Swedish Metrology and Quality AB

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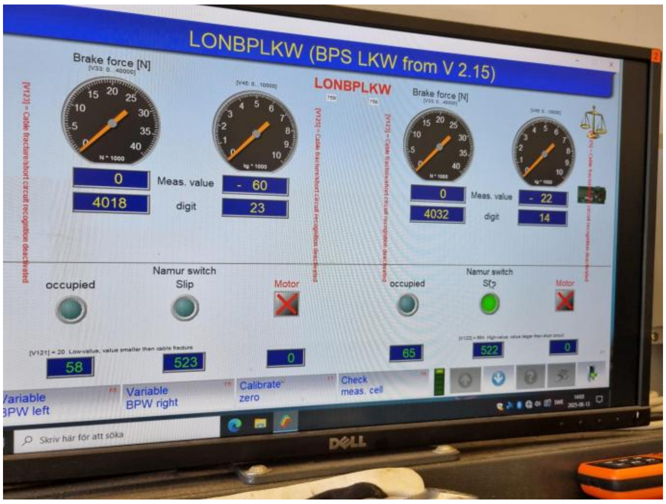
To participants

Report on intercomparison ILC brake tester and manometer 2025:1.

Indicating screen



Pressure sensor P2 was calibrated

Brake rollers

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Content

Abstract

This interlaboratory comparison (ILC) was organized to evaluate and verify calibration results for brake testers and pressure manometers performed by several accredited laboratories. The aim was to provide objective evidence of technical competence in accordance with ISO/IEC 17025:2017 and the principles of ISO/IEC 17043:2023. Participating laboratories carried out calibrations under controlled conditions, using either load cells or mechanical weights as reference equipment.

The comparison covered calibration points for brake forces between 1.8 kN and 40 kN on both left and right brake tester sides, as well as manometer calibrations at pressures from 1 bar to 7 bar. The assigned reference values were established through consensus among participants, using arithmetic means and supported by chi-square statistical test. En-values were calculated for each participant to assess the agreement of results relative to the reference values and associated uncertainties.

The overall outcome demonstrated a high level of consistency among laboratories. For the brake tester measurements, all En-values remained within the acceptance criteria (En ≤ 1), while two out of 37 En-values exceeded unity for the manometer calibrations. No significant differences were observed between calibrations performed with load cells and those performed with mechanical weights.

This ILC confirms the reliability of the participating laboratories' calibration practices and supports their continued accreditation. The results strengthen confidence in brake tester and pressure sensor calibrations, providing traceability and comparability across laboratories in Europe.

The purpose of this comparison

This comparison calibration serves as a tool to verify calibration results from different laboratories. It is a recognized method to demonstrate the technical capacity of calibration laboratories as a basis for the accreditation required by ISO/IEC 17025:2017 (SS-EN ISO/IEC 17025:2018) specified in point 7.7.2.

Advisory Group

Implementation of this ILC is based on experience from earlier intercomparisons of this type

Information about this calibration intercomparison

Information about this calibration comparison was provided in 2 ways:

- On the website https://smquality.se/interlaboratory-comparisons-ilc
- Email to accredited laboratories in this field in Europe

Detailed information with a description of this ILC was published on smquality.se

Participants could choose if they wanted to calibrate the brake tester or the pressure sensor or both.

Lab Participation

The planning was organized to conduct the exercises over a period of 2 hours per participant. Based on this, a work schedule was established so that the participants would not disturb or influence each other. This schedule was finalized the week before the actual calibration was to take place.

Most of the laboratories have an accreditation in this area from Swedac. The laboratories were asked to provide preliminary results for the comparison to the organizer immediately upon completion of the calibration. This avoided the possibility for the laboratories to compare the results with each other.

Laboratory
Fordonslyftar AB (4 participants)
Sun Maskin
Lidköpings Carpart
DEKRA
JB Maskin

Calibration Instructions and Calibration Points

The laboratories were asked to use the uncertainty analyses they have in their methods regardless of whether they provide the same values as the decided CMC values. It was sent as an excel file to the participants a few days before the measurement occasion.

The laboratories should report the values that apply to the force provider directly, not the calculated braking force. That is not clearly indicated in all cases.

