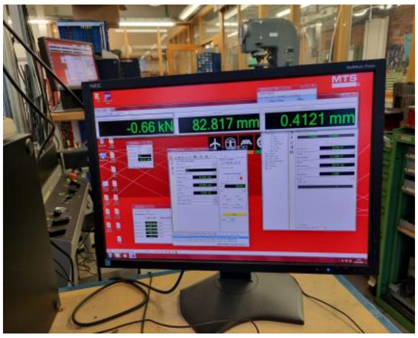
To participants

Report on an interlaboratory comparison (ILC) of the calibration in the force area

(Concerning the calibration of a tensile testing machine)

10 MN Machine

500 kN Machine



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Content

Abstract

This report presents the outcome of an intercomparison/ILC in calibrating 2 different tensile testing machines.

The calibrated objects:

- Compression and tension on a 500 kN machine, type Lebow Axial LC
- Compression on an 8 MN machine, MTS Storebror LC

The comparison focused on the stated indication errors found by the participants with respect to their own reference load cells and their reported measurement uncertainties.

The outcome of this comparison is presented by showing those data in tables and diagrams thus giving a qualitative picture of the conformity between the laboratories work. It is, however, custom to also inform about quantitative measures how close or distant the various results are from a reliable reference incorporating the stated uncertainties as well. This is typically accomplished using the En-criteria for each participant and each measuring point.

In a comparison of this kind, it is not possible to provide such a neutral reference from a laboratory with high credibility. The only way to achieve asked En-values is to determine a refence value for every indication error as a consensus value based on the available calibration data delivered by the participants. Such a consensus value is quite trouble-free if the results do not differ much and have comparable uncertainties. It is also easy to accept such a reference when results differ, but the number of participants is large enough to use statistical methods for deriving a mean and eventually excluding some outlying result based on statistical tests.

In the current comparison the number of results is small, and the results differ to an extend that is not really covered by the reported uncertainties. Given these conditions it is still possible to derive reference values to present quantitative measures to review the participants results (see below for details).

The number of participants were 6 and coming from Denmark, Sweden, Estonia, Rumania, and Kenya.

Two of the laboratories participated to confirm their CMC values that they will use in their application for accreditation and the other 4 wanted to validate that their CMC values are relevant.

The calibrations were made on 8 measurement points in both tension and compression.

These comparison results are presented in all together 21 tables and 24 diagrams. Not all six participants managed to perform all the stipulated calibration points.

There are 96 En values established and 25 are above 1.

Purpose and implementation of the comparison

This interlaboratory comparison serves as a tool to verify results from the calibrations carried out by calibration laboratories. It is an effective method to demonstrate the 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

A part of the work as an accredited organiser of proficiency testing schemes (PT/ILC) is to establish professional reference groups related to the actual subject.

The advisory group in this case consists of Aykurt Altintas, Denmark, Peter Lau MNE Konsult and Håkan Källgren Swedish Metrology and Quality.

The intercomparison has followed the recommendations of the advisory group. The advisory group has defined the choice of measuring points to be included in the evaluation of the results. Some lower values were added later because some laboratories had problems to reach the high values.

Information about the testing machines that were calibrated.

The machines that were used in this intercomparison (ILC) are installed at KTH Royal Institute of Technology in Stockholm.They are normally used for studies by students and research in several different areas.

Participants in the intercomparison and time schedule.

Date	Lab	Force 500 kN	Force 8 MN
Week 16			
2023-04-17	Preparations		
2023-04-18	Force Technology, Denmark	X	X
2023-04-19			
2023-04-20	MTS System AB, Sweden	X	X
2023-04-21	RISE Research Institutes of Sweden	X	X
Week 17			
1023-04-24	AS Metrocert Estonia	X	
2023-04-25-27	KENYA BUREAU OF STANDARDS, Kenya	X	X
2023-04-26-27	SARTOROM IMPEX SRL, Romania	X	

This intercomparison was originally initiated by a laboratory wanting an intercomparison/ILC for higher forces than 1 MN.

The leader of SMQ Håkan Källgren was present all the time to handle practical issues such as confidentiality and practical planning. The head of KTH laboratory Martin Öberg gave a lot of support in installation of equipment and running the machines during the calibrations but was not allowed to support the calibrations itself.

Calibration instructions

The basic instructions to participate in the intercomparison were found here: [ILC in force, torque, hardness, and related areas – SMQ Conference (smquality.se)]

The laboratories were advised to use their own calibration procedures with focus on agreed calibration points described below.

They should use their own mechanical equipment and the software they normally use. The KTH laboratory had earlier produced some fitting equipment that gave all laboratories possibilities to connect their reference loadcells to the machines.

Agreed calibration points.

Force compression, kN	Force tension, kN	Force compression, kN
0	0	0
-25*	25*	-200
-50	50	-400
-75*	75*	-600
-100	100	-800
-200	200	-1000
-300	300	-2000
-400	400	-4000
-500	500	-5000
0	0	-6000

Note: 2 extra calibration points marked * are not included in the relevant ISO Standards, but they were requested by the participants. The calibration points on the 10 MN-machine were changed according to the capacity of the participants.

Planning and instruction details

For protocolling the participants received excel sheets (enclosed in Annex) to fill in and deliver to the organizer before leaving the site.

The participants were asked to send calibration certificates to the organiser within one week after finishing the calibration.

Administrative information

Address to send the required documents:
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Analysis of the calibration results using En-values

For a quantitative description of the comparison outcome En-values were calculated for all participants (eq. 1) and all calibration points. This measure uses the deviation of a reported indication values from a derived reference value. By dividing this deviation for each calibration point with the uncertainty in this difference it is possible to set limits for a reasonably allowed discrepancy with respect to the reported measurement uncertainty.

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

x_i: Single measurement result (error of indication); the index i counts the various participants.

x_{ref}: Calculated inter-comparison reference value – based on a chosen consensus.

U_i: The estimated expanded uncertainty (k=2) stated by each laboratory for each calibration point.

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

The indication error is the difference between the individually recorded instrument readings (force or length) and the records from the reference equipment used by the participants for their calibration. A calibration result is generally accepted if its En-value is between -1 and +1. In this comparison all indication errors were presented in relative units, i.e. the actually registered values were divided by the actual reference value.

Assigned inter-comparison reference value for consensus.

