



**To participants**

## **Report on an interlaboratory comparison (ILC force 2022:3) on 1000 N-Part 1**

**Part 1 covering 1000 N load cell using a distributed amplifier**

Part 2 will cover 100 N load cell using a distributed amplifier

Part 3 will cover 100 and 1000 N load cell without distributed amplifier and will not be published as there was only one participant



The bags carrying the equipment for calibration.

**Author**

Håkan Källgren

Swedish Metrology and Quality AB

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## ***Abstract***

This report is about an inter-comparison/ILC of two load cells with 5 participating laboratories.

The load cells were calibrated with a possibility to calibrate the load cells either separate or with a circulated amplifier. Part 1 of the report covers the results on the 1000 N load cell together with the circulated amplifier.

Calibration should be done in tension and compression.

The calibration was documented by the reading and its uncertainty at all calibrations points. This 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.

RISE (Swedish National Metrological Institute) and HBM calibrated the sensor before 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.

The report covers 8 forces on compression and tension on the 1000 N load cell.

Of a total number of 80 results by calibration laboratories using the supplied amplifier were all laboratories getting En values below 1.

## ***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 force 2022:3 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 force 2022:3 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](https://smquality.se) and enclosed to this report the reporting forms as annex 2 and appendix 1.

### ***Object***

Load cells 100 N and 1000 N as well as an amplifier



### ***Participating laboratories and measuring scheme for the comparison***

| <b>Laboratory</b>                         |
|-------------------------------------------|
| RISE, reference laboratory Sweden and HBM |
| CA Mätssystem AB, Sweden                  |
| Element Metech, Sweden                    |
| Teknologiskt Institut, Denmark            |
| TAP air Portugal                          |
| LABORATRONIC Poland                       |
| RISE, reference laboratory Sweden         |

The circulation ended in week 20 in 2024.

All participants are accredited by SWEDAC, PCA, COFRAQ and DANAK.

The reference laboratory RISE, Sweden has the status as a National Metrology Institute, NMI.

### ***Principles concerning the calibration in general.***

The reference laboratories 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.

### ***Compulsory calibration points***

The participants were asked to calibrate at the following points both at tension and compression.

Range: 0-1000 N

Calibration points: 100, 200, 300, 400, 500, 600, 800 and 1000 N

### ***Calibration instructions***

The laboratories were allowed maximum 10 days for each calibration. In the call they were advised to use their own calibration procedures with focus on the 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.

The prepared excel sheets documented the results 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<br>Håkan Källgren<br>Dragspelsgatan 21<br>SE-504 72 Borås, Sweden<br>e-mail: <a href="mailto:hakan.kallgren@smquality.se">hakan.kallgren@smquality.se</a><br>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 are 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 17043:2022 in the reporting.

As an easy-to-understand measure to judge each result of the participant 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).

$$E_n = \frac{x_i - x_{ref}}{\sqrt{U_i^2 + U_{ref}^2}} \quad (\text{eq. 1})$$

$x_i$  Single measurement result indication the various participants..

$x_{ref}$  Assigned inter-comparison reference value for calibration point.

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

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

$E_n$  The calculated En value at actual point.

### ***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.

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

For each instrument

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

$j$ : Counting points.

$R_{1,j}$  &  $R_{2,j}$ : The assigned comparison reference values provided by the reference laboratories at start and end.

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).

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

For each instrument

$U_j$ : 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.

The data supplied by the reference laboratory indicated a small drift which, however, on the limit of the always was within the stated uncertainty. 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.

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

For details se appendix 2

### ***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.

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

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  $U_i$ .

### ***Measuring results on calibration in the ILC***

The following tables 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.

The following tables are built with increasing participant identity numbers (but not in chronicle order) and list at the bottom the belonging reference value based on the average of two calibrations by the reference laboratory.

The laboratories will get their identity code by separate mails.

The load cells were new and not used before. The amplifier was from Force in Denmark.