The measurement points that the participants were asked to calibrate were established in advance and are reflected in the result tables below. The documentation list in Excel (Annex 1) was completed and handed over to the participants. The comparison was only evaluated for a few specific points as indicated in the result presentation below.

Planning Details

The signed calibration certificates should then be delivered to the organizer within a week after the calibration was completed. The organizer applies the principles in ISO/IEC 17043:2023 in reporting this comparison. The participants were asked to use their own methodology for the calibrations. The calibration certificates should be complete and include measurements and uncertainties for the calibrated values. There were also opportunities for the laboratories to provide additional information.

The reality was that the participants used specific software or made hand notes of the results from the calibration and the organizer decided to use the excel sheets in all cases.

Administrative information

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Traceability of reference values

During the calibrations, the consensus principle was applied (described further below) and the calculations, and traceability is based on calibration laboratories providing accredited calibration certificates or calibration certificates from recognized National Metrology Institutes (NMI) for the reference equipment used. Most of the participating laboratories could demonstrate that they have accredited reference equipment. One laboratory has factory calibration certificates that are not accredited but have enough information on traceability that makes it possible to use their results as a part of the calculations in this ILC.

Discussions about the calibration results

As it is not possible to establish a reference measurement on this intercomparison, the reference value for the comparison needs to be based on a consensus value among the participants. This is chosen at all results reported values of the participants. Overall, the participants' results are so consistent, with a few exceptions, that the simplest and most reasonable approach is to choose the arithmetic means, i.e., to assign the same significance to all results.

The first action to evaluate that was therefore to perform a chi-square test. That test indicated that there was no need to calculate the mean result as the principles in the calculations of a weighed mean.

The results imply that it would not be fair to rank some results higher if their low uncertainty claims are not reliable. This decision is of course difficult to make. But if the reported uncertainty values are unreasonably different and don’t harmonize with the spread in results then it is impartial to give all the same weight. For this situation therefore the arithmetic mean is chosen as base for the consensus value.

$$x_{ref} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The opposite would be a weighted average according to uncertainty, where the result with the least uncertainty influences the average much more strongly than that with the largest uncertainty indication. Generally, the weighted mean is preferred. The reason is twofold. First, results with low uncertainties have considerably higher weight than those with large.

Second, the consensus uncertainty does depend on the presented uncertainties and not on the eventual spread between results. In this case the uncertainty levels are not very different and there is no proof that some laboratories have more knowledge about uncertainties. That is as well a base to decide to use the arithmetic mean.

There are a few values that could also be suspected as "outliers” but passed a chi-square test. The uncertainty in the reference values thus defined was determined from the standard deviation of all.

Chi square test

It is expected that the reported results are part of the same normal distribution and that the spread between them is only due to random, not systematic effects. To check if this is the case and that the results are consistent a Pearson's Chi squared test[1] is performed in the situation where all results are considered credible.

In this statistical hypothesis test the observed test parameter is calculated according to

$$\chi^2_{obs} = \frac{\left(x_1 - x_{ref}\right)^2}{u^2(x_i)} + \cdots \frac{\left(x_N - x_{ref}\right)^2}{u^2(x_N)} \qquad (4)$$

Where the nominator in each term is the difference to the weighted mean squared and $u(x_i)$ denotes the reported uncertainties of the participants.

The observed value is compared to a critical value $\chi^2(\nu)$ which is taken from a Chi-squared distribution. The distribution presents critical values depending on the number of degrees of freedom (n = N-1) for several probabilities or significance levels. A reasonable probability is 0,05 or 5%. If the differences between the participants results are generated by chance (given the degree of freedom) then $\chi^2(\nu) > \chi^2_{obs}$ on a 5% significance level. If one instead finds $\chi^2(\nu) < \chi^2_{obs}$ at least one result is not consistent and is excluded from forming the reference value

To transform the uncertainty to an expanded level, the standard deviation for all series was multiplied by a factor from Student's t-distribution corresponding to a confidence level of 95%.

In total, the comparison is presented with 7 tables for the left side and for the right side for the mandatory measurement points on brake force (1.8, 6, 9, 15, 20, 3on 5 different tables0, and 40 kN).

The presentation on the manometer is done with 5 different tables (1,2,3,5 and 7 bar).