The preferred option to assign a reference value is to use the weighted mean among the presented calibration results for each measurement point. The main argument is that it in contrast to the arithmetic mean also considers the stated uncertainty with each result. Consequently, results having low uncertainties can dominate this reference drastically over those results stated with larger uncertainties. This is a fair decision if all uncertainties are credible. A prerequisite, however, is that results with low uncertainty need to lie closer to the reference they form as results with larger uncertainties. If they do not fulfil this claim, they must be excluded from taking part in building the consensus value. The decision whether a result must be excluded is based on a chi-square test that determines if all values in the tested data sample belong to the same distribution with a certain probability. If this is not the case one results must be removed and the test be repeated. Eventually more than one results must be discarded from the data sample until the rest is regarded as consistent. For a large sample this method is very useful and convincing. For small samples as in this comparison it is not transcendent. Any statistical treatment is simply problematic if a consensus must be built on 4 or 3 of 5 results or eventually only 2 of 4 results. Not only the calculated consensus is questionable its uncertainty is as well. As it is based on the uncertainties of the remaining results in the sample it might be unreasonably low compared to the spread in the sample.

Another way to form a consensus value disregarding the reported uncertainties is to use the arithmetic mean. In this case its uncertainty depends on the spread in the sample, meaning the reference uncertainty can be too large for a reliable En-calculation. Before using the arithmetic mean of a sample eventual outlier too must be detected and removed. This is decided using Grubb’s outlier test. Here a result lying most distant from the mean is statistically tested based on the samples standard deviation. Failing the test means it must be as well excluded from the calculation of the mean and eventually a new test is performed on the rest. Even here small samples do not provide reliable statistics and the uncertainty of such a calculated consensus value is mainly due to the spread in the remaining sample.

To make sensible En-calculations here a subjective decision was taken to suggest using a combination of both options (500 kN-machine). This combination uses the average of both the alternatively calculated consensus values and their respective uncertainties as reference for every measurement point between -500 and 500 kN of the smaller force machine. For the 10 MN force machine, however, the weighted mean was used. There are further methods to distil a reference value out of a sample, but they all face the same statistical deficit with few results in a sample.

Weighted mean value and its uncertainty.

$$\boldsymbol{x_{wm}} = \frac{\frac{x_1}{u^2(x_1)}+\frac{x_2}{u^2(x_2)}+\cdots+\frac{x_n}{u^2(x_n)}}{\frac{1}{u^2(x_1)}+\frac{1}{u^2(x_2)}+\cdots+\frac{1}{u^2(x_n)}} \quad \text{(eq. 2)} \qquad u(\boldsymbol{x_{wm}}) = \sqrt{\frac{1}{\frac{1}{u^2(x_1)}+\frac{1}{u^2(x_{12})}+\cdots+\frac{1}{u^2(x_n)}}} \quad \text{(eq 3)}$$

Arithmetic mean value and its uncertainty.

$$\boldsymbol{x_m} = \frac{x_1+x_2+\cdots.+x_n}{n} \quad \text{(eq.4)} \qquad u(x_m) = \frac{s}{\sqrt{n}} = \frac{\sqrt{\frac{(x_1-x_m)^2+(x_2-x_m)^2+\cdots+(x_n-x_m)^2}{n-1}}}{\sqrt{n}} \quad \text{(eq. 5)}$$

Suggested refence value as combination between weight and arithmetic mean and its uncertainty

$$x_{ref} = \frac{x_{wm}+x_m}{2} \quad \text{(eq. 6)} \qquad U_{ref} = 2 \cdot u_{ref} = 2 \cdot \frac{u(x_{wm})+u(x_m)}{2} \quad \text{(eq. 7)}$$

x_{wm}	weighted mean with standard uncertainty $u(x_{wm})$
x_m	arithmetic mean with standard uncertainty $u(x_m)$
x_i	single participant result with standard uncertainty $u(x_i)$ (k=1)
s	sample standard deviation
n	number of results in sample
x_{ref}	combined reference value
U_{ref}	Expanded uncertainty of combined reference value (k=2)

Traceability of reference values

The traceability of the reported values was demonstrated by the participants via documenting their reference equipment in their calibration certificates. The laboratories equipment was calibrated by accredited laboratories or National Metrology Institutes.

Comments on the set up of equipment and use of references.

The laboratories used different types of mechanical attachments for their reference load cells.
The number of load cells used to cover the expected force range varied from 1 to 3.

Some laboratories used the same load cell both for compression and tension.

Most of the laboratories used a warming up procedure by loading the load cell 3 times to maximum load.

Calibration of 10 MN-force machine in compression mode – 4 participants

The machine has a capacity of 10 MN but was used up to 6 MN in this intercomparison)

An overview of all results is given in diagram 1. All participants reported the indication error and the stated uncertainty in relative units, i.e. in percent of the applied force. These data were translated to absolute values in kN-units for diagram 1, because in that way it is easier to see the actual agreement.

