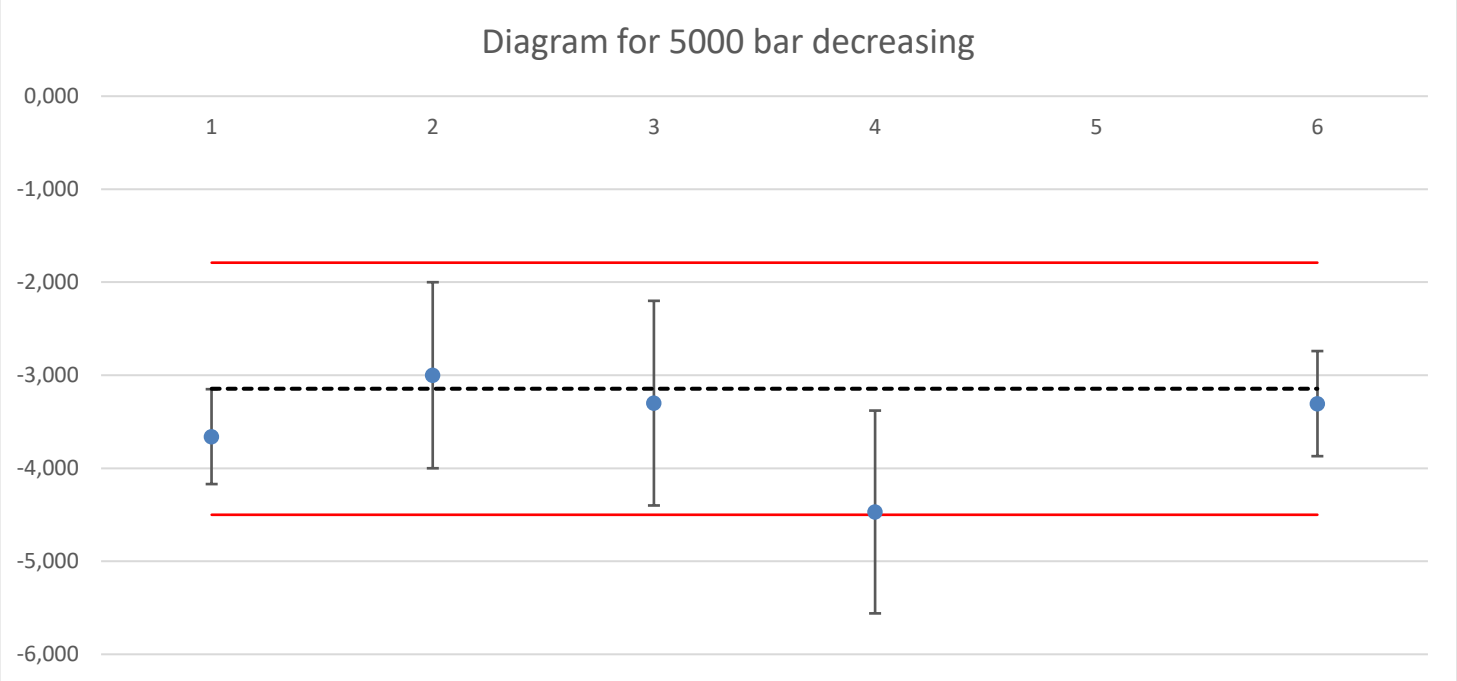


Table 11 Calibration at 5000 bar decreasing pressure.

Lab number	Calculated indication error	Stated measurement uncertainty	Error, reference laboratory	Uncertainty, reference laboratory	En-value
1	-3,660	0,510	-3,145	1,355	-0,36
2	-3,000	1,000	-3,145	1,355	0,09
3	-3,300	1,100	-3,145	1,355	-0,09
4	-4,470	1,090	-3,145	1,355	-0,76
5					
6	-3,305	0,565	-3,145	1,355	-0,11



Comments on the calibration certificates

-- not a part of the intercomparison

Most of the laboratories report measurement error, but others correction.

Some laboratories give the formula in calculation of uncertainty in the calibration certificate.

Some laboratories give separate results of increasing pressure and decreasing pressure as well as the mean value.

Most of the laboratories indicate two results for the highest applied pressure even if the value and uncertainty are the same.

Several laboratories included diagrams related to errors on increasing and decreasing pressures.

Some laboratories were explaining the relations between reference value and instrument value and others indicated the result as deviation without explanation the exact meaning.

Some laboratories specify in their certificate only the average value for both increasing and decreasing pressure with a common uncertainty, but the excel-protocol revealed eventually differences in up- and downward direction.

All laboratories have an accreditation by their national accreditation body.

Additions and changes to the DRAFT report

There have been discussions about the uncertainty of the reference values, and we regret that the drift during the intercomparison added to the final reference uncertainty.

This was the original description

Calibration Point/Pressure	CMC values Reference laboratory	Possible reference uncertainty
[bar]	bar	bar
0	0	0,1
1000	0,072	0,1
2000	0,19	0,2
3000	0,34	0,4
4000	0,53	0,6
5000	0,76	0,8

These are the results

Calibration point, bar	Resulting uncertainty, increasing pressure bar	Resulting uncertainty Decreasing pressure bar
0	0,01	
1000	0,183	0,242
2000	0,260	0,620
3000	0,470	0,786
4000	0,850	0,995
5000	1,355	1,355

We hope that those facts explain the situation.

Final conclusions

In this inter comparison most of the participants could demonstrate a capacity to calibrate and give relevant values in relationship to their uncertainties.

On increasing pressure including starting at zero point are all 35 En values below 1.

On decreasing pressure from 5000 bar to 2000 bar are all En values below 1..

On decreasing pressure on 1000 bar 3 En values of 6 are above 1

The results at zero point are not included in this report as that gave several confusing results.

The tables are given with 1 more digit that is the common use as this helps the participant to evaluate the figures. This will be changed in the final report.

Evaluation of the results of the participants.

The participants shall evaluate their results according to ISO/IEC 17025:2017 7.7.3

It is then recommended to evaluate according to descriptions above including the fact where:

- The size of En-values
- En- values in relation to their CMC values

Acknowledgement

We gratefully thank the member of the advisory board and expert in pressure calibrations Mr Aykurt Altintas Denmark.

We also acknowledge the primary calibrations by RISE Sweden that supported the ILC with reference calibrations.

Annex 1 ILC pressure 2023:2

Published on https://smquality.se/

Annex 2 *D*escription of the intercomparison/ILC

Published on https://smquality.se/

Appendix 1 Reporting forms

ILC- Pressure gauge 2023:2

Documentation protocol for participant

Laboratory:	
Person:	
e-mail:	
Date:	

Please arrange zeroing/offseting according to the description in the manual

for each new series

Pressure gauge

Obligatory calibration points	Applied reference pressure	Measured gauge pressure	Calculated indication error	Stated measurement uncertainty
[bar]	[bar]	[bar]	[bar]	[bar]
0				
1000				
2000				
3000				
4000				
5000				
5000				
4000				
3000				
2000				
1000				
0				

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)