There were possibilities for the participants to calibrate using load cells or mechanical equipment using weights.

[1] A G Steele and R J Douglas (2005), Chi-squared statistics for KCRV candidates Metrologia **42** (2005) 253–261.

Analysis of the calibration results

The evaluator used the principles in the ISO/IEC 17043:2023.

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 En-value is calculated for every calibrated point according to equation (1).

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

$x_{i,j}$: Single measurement result (deviation from nominal mass value); index *i* and *j* count the various participants respectively.

$x_{ref,j}$: Assigned inter-comparison reference value j.

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

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

$En_{i,j}$: The calculated En-value for each participant

Tables and diagrams on brake tester left side

The following shows the results of the calibration comparison. For each force there is a table on the left and a graphical image on the right.

The value that constitutes the reference value R for the correction in the comparison can be found in the bottom of the table. These two values are used together with each participant's corresponding values to calculate their En value. The diagrams on the right illustrate the correction indicated by participants along with the reference value for comparison organized by the different measurement points. The error bars indicate the reported uncertainty.

Table 1--brake force 1,8 kN

	1,8kN	left	
Identification	Error	Uncertainty	En value
1			0,03
2	0,017	0,045	0,34
3	-0,027	0,084	0,30
4	0,027	0,045	0,53
5	-0,005	0,070	0,06
6	-0,03	0,06	0,44
7	-0,004	0,045	0,06
8	0,017	0,045	0,34
	Ref error	Ref Uncertainty	
	-0,0007	0,0272	

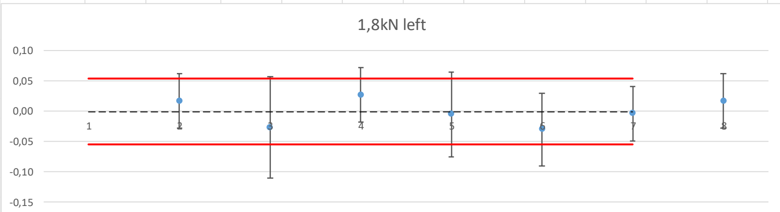

Table 2--brake force 6 kN

	6kN	left	
Identification	Error	Uncertainty	En value
1	0,09	0,12	0,40
2	0,066	0,12	0,22
3	-0,023	0,127	0,45
4	0,066	0,12	0,22
5	0,011	0,093	0,26
6	-0,01	0,10	0,42
7	0,037	0,120	0,01
8	0,066	0,120	0,22
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	0,0379	0,0486	

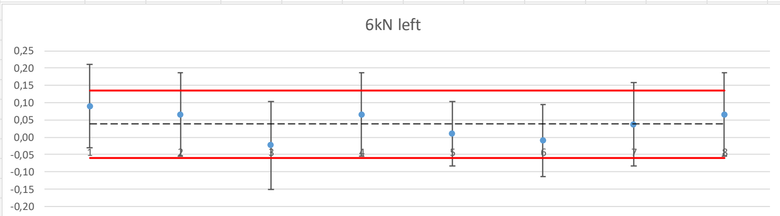


Table 3--brake force 9 kN

	9kN	left	
Identification	Error	Uncertainty	En value
1	0,15	0,18	0,42
2	0,044	0,18	0,10
3	-0,038	0,127	0,65
4	0,06	0,18	0,05
5	0,022	0,124	0,28
6	-0,02	0,15	0,49
7	0,172	0,180	0,53
8	0,133	0,180	0,34
	Ref error	Ref Uncertainty	
	0,0648	0,0932	

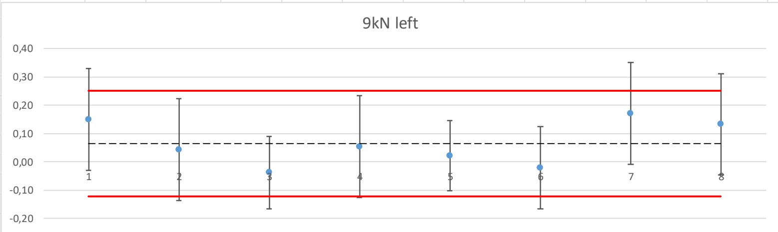


Table 4--brake force 15 kN

	15kN	left	
Identification	Error	Uncertainty	En value
1	0,03	0,30	0,15
3	-0,090	0,127	0,38
5	-0,001	0,214	0,08
	Ref error	Ref Uncertainty	
	-0,0203	0,1340	