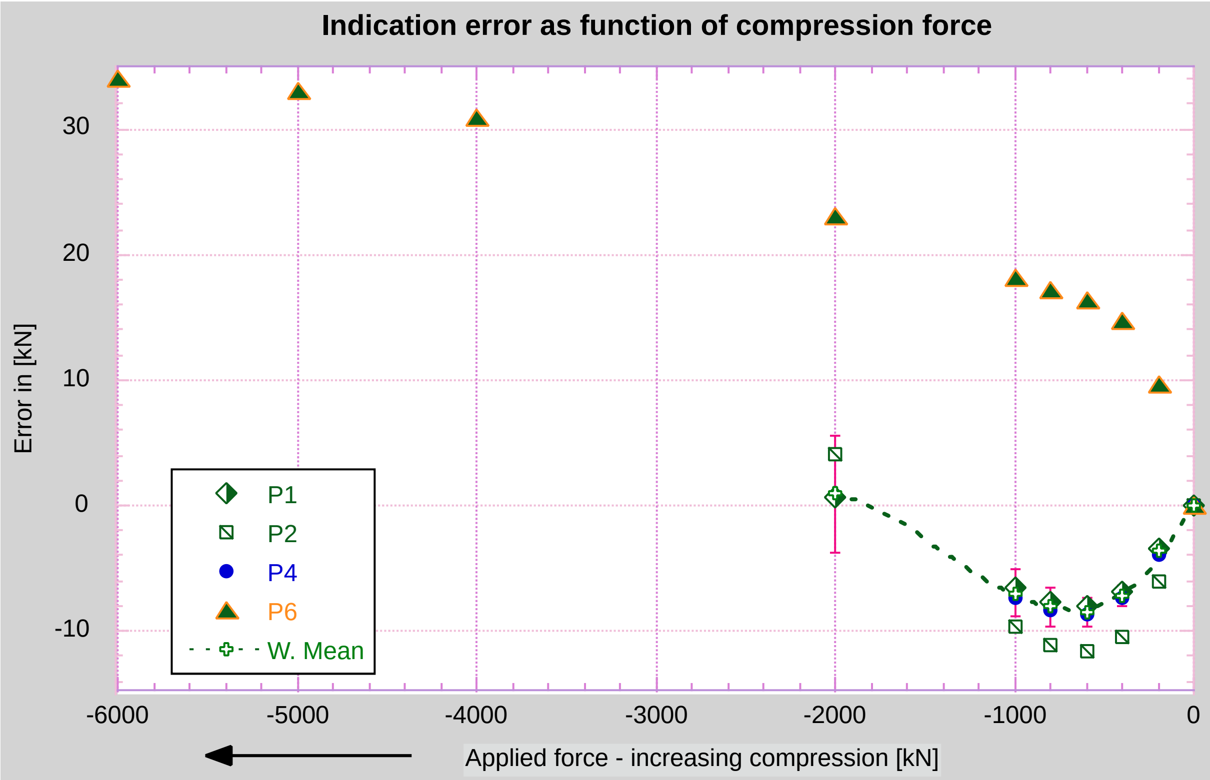


Diagram 1. Compression is indicated with -sign. Three results match quite well but one indicates a totally different behaviour. None of those three participants had reference loadcells for compression forces above 2000 kN. The reference points shown are determined as the weighted mean and shown with their uncertainties. A dashed line is fitted to them.

Compression machine 10 MN named MTS Storebror LC

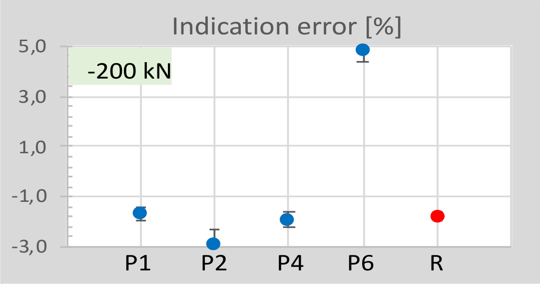
As many force machines can work in both tension and compression mode the later direction is often distinguished with a -sign. In the received calibration certificates both + and -signs were used. This has critical influence on the calculation of the found indication error. Given the absolute value of the machine reading is larger than that of the reference load cell the error definition (object reading minus reference reading) produces a positive error if using no sign but a negative error when using the -sign. Thus, the error definition in compression must be changed when using the -sign. This was somewhat confusing and resulted even in entering the data in the wrong column of the excel protocol.

The results of this part of the inter-comparison are presented in 6 tables and corresponding diagrams. The participants are numbered in arbitrary order. The calibration was planned for 6 force levels and at zero. One laboratory P6 added three extra points up to 6 MN. The coloured data columns are also given as diagram. The symbol R stands for reference value x_{ref} (weighted mean) throughout the force interval. It is indicated in red in the diagrams.

Table 1 Reported error at 200 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-1,68	0,26	**0,33**
P2	-2,95	0,63	**-1,76**
P4	-1,94	0,31	**-0,41**
P6	4,80	0,40	**14,75**
R	-1,79	0,20	

Diagram 2.

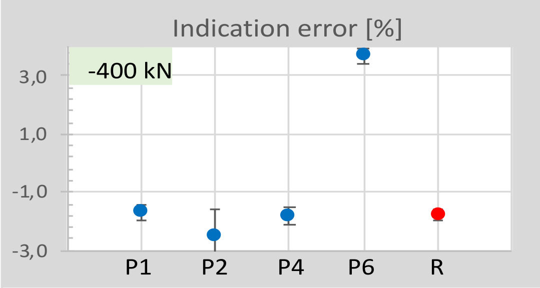


Comment: P6 is a clear outlier (Chi-square test) which is obvious for the eye, and it was excluded from the determination of x_{ref}. Due to the large difference in the results its uncertainty bars are hard to show.

Table 2. Reported error at 400 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-1,69	0,25	**0,26**
P2	-2,53	0,98	**-0,76**
P4	-1,82	0,30	**-0,13**
P6	3,68	0,25	**17,41**
R	-1,77	0,19	

Diagram 3.

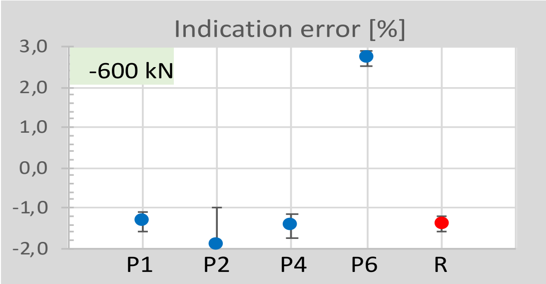


Comment: The scale is changed between the diagrams; that they all look quite alike is because the relative error does not increase with increasing force as the absolute error does.

Table 3. Reported error at 600 kN.

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-1,33	0,24	**0,20**
P2	-1,92	0,95	**-0,55**
P4	-1,43	0,30	**-0,11**
P6	2,72	0,18	**15,96**
R	-1,39	0,18	

Diagram 4.

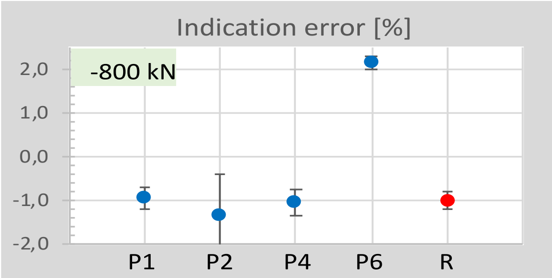


Comment: All data, especially the reference values are calculated with more decimals than shown in the tables.