**1000 N load cell with supplied amplifier.****Table 1 tension 100 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -0,20005   | 0,0001           | 0,04     |
| 5              | -0,20005   | 0,00400          | 0,00     |
| 6              | -0,20011   | 0,00016          | 0,33     |
| 7              | -0,20000   | 0,004            | 0,01     |
| 8              | -0,200003  | 0,00010          | 0,46     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -0,200055  | 0,000050         |          |

**Table 2 tension 200 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -0,4001    | 0,0002           | 0,17     |
| 5              | -0,40018   | 0,00800          | 0,01     |
| 6              | -0,40019   | 0,00028          | 0,19     |
| 7              | -0,40009   | 0,008            | 0,01     |
| 8              | -0,400060  | 0,00020          | 0,36     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -0,400135  | 0,000060         |          |

**Table 3 tension 300 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -0,60015   | 0,0003           | 0,19     |
| 5              | -0,60025   | 0,01201          | 0,00     |
| 6              | -0,60025   | 0,00040          | 0,10     |
| 7              | -0,60009   | 0,012            | 0,01     |
| 8              | -0,600107  | 0,00030          | 0,33     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -0,600210  | 0,000090         |          |

**Table 4 tension 400 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -0,80018   | 0,0004           | 0,19     |
| 5              | -0,80003   | 0,01600          | 0,01     |
| 6              | -0,80028   | 0,00053          | 0,04     |
| 7              | -0,80012   | 0,016            | 0,01     |
| 8              | -0,800133  | 0,00040          | 0,31     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -0,800260  | 0,000115         |          |

**Table 5 tension 500 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -1,00018   | 0,0005           | 0,16     |
| 5              | -1,00023   | 0,0200           | 0,00     |
| 6              | -1,00028   | 0,00065          | 0,02     |
| 7              | -0,99999   | 0,020            | 0,01     |
| 8              | -1,000107  | 0,00050          | 0,31     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -1,000265  | 0,000130         |          |

**Table 6 tension 600 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -1,20012   | 0,0006           | 0,19     |
| 5              | -1,2000    | 0,02400          | 0,01     |
| 6              | -1,20023   | 0,0077           | 0,00     |
| 7              | -1,19966   | 0,024            | 0,02     |
| 8              | -1,200043  | 0,00070          | 0,27     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -1,20024   | 0,000160         |          |

**Table 7 tension 800 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -1,59994   | 0,0008           | 0,16     |
| 5              | -1,60029   | 0,03201          | 0,01     |
| 6              | -1,60003   | 0,00101          | 0,04     |
| 7              | -1,59924   | 0,032            | 0,03     |
| 8              | -1,599840  | 0,00080          | 0,28     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -1,600075  | 0,000205         |          |

**Table 8 tension 1000 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | -1,99958   | 0,001            | 0,24     |
| 5              | -1,99927   | 0,03999          | 0,01     |
| 6              | -1,99963   | 0,00126          | 0,15     |
| 7              | -1,99861   | 0,040            | 0,03     |
| 8              | -1,999517  | 0,0010           | 0,30     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | -1,999825  | 0,000245         |          |

**Table 9 compression 100 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 0,2001     | 0,0001           | 0,00     |
| 5              | 0,19975    | 0,0040           | 0,09     |
| 6              | 0,20006    | 0,00016          | 0,24     |
| 7              | 0,19976    | 0,0040           | 0,08     |
| 8              | 0,20008    | 0,00010          | 0,19     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 0,20010    | 0,000040         |          |

**Table 10 compression 200 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 0,40015    | 0,0002           | 0,12     |
| 5              | 0,39987    | 0,0080           | 0,04     |
| 6              | 0,40012    | 0,00028          | 0,19     |
| 7              | 0,40004    | 0,0080           | 0,02     |
| 8              | 0,40012    | 0,00020          | 0,26     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 0,400175   | 0,000060         |          |

**Table 11 compression 300 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 0,60021    | 0,0003           | 0,10     |
| 5              | 0,60033    | 0,0120           | 0,01     |
| 6              | 0,60019    | 0,00040          | 0,12     |
| 7              | 0,60006    | 0,0120           | 0,01     |
| 8              | 0,60017    | 0,00030          | 0,23     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 0,600240   | 0,000080         |          |

**Table 12 compression 400 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 0,80028    | 0,0004           | 0,11     |
| 5              | 0,80046    | 0,0160           | 0,01     |
| 6              | 0,80025    | 0,00053          | 0,14     |
| 7              | 0,80034    | 0,0160           | 0,00     |
| 8              | 0,80023    | 0,00040          | 0,23     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 0,800325   | 0,000105         |          |