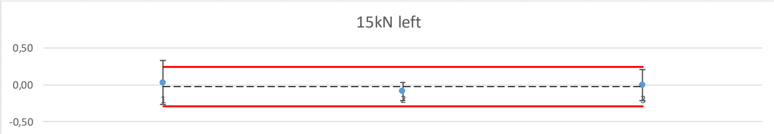


Table 5-brake force 20 kN

	20kN	left	
Identification	Error	Uncertainty	En value
3	-0,193	0,127	0,11
5	-0,038	0,214	0,11
	Ref error	Ref Uncertainty	
	-0,116	0,696	

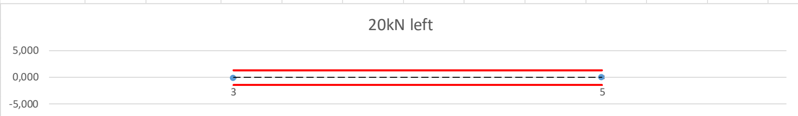


Table 6--brake force 30 kN

	30kN	left	
Identification	Error	Uncertainty	En value
2	-0,123	0,60	0,17
3	-0,379	0,209	0,37
4	-0,02	0,60	0,32
5	-0,268	0,310	0,07
6	-0,76	0,49	0,89
7	0,013	0,600	0,37
8	-0,12	0,600	0,17
	Ref error	Ref Uncertainty	
	-0,2367	0,3279	

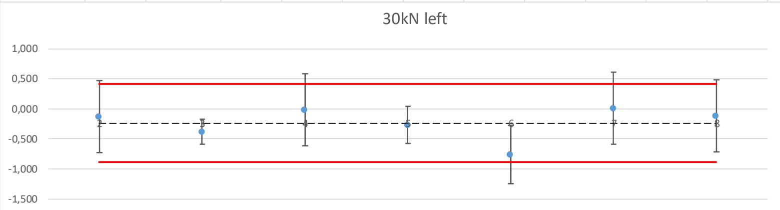


Table 7--brake force 40 kN

	40kN	left	
Identification	Error	Uncertainty	En value
3	-0,473	0,209	0,09
5	-0,41	0,403	0,06
	Ref error	Ref Uncertainty	
	-0,442	0,283	

Tables and diagram on brake tester right side.

Table 8--brake force 1,8 kN

	1,8kN	right	
Identification	Error	Uncertainty	En value
2	0,017	0,045	0,27
3	-0,004	0,084	0,09
4	-0,004	0,045	0,17
5	-0,015	0,070	0,26
6	0,000	0,06	0,06
7	0,017	0,045	0,27
8	0,017	0,045	0,27
	Ref error	Ref Uncertainty	
	0,004	0,016	

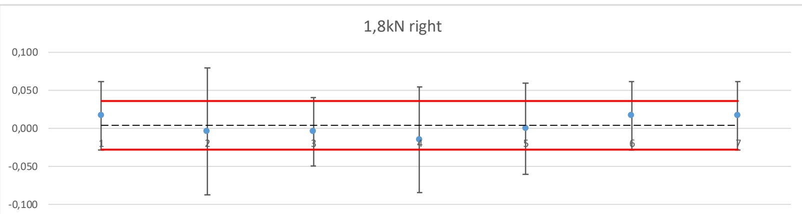


Table 9--brake force 6 kN

	6kN	right	
Identification	Error	Uncertainty	En value
1	0,05	0,12	0,07
2	0,066	0,12	0,20
3	0,022	0,127	0,14
4	0,044	0,12	0,02
5	0,000	0,093	0,40
6	-0,01	0,10	0,46
7	0,089	0,120	0,38
8	0,066	0,120	0,20
	Ref error	Ref Uncertainty	
	0,041	0,041	