Table 4. Reported error at 800 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-0,95	0,24	**0,16**
P2	-1,37	0,95	**-0,38**
P4	-1,04	0,30	**-0,11**
P6	2,15	0,16	**12,92**
R	-1,00	0,18	

Diagram 5.



Comment: One laboratory has mentioned that their load cell below 800 kN is not included in their accreditation scope but the outcome is kept in the result for information and future adaption.

Table 5. Reported error at 1000 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-0,66	0,24	**0,12**
P2	-0,95	0,91	**-0,27**
P4	-0,72	0,30	**-0,09**
P6	1,81	0,16	**10,27**
R	-0,69	0,18	

Diagram 6.

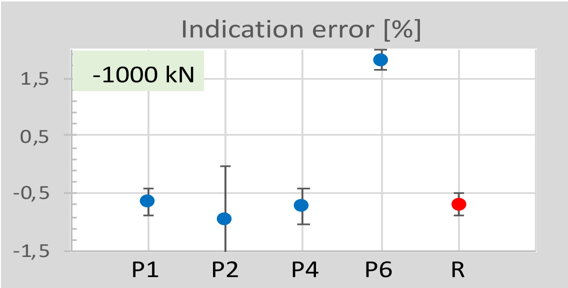
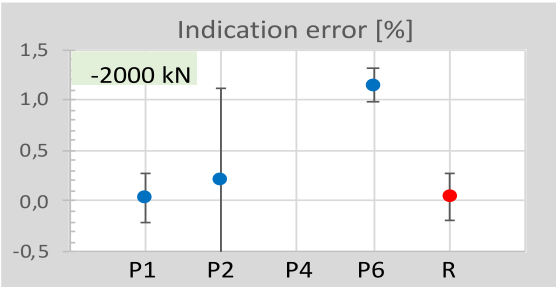


Table 6. Reported error at 2000 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,04	0,24	**-0,03**
P2	0,21	0,92	**0,17**
P4			
P6	1,15	0,16	**3,92**
R	0,05	0,23	

Diagram 7.



Comment: The lacking results for P4 means their loadcell could not reach 2 MN. The diagrams all look alike due to that two or three results are close to each other but a fourth is distant. The small sample size is a major reason that the uncertainty of the reference value only is slightly lower than that of the results that contribute to it. Looking to the En-definition this leads to lower values than if the reference uncertainty had been 1/3 of the lowest participant uncertainty, which is desirable. This mean all En-values with participant uncertainties close to that of the reference are somewhat mor optimistic due to this fact. To exemplify this effect, one can look at the results of P1 and P4 at 200 kN. Had Uref been 1/3 of Ui then for P1 the En-value of 0,33 would have been 0,39. For P4 En -0,41 would change to -0,47. Thus one can conclude that all accepted En-values would still be clearly below ±1 had the reference uncertainty been as low as wished.

Compression and tension machine –Lebow Axial LC 500 kN

An overview of all participant results is given in diagram 8. It shows the reported indication errors in kN at all eight levels at increasing compression and tension. The reference values shown as crosses with the corresponding uncertainty bars were determined as a combination of weighted mean and arithmetic mean values as explained above.

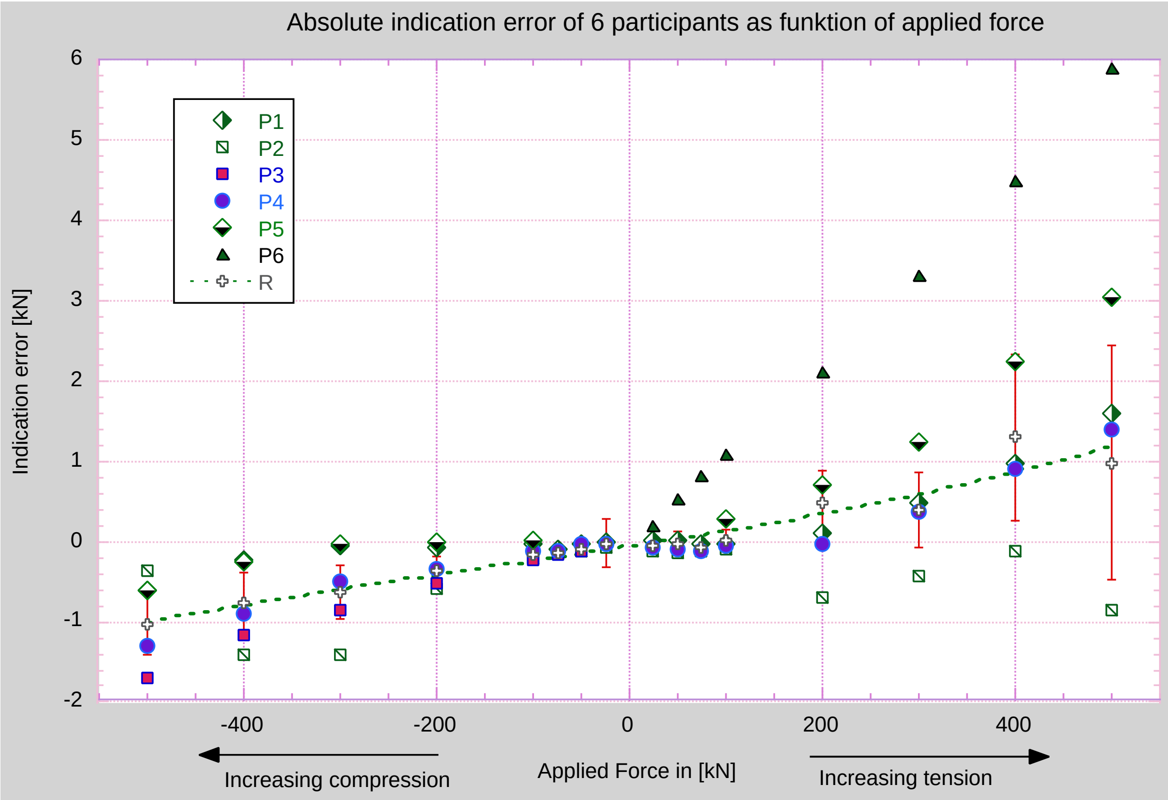


Diagram 8. Collection of all reported errors together with the calculated reference values (crosses) at each applied force point. A simple polynomial is fitted to these points and the uncertainty staples are set out.