**Table 13 compression 500 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 1,00035    | 0,0005           | 0,10     |
| 5              | 1,00086    | 0,0200           | 0,02     |
| 6              | 1,00031    | 0,00065          | 0,14     |
| 7              | 1,00073    | 0,0200           | 0,02     |
| 8              | 1,00025    | 0,00050          | 0,29     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 1,00040    | 0,000140         |          |

**Table 14 compression 600 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 1,20042    | 0,0006           | 0,08     |
| 5              | 1,20165    | 0,0240           | 0,05     |
| 6              | 1,20036    | 0,00077          | 0,14     |
| 7              | 1,20107    | 0,0240           | 0,02     |
| 8              | 1,20029    | 0,00060          | 0,29     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 1,200470   | 0,000165         |          |

**Table 15 compression 800 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 1,60054    | 0,0008           | 0,09     |
| 5              | 1,60089    | 0,0320           | 0,01     |
| 6              | 1,60045    | 0,00101          | 0,16     |
| 7              | 1,60107    | 0,0320           | 0,01     |
| 8              | 1,60039    | 0,00080          | 0,27     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 1,600615   | 0,000230         |          |

**Table 16 compression 1000 N**

| Identification | Error mv/V | Uncertainty mv/V | En value |
|----------------|------------|------------------|----------|
| 2              | 2,0006     | 0,001            | 0,14     |
| 5              | 2,00195    | 0,0400           | 0,03     |
| 6              | 2,00051    | 0,00126          | 0,18     |
| 7              | 2,00109    | 0,0400           | 0,01     |
| 8              | 2,00045    | 0,00100          | 0,28     |
|                | <b>Ref</b> | <b>U</b>         |          |
|                | 2,000745   | 0,000285         |          |

**Comments on the calibration certificates**

-- not a part of the intercomparison

Some laboratories give the classification explaining in relation to ISO 376:2011 and the decision rule including an explanatory diagram.

Some laboratories refer to the specification from the manufacturer even if this was not asked in the intercomparison and decided if the equipment would pass or fail the specification.

Some laboratories are clearly explaining when the reference equipment is calibrated and when the next calibration shall be done

Most of the laboratories refer to EA-4/02 as a base for uncertainty evaluations.

Several laboratories explain clearly the used excitation voltage to be 5 V.

Some laboratories give the value on the object in mV/V und uncertainty in N

Some laboratories explain clearly that the result is the mean value of 3 measurements and documents the results in rotation angles 0, 120 and 240.

Used reference weights are explained in some cases

Uncertainty is expressed in fixed values and/or percentage.

Some laboratories document the MRA agreement in their calibration certificates.

All laboratories document temperature during the calibration.

Zero drift and interpolation effect are explained in some cases.

Most of the laboratories specified their uncertainty with 2 digits in the certificate, but some laboratories gave 1 or more significant digits.

Most of the laboratories gave both reading and uncertainty at zero while others did not indicate anything at the zero point.

All laboratories document the accreditation by their national accreditation body.

***Additions and changes to the first DRAFT report***

There are 16 loading points which are included in opposition to 6 in the DRAFT report.

The reporting will be subdivided into 3 reports and this report is part number 1.

Some results from one participant were misinterpreted and is updated

There are some redactional changes done as well.

***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.

Of a total number of 80 results by calibration laboratories using the supplied amplifier were all laboratories getting En values below 1.

**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.

We acknowledge support for the calculations and checking of the details made by Wilmer Manfredsson and Arvid Manfredsson.

Annex 1 ILC force 2022:3

***Published on*** <https://smquality.se/>

Annex 2 Description of the intercomparison/ILC

***Published on*** <https://smquality.se/>

**Appendix 1 Reporting forms****ILC- Force 2022:3****Calibration of load-cell 1**

Between 0 and 100 N in both directions separately

Code to open the box: **504**Comparison  
ID **Documentation protocol for participant**

Laboratory:

Person:

e-mail:

Date:

|  |
|--|
|  |
|  |
|  |
|  |

**No adjustments allowed**  
**- no zeroing during the**  
**whole calibration procedure**

**Preferred excitation voltage**  
**5V AC 225 Hz**

**Only increasing load i calibration**

**Load cell 1****TENSION****use this table with own measurement equipment**

| Obligatory calibration points | Applied reference force | Average signal* Xr from signal amplifier ** | Stated*** measurement uncertainty of mV-signal |
|-------------------------------|-------------------------|---------------------------------------------|------------------------------------------------|
| [N]                           | [N]                     | [mV/V]                                      | [mV/V]                                         |
| 0                             |                         |                                             |                                                |
| 10                            |                         |                                             |                                                |
| 20                            |                         |                                             |                                                |
| 30                            |                         |                                             |                                                |
| 40                            |                         |                                             |                                                |
| 50                            |                         |                                             |                                                |
| 60                            |                         |                                             |                                                |
| 80                            |                         |                                             |                                                |
| 100                           |                         |                                             |                                                |

\* Please state for each force level the average from three mounting angles

\*\* Report the difference between the recorded mV-signal and the actual zero-value at start of each series.

\*\*\* Only for tension application

**Load cell 1****COM-  
PRESS-  
ION****when using own measurement  
equipment**

| Obligatory calibration points | Ap-<br>plied<br>refe-<br>rence<br>force | Average<br>signal* Xr<br>from sig-<br>nal ampli-<br>fier ** | Stated***<br>measure-<br>ment un-<br>certainty of<br>mV-signal |
|-------------------------------|-----------------------------------------|-------------------------------------------------------------|----------------------------------------------------------------|
| [N]                           | [N]                                     | [mV/V]                                                      | [mV/V]                                                         |
| 0                             |                                         |                                                             |                                                                |
| -10                           |                                         |                                                             |                                                                |
| -20                           |                                         |                                                             |                                                                |
| -30                           |                                         |                                                             |                                                                |
| -40                           |                                         |                                                             |                                                                |
| -50                           |                                         |                                                             |                                                                |
| -60                           |                                         |                                                             |                                                                |
| -80                           |                                         |                                                             |                                                                |
| -100                          |                                         |                                                             |                                                                |

\*\*\*Only applied to com-  
pression**Load cell 1****TENS-  
ION****use this table with supplied amplifier**

| Obligatory calibration points | Ap-<br>plied<br>refe-<br>rence<br>force | Average<br>signal* Xr<br>from sig-<br>nal ampli-<br>fier ** | Stated***<br>measure-<br>ment un-<br>certainty of<br>mV-signal |
|-------------------------------|-----------------------------------------|-------------------------------------------------------------|----------------------------------------------------------------|
| [N]                           | [N]                                     | [mV/V]                                                      | [mV/V]                                                         |
| 0                             |                                         |                                                             |                                                                |
| 10                            |                                         |                                                             |                                                                |
| 20                            |                                         |                                                             |                                                                |
| 30                            |                                         |                                                             |                                                                |
| 40                            |                                         |                                                             |                                                                |
| 50                            |                                         |                                                             |                                                                |
| 60                            |                                         |                                                             |                                                                |
| 80                            |                                         |                                                             |                                                                |
| 100                           |                                         |                                                             |                                                                |

**Load cell 1****COM-  
PRESS-  
ION****use this table with supplied amplifier**

| <b>Obligatory calibration points</b> | <b>Ap-<br/>plied<br/>refe-<br/>rence<br/>force</b> | <b>Average<br/>signal* Xr<br/>from sig-<br/>nal ampli-<br/>fier **</b> | <b>Stated***<br/>measure-<br/>ment un-<br/>certainty of<br/>mV-signal</b> |
|--------------------------------------|----------------------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------|
| <b>[N]</b>                           | <b>[N]</b>                                         | <b>[mV/V]</b>                                                          | <b>[mV/V]</b>                                                             |
| 0                                    |                                                    |                                                                        |                                                                           |
| -10                                  |                                                    |                                                                        |                                                                           |
| -20                                  |                                                    |                                                                        |                                                                           |
| -30                                  |                                                    |                                                                        |                                                                           |
| -40                                  |                                                    |                                                                        |                                                                           |
| -50                                  |                                                    |                                                                        |                                                                           |
| -60                                  |                                                    |                                                                        |                                                                           |
| -80                                  |                                                    |                                                                        |                                                                           |
| -100                                 |                                                    |                                                                        |                                                                           |

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