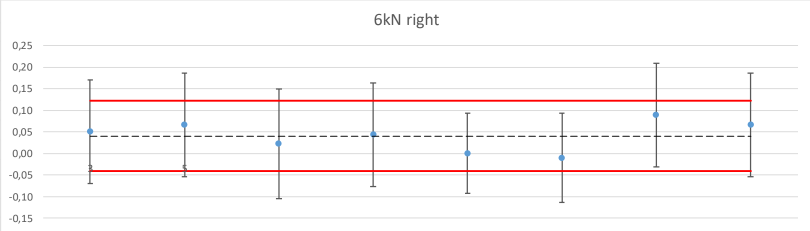


Table 10--brake force 9 kN

	9kN	right	
Identification	Error	Uncertainty	En value
1	0,07	0,18	0,14
2	0,044	0,18	0,01
3	0,028	0,127	0,10
4	0,094	0,18	0,27
5	-0,017	0,124	0,42
6	-0,04	0,15	0,52
7	0,030	0,180	0,07
8	0,133	0,180	0,47
	Ref error	Ref Uncertainty	
	0,043	0,067	

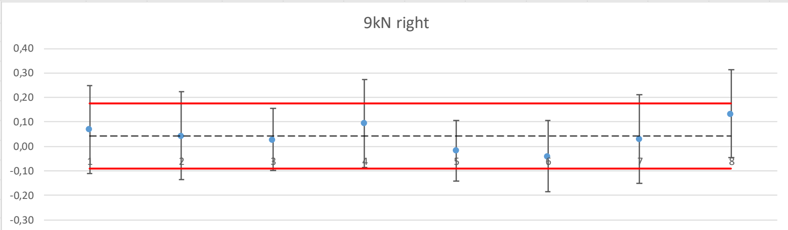


Table 11--brake force 15 kN

	15kN	right	
Identification	Error	Uncertainty	En value
1	0,12	0,30	0,26
3	-0,005	0,127	0,16
5	-0,027	0,214	0,21
	Ref error	Ref Uncertainty	
	0,029	0,171	

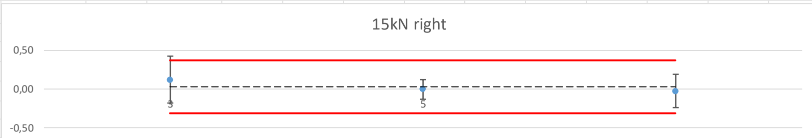


Table 12-brake force 20 kN

	20kN	right	
Identification	Error	Uncertainty	En value
3	-0,147	0,127	0,09
5	-0,103	0,214	0,08
	Ref error	Ref Uncertainty	
	-0,125	0,198	

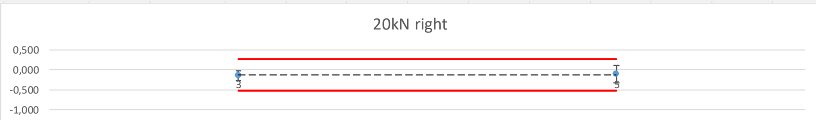


Table13--brake force 30 kN

	30kN	right	
Identification	Error	Uncertainty	En value
2	-0,123	0,60	0,20
3	-0,231	0,209	0,08
4	0,035	0,60	0,43
5	-0,342	0,310	0,16
6	-0,86	0,49	0,99
7	-0,213	0,600	0,07
8	-0,12	0,600	0,21
	Ref error	Ref Uncertainty	
	-0,265	0,351	

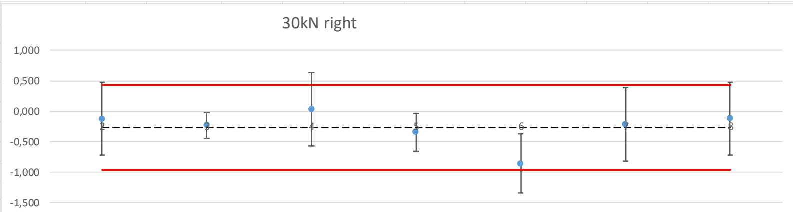


Table 14--brake force 40 kN

	40kN	right	
Identification	Error	Uncertainty	En value
3	-0,388	0,209	0,08
5	-0,438	0,403	0,05
	Ref error	Ref Uncertainty	
	-0,413	0,225	

Comments

The quality of the calculated reference values and En values is not enough in the tables where less than 4 participants have done the calibration.