Comment: Whereas the compression side shows a reasonable consensus the tension side exhibits considerable spread. Perhaps, one would expect a better agreement in tension due to a less problematic force application on the participants reference loadcells. Some participants also stated lower uncertainties in tension mode. Whereas the variation in the uncertainty claims in tension mode was lower than in compression mode the actual spread in the results was between 3 to 5 times bigger in tension mode. This made it difficult to find a good consensus in this small sample. When performing the Grubb's test for a maximum in tension mode it was always close to the border sometimes accepting sometimes rejecting it as outlier.

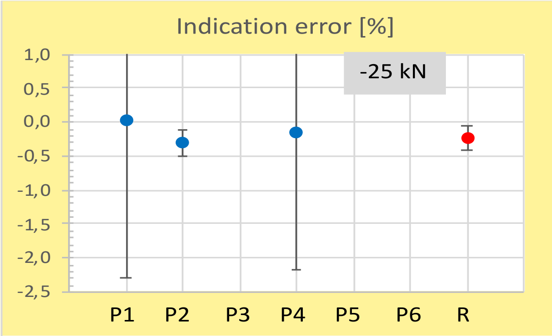
Compression

This force machine was first calibrated in compression mode from zero to -500 kN. The calibration after a new zeroing in tension mode up to 500 kN was also performed in 8 steps at predefined pressure levels. Most of the participants used different reference load cells for compression and tension and some even used different load cells in one direction due to the better uncertainty in low and high region respectively. Some participants made use of the -sign in compression, but most did not follow this convention. The results of the comparison are listed in 16 tables and 16 diagrams half in both force directions.

Table 7. Reported error at -25 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	0	2,3	**0,10**
P2	-0,31	0,19	**-0,29**
P3			
P4	-0,17	2,0	**0,03**
P5			
P6			
R	-0,23	0,18	

Diagram 9. Compression mode

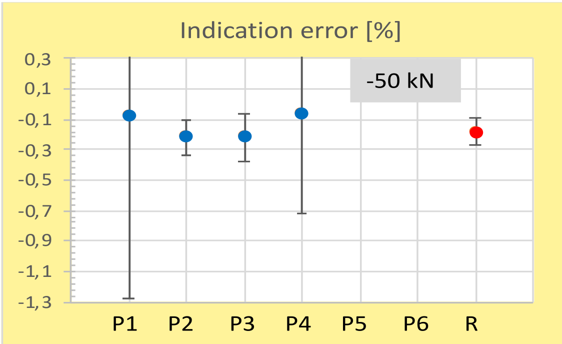


Comment: Altogether 6 participants took part in this calibration. One, P6 only calibrated the tension side of the force machine. Two others P3 and P5 started first at higher forces.

Table 8. Reported error at -50 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,08	1,2	**0,08**
P2	-0,22	0,11	**-0,28**
P3	-0,22	0,16	**-0,21**
P4	-0,06	0,66	**0,18**
P5			
P6			
R	-0,18	0,09	

Diagram 10. Compression mode

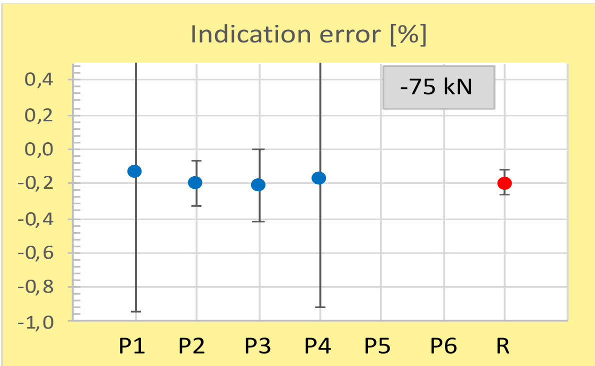


Comment: As can be seen the reported errors are comparable, the stated uncertainties on the other hand differ considerably. Consequently, even the determined reference value as the combination of weighted and arithmetic mean obtains an uncertainty that is not much lower than that of P2 and P3. Looking to En-criteria their low En-value is slightly favoured by that fact. However, they are clearly acceptable. This statement is valid for all following tables.

Table 9. Reported error at -75 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,13	0,81	**0,07**
P2	-0,20	0,13	**-0,06**
P3	-0,21	0,21	**-0,10**
P4	-0,17	0,75	**0,03**
P5			
P6			
R	-0,19	0,07	

Diagram 11. Compression mode

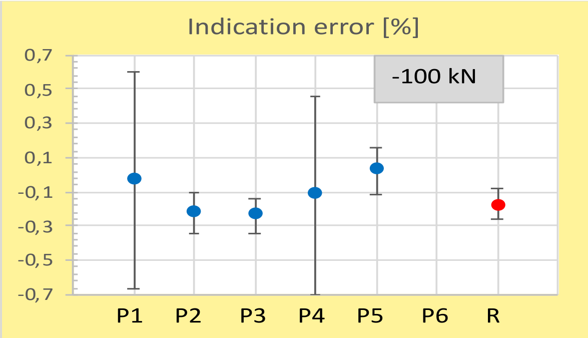


Comment: All tabled values, especially the reference values are calculated with a higher resolution than shown here. A manual recalculation of the En-values from the tabled data will give a slightly different result.

Table 10. Reported error at -100 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,03	0,63	**0,22**
P2	-0,22	0,12	**-0,31**
P3	-0,24	0,10	**-0,50**
P4	-0,12	0,58	**0,09**
P5	0,02	0,14	**1,17**
P6			
R	-0,17	0,09	

Diagram 12. Compression mode

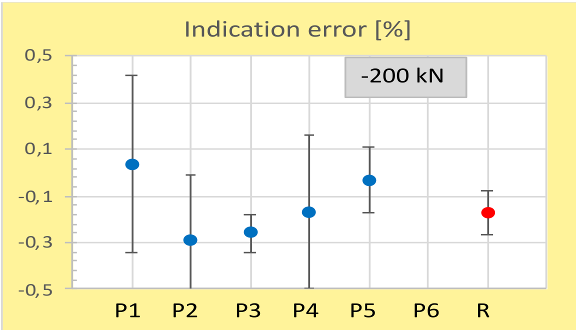


Comment: Participant P5 could first start its calibration at this pressure level.

