TECHNICAL PROTOCOL