Those tables can only be used to roughly evaluate ´the level of the calibration result between the involved laboratories

Two laboratories used load cells as reference and the others mechanical equipment with weights.

The results are not different between the 2 principles.

Results manometer

The manometer no 2 was calibrated

Table 15 –1 bar

	1	bar	
Identification	Error	Uncertainty	En value
1	-0,04	0,16	0,14
2	0,02	0,16	0,23
3	0,026	0,033	0,91
4	-0,04	0,16	0,14
5	-0,017	0,074	0,01
6	0,00	0,10	0,17
7	-0,05	0,16	0,20
8	-0,04	0,16	0,14
	Ref error	Ref Uncertainty	
	-0,0176	0,035	

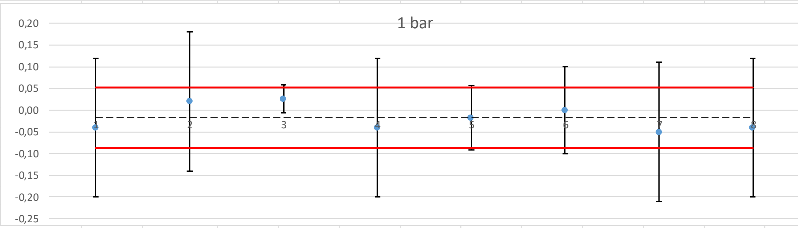


Table 16 –2 bar

Identification	Error	Uncertainty	En value
1	0,01	0,16	0,10
2	0,02	0,16	0,16
3	0,039	0,033	0,96
4	-0,04	0,16	0,21
5	-0,02	0,074	0,17
6	0,00	0,10	0,06
7	-0,04	0,16	0,21
8	-0,02	0,16	0,08
	Ref error	Ref Uncertainty	
	-0,006	0,034	

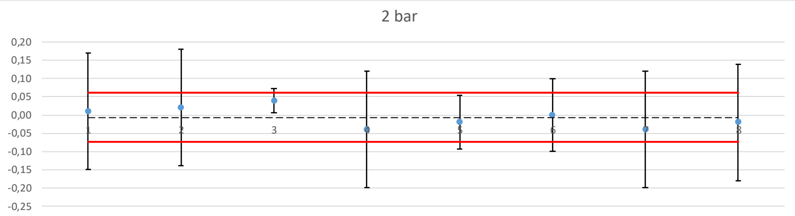


Table 17 –3 bar

	3	bar	
Identification	Error	Uncertainty	En value
1	-0,02	0,16	0,06
2	0,02	0,16	0,19
3	0,040	0,033	1,07
4	-0,04	0,16	0,18
5	-0,023	0,074	0,16
6	0,00	0,10	0,10
7	-0,04	0,16	0,18
8	-0,02	0,16	0,06
	Ref error	Ref Uncertainty	
	-0,010	0,034	

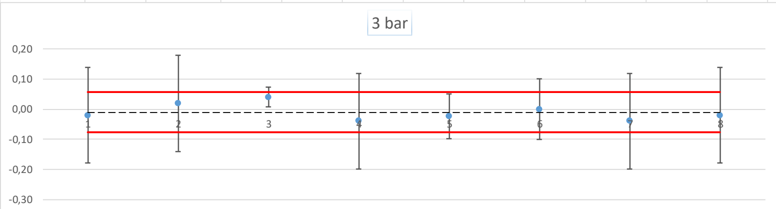


Table 18 –5 bar

	5	bar	
Identification	Error	Uncertainty	En value
1	0,02	0,16	0,14
2	0,02	0,16	0,14
3	0,079	0,033	1,36
4	-0,04	0,16	0,21
5	-0,052	0,074	0,53
6	0,00	0,10	0,04
7	-0,04	0,16	0,21
8	-0,02	0,16	0,09
	Ref error	Ref Uncertainty	
	-0,004	0,051	