Table 11. Reported error at -200 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	0,035	0,38	**0,53**
P2	-0,29	0,28	**-0,40**
P3	-0,26	0,08	**-0,70**
P4	-0,17	0,33	**0,01**
P5	-0,03	0,14	**0,82**
P6			
R	-0,17	0,10	

Diagram 13. Compression mode

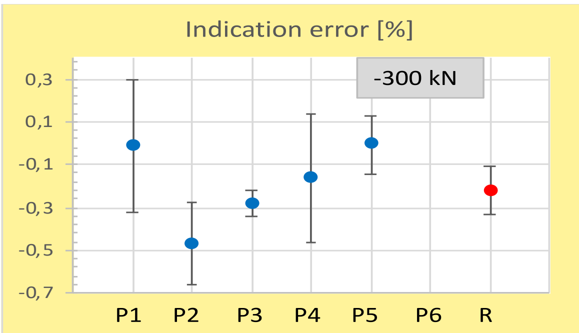


Comment: The scale of the diagrams is changed between pressure levels to resolve the spread and the uncertainties. The optical impression of increasing spread with increasing compression is true.

Table 12. Reported error at -300 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,017	0,31	**0,61**
P2	-0,47	0,19	**-1,14**
P3	-0,28	0,06	**-0,50**
P4	-0,17	0,30	**0,16**
P5	-0,01	0,14	**1,17**
P6			
R	-0,22	0,11	

Diagram 14. Compression mode

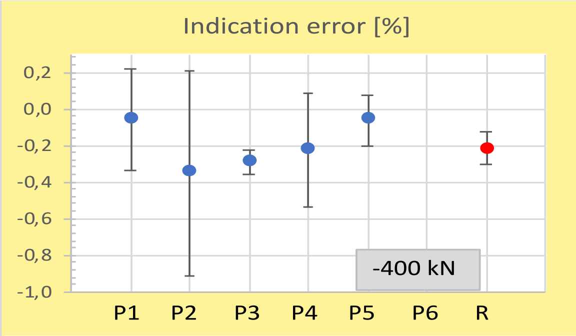


Comment: As all participants reported both the indication error and the uncertainty in percent of the applied pressure this way is followed here as well. This gives the impression that the uncertainties are rather the same over the pressure range, in absolute kN this is not the case.

Table 13. Reported error at -400 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,06	0,28	**0,54**
P2	-0,35	0,56	**-0,23**
P3	-0,29	0,07	**-0,65**
P4	-0,22	0,31	**-0,02**
P5	-0,06	0,14	**0,94**
P6			
R	-0,22	0,09	

Diagram 15. Compression mode

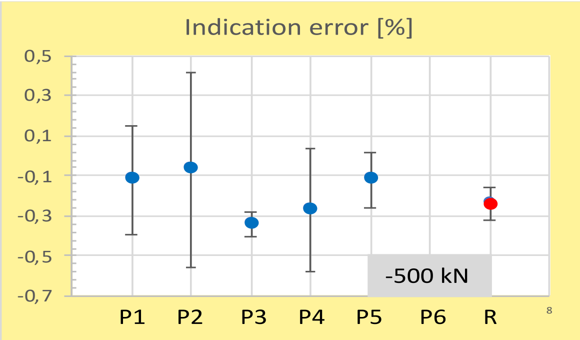


Comment: A En-value below 1 (absolute) optically means the uncertainty staple of a result needs to almost touch the reference value (red colour) in the diagrams.

Table 14. Reported error at -500 kN

Partici-pant	Stated indi-cation error [%]	Stated uncertainty [%]	En-value
P1	-0,12	0,27	**0,43**
P2	-0,07	0,49	**0,34**
P3	-0,34	0,06	**-1,02**
P4	-0,27	0,31	**-0,09**
P5	-0,12	0,14	**0,75**
P6			
R	-0,24	0,08	

Diagram 16. Compression mode



The consensus values for this force machine were evaluated in three version a) based on the weighted mean, b) as the arithmetic mean and c) as the combination of both. For the various reference values alternative c) was chosen as a compromise. This is a quite unorthodox way. It was applied simply to find a reasonably fair way to deal with the spread in the results in comparison with the partly optimistic uncertainty claims. For both constructions a Chi-square and a Grubb's outlier test were applied. For the Grubb's test, that only focuses on the distance from the reference, three results (max or min) were excluded with respect to the samples standard deviation (out of 16 force levels). Concerning the Chi-square test, that also takes the uncertainty of results into consideration, 8 participant results were excluded at the same 16 force levels. Further 6 lying on the edge should have been excluded as well to strictly follow the test, simply because their uncertainties were too low. But they were kept. It was mainly on the tension side 25 to 500 kN the dispersion was cumbersome to find an acceptable reference. The main reason seems to be that the participants in tension mode generally stated lower uncertainties 0,35 % than in compression mode 0,41 % both at average. But the range in uncertainty statements ($Ui_{max} – Ui_{min}$) was with 2,24 % in both parts very large.

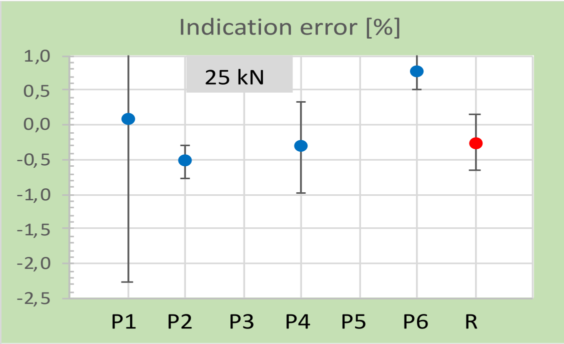
Tension

In compression mode the adjustment of the reference load cell for introducing the force as central as possible is expected to be a critical part of the calibration. In tension mode it was assumed that this would be less troublesome. The following results seem not to confirm this. Again, the calibration was performed in the same steps after zeroing both the reading of the force machine and the reference load cells.

Table 15. Reported error at 25 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,07	2,32	**0,13**
P2	-0,53	0,24	**-0,60**
P3			
P4	-0,32	0,65	**-0,09**
P5			
P6	0,77	0,26	**2,14**
R	-0,25	0,40	

Diagram 17. Tension

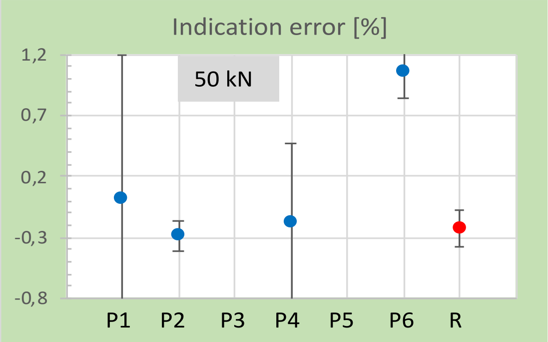


Comment: Participant P3 could not use his load cells in tension mode. The opposite was true for participants P6 who was active in this part of the comparison. Participant P5 could only achieve results from 100 kN upwards so that in the lower part 4 and in the upper force range 5 results respectively can be compared.

Table 16. Reported error at 50 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,01	1,18	**0,19**
P2	-0,29	0,13	**-0,36**
P3			
P4	-0,18	0,65	**0,06**
P5			
P6	1,05	0,21	**4,92**
R	-0,22	0,15	

Diagram 18. Tension



Comment: The reference uncertainty is not as one would wish always smaller than the reported ones from the participants. This is partly most probably caused by too small participant uncertainties and partly by the spread in the result which by far exceeds the reported uncertainties.

Table 17. Reported error at 75 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-0,03	0,81	**0,14**
P2	-0,18	0,15	**-0,19**
P3			
P4	-0,15	0,36	**0,00**
P5			
P6	1,11	0,23	**4,88**
R	-0,15	0,11	

Diagram 19. Tension

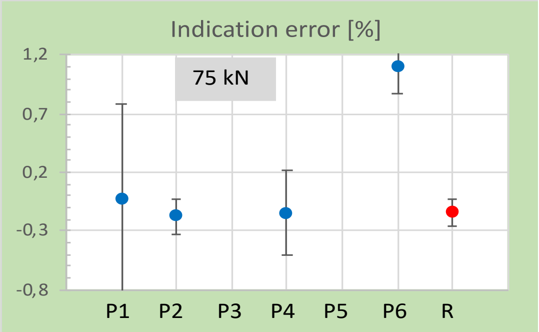
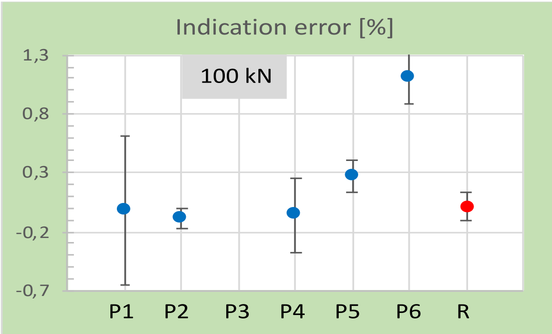


Table 18. Reported error at 100 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	-0,03	0,63	**-0,07**
P2	-0,09	0,09	**-0,71**
P3			
P4	-0,06	0,32	**-0,22**
P5	0,27	0,14	**1,39**
P6	1,10	0,21	**4,49**
R	0,02	0,12	

Diagram 20. Tension

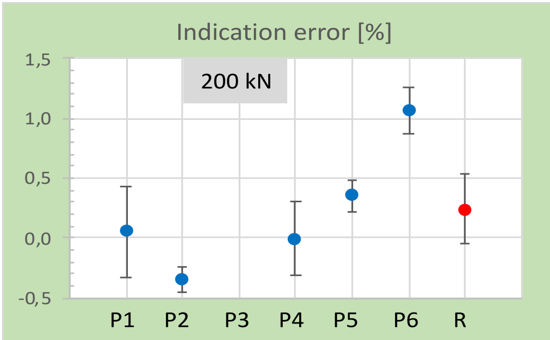


Comment: Compared to the compression mode there is a larger variation in the results, which grows with increasing pressure.

Table 19. Reported error at 200 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,06	0,38	**-0,39**
P2	-0,35	0,11	**-1,87**
P3			
P4	-0,01	0,31	**-0,59**
P5	0,35	0,14	**0,32**
P6	1,06	0,19	**2,31**
R	0,24	0,30	

Diagram 21. Tension

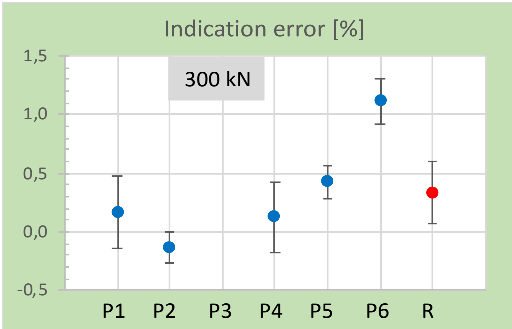


Comment: In all tables the En-values calculated with Ui ≈ Uref or smaller look somewhat better than had been the case when Uref always were clearly lower than the Ui's. But in none of these situations the En-value would come close to 1. And in cases where |En| > 1 this aspect is not relevant.

Table 20. Reported error at 300 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,16	0,31	**-0,42**
P2	-0,14	0,13	**-1,58**
P3			
P4	0,12	0,30	**-0,52**
P5	0,42	0,14	**0,27**
P6	1,11	0,19	**2,34**
R	0,34	0,27	

Diagram 22. Tension

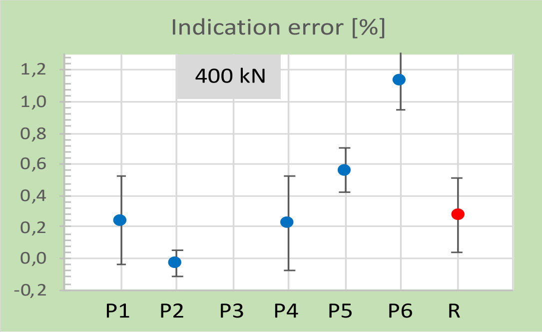


Comment: The comparable large uncertainty of the reference reduces the calculated En-values in some cases. On the other hand, larger participant uncertainties would have lowered it. Both aspects compensate each other and allow to take the presented values as credible..