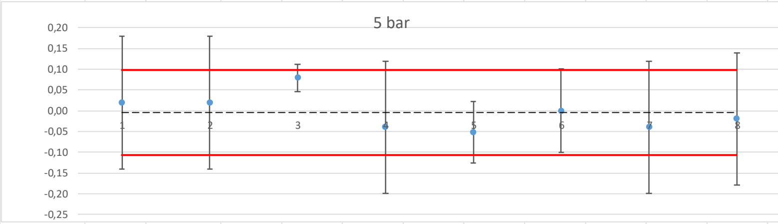
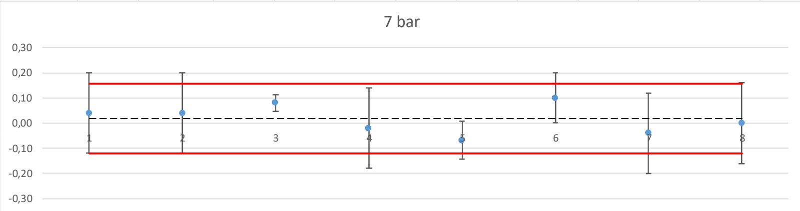


Table 19 –7 bar

	7	bar	
Identification	Error	Uncertainty	En value
1	0,04	0,16	0,13
2	0,04	0,16	0,13
3	0,080	0,033	0,83
4	-0,02	0,16	0,21
5	-0,068	0,074	0,83
6	0,10	0,10	0,69
7	-0,04	0,16	0,32
8	0,00	0,16	0,09
	Ref error	Ref Uncertainty	
	0,017	0,069	



Comments:

All laboratories calibrated pressure and there were 2 En-values above 1.

Comments on the calibration certificates

--Not a part of the report

Comments on manometer

One laboratory explains that the results are collected from the PC display.
One laboratory approves the results and is clearly describing the decision criteria. One laboratory is describing the decision criteria without informing about which tolerance is the base for the decision.
One laboratory is giving the result by 2 decimals points while the others document by 1 decimal point.
Most of the laboratories indicate how the uncertainty is developed according to EA-4/o2.
All laboratories indicate that pressure sensor P2 is calibrated.
Most of the laboratories indicate the environment by the temperature during the calibration

Comments on brake tester

Some laboratories are not declaring clearly that the documented force is the values that apply to the power provider directly and not the calculated braking force.

The laboratories give different maximum brake forces from 15 kN to 40 kN.
One laboratory explains that the results are collected from the PC display.
Two laboratories approve the results according to ISO 21069-1 and are clearly describing the decision criteria.
Most of the laboratories indicate the environment by the temperature during the calibration
One laboratory indicates the diameter on the brake rollers.
One laboratory is giving the result by 3 decimals points while the others document by 2 decimal points.
Most of the laboratories indicate how the uncertainty is developed according to EA-4/o2.
One laboratory documents the different brake force between left and right in percentage on some brake forces

Summary

The number of En-values above 1 on 37 values are:

- Brake tester left 1 is 0
- Brake tester right 1 is 0
- Pressure gauge is 2

It turned out to register no significant difference between calibration with a load cell or weights.

Changes since the DRAFT report

The calibration instructions are updated by explaining about the measured force.
The part ccomments on the calibration certificates is added to the report.
The applied values have been corrected in 3 cases.
Some redactional changes are being made.

Acknowledgment

We are very grateful to BA Fordonslyftar AB for arranging the venue where we could operate undisturbed during the calibrations.

Tage Rejmes I Örebro Lastvagnar AB as the owner of the site.

Wilmer Manfredsson contributed as an expert in calculations.

Annex 1 excel forms used in documentation

ILC brake force 2025:1

Documentation protocol for participant

Laboratory:	
Person:	
e-mail:	
Date:	

Please arrange zeroing/offseting according to the description in the manual
No adjustments shall be done

Pressure gauge

Obligatory calibration points	Applied reference pressure	Measured gauge pressure	Calculated indication error	Stated measurement uncertainty
[bar]	[bar]	[bar]	[bar]	[bar]
1				
2				
3				
5				
7				

Brake force left side

Obligatory calibration points	Applied reference pressure	Measured gauge pressure	Calculated indication error	Stated measurement uncertainty
kN	kN	kN	kN	N
1,8				
6				
9				
15				
20				
30				
40				

Brake force right side

Obligatory	Applied	Measured	Calculated	Stated
kN	kN	kN	kN	N
1,8				
6				
9				
15				
20				
30				
40				

References

- ISO/IEC 17043:2023 Conformity assessment – General requirements for proficiency testing
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