Table 21. Reported error at 400 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,24	0,28	**-0,10**
P2	-0,03	0,08	**-1,25**
P3			
P4	0,23	0,30	**-0,14**
P5	0,56	0,14	**1,04**
P6	1,14	0,19	**2,85**
R	0,28	0,23	

Diagram 23. Tension

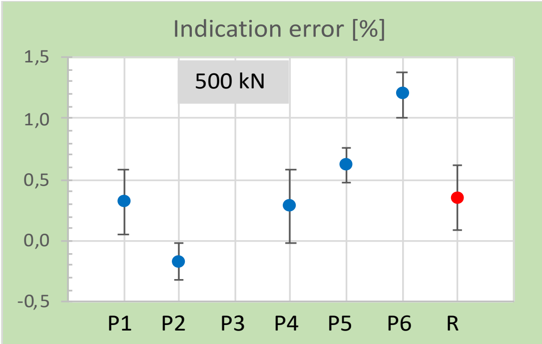


Comment: Using relative units for the indication error leaves the impression of a quite steady reference between the different levels. This is, however, an erroneous point of view. The reality is better seen in diagram 8.

Table 22. Reported error at 500 kN

Participant	Stated indication error [%]	Stated uncertainty [%]	En-value
P1	0,32	0,27	**-0,09**
P2	-0,17	0,15	**-1,70**
P3			
P4	0,28	0,30	**-0,18**
P5	0,61	0,14	**0,85**
P6	1,19	0,18	**2,59**
R	0,35	0,27	

Diagram 24. Tension



Corrections/changes after participant comments to the draft report

After receiving all participants comments on the draft one table 9 was exchanged. The reference value, its uncertainty and the calculated En-values were correct with one exception. For P4 a tabled indication error was falsely linked into the evaluation table.

All diagrams 26 to 32 were exchanged. Now they show better upper and lower limits and a higher resolution on the y-axis. However, no data were changed.

Certificates

-- not a part of the intercomparison

The calibration certificates showed a large variety and contained headlines which have no self-evident definition in a metrological sense. Is it questionable if a user of the equipment can draw correct conclusions how to correct for a measurement reading, especially if neither a correction nor an error is explicitly expressed. Maybe the classification of the machine is good enough for the user?

Some laboratories documented 3 calibration tests and the mean value in the force calibrations.

The error and uncertainty are normally given in % as the ISO 7500-1:2018 prescribes this but some laboratories gave the absolute value as well.

Several laboratories classified the machine according to ISO 7500-1:2018 but different decisions are given from class 0,5 to class 2 by different laboratories.

Some laboratories indicated the force from the calibrated machine by a minus or plus sign and others not. This will probably confuse the user of the machine when the purpose is not mentioned. For a customer both a negative and positive error should not be a problem if they know the convention used. A problem, however, occurs if the error is not explicitly stated in the certificate and the result tables use not clearly defined headlines. In that case a -sign exaggerates the problem of interpretation.

One laboratory indicated the decision rules in a sketch and related the decisions to the ISO standard and the ASTM standard in the classification.

Some comments on implementation of ISO standards

(Not a part of the intercomparison)

All laboratories handled the temperature effect on the load cells by keeping the load cells inside the laboratory building at least one night before the calibration day.

Temperature was measured during the calibration on the surface of the load cell or in the room where the machines are situated. One laboratory looked at the temperature change inside the load cell by looking at changes in the mV signal at no load.

All laboratories waited at least 30 minutes after connection of signal cables and power on transducers before the starting the operations.

All laboratories exercised the machine and the connected load cell 3 times before starting the calibrations.

Final conclusions

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

As a result of this intercomparison the following can be pointed out:

Results on compression 6 MN	7 En-values of 23 are higher than 1.
Results on compression 500 kN	4 En-values of 36 are higher than 1.
Results on tension 500 kN	14 En-values of 37 are higher than 1.

The participants shall evaluate their results according to the requirement in EN ISO 17025:2017 point 7.7.3 in relation to the En-values and their CMC values.

Acknowledgement

Kungliga Tekniska Högskolan,KTH made this intercomparison possible as their machines could be used as the machine in the intercomparison.

A special thanks to Martin Öberg that supported all laboratories to run the machines and support in arranging he equipment in a safe way.

We gratefully thank the member of the advisory board and expert in pressure calibrations Aykurt Altintas, Denmark as well as the main evaluator of the results Peter Lau (Aykurt did not participate in evaluation of the result as Force was one of the participants).

Annex

ILC force 2022:2 Calibration of force and extension on a static tensile testing machine

KTH Stockholm April 2023

Liten Dragprovmaskin Type BZ2.5/TN1S VideoXtens

Reporting form for preliminary calibration results

Laboratory:		Comparison ID
Name:		
e-mail:		
Reporting date:		

Liten Dragprovmaskin **Date of calibration**

Force calibration - increasing compression

Compulsory calibration points	Reference gauge value	Indicated measure-ment value	Indication error absolute	Relative display deviation	Stated measurement uncertainty	
[kN]	[kN]	[kN]	[kN]	[%]	[kN]	[%]
0						
-25						
-50						
-75						
-100						
-200						
-300						
-400						
-500						
0						

Please do not perform any adjustments and state average values

Please state no. of repetitions

Comments or additional information:

Force calibration - increasing tension

Compulsory calibration points	Reference force value	Indicated measure-ment value	Indication error absolute	Relative display deviation	Stated measurement uncertainty	
[kN]	[kN]	[kN]	[kN]	[%]	[kN]	[%]
0						
25						
50						
75						
100						
200						
300						
400						
500						
0						

Please state average values

Comments or additional information:

Length calibration - extensiometer

Compulsory calibration points	Reference force value	Indicated measure-ment value	Absolute display deviation	Relative display deviation	Stated measurement uncertainty	
[mm]	[mm]	[mm]	[∝m]	[%]	[∝m]	[%]
1						
2						
3						
4						
5						
10						
12,5						

Please state no. of repetitions

Stor Dragprovmaskin

Force calibration - increasing compression

Compulsory calibration points	Reference force value	Indicated measure-ment value	Indication error absolute	Relative display deviation	Stated measurement uncertainty	
[kN]	[kN]	[kN]	[kN]	[%]	[kN]	[%]
0						
100						
200						
400						
600						
800						
1000						
2000						
5000						
8000						
0						

Please state no. of repetitions

Comments or additional information:

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 7500-1:2018 calibration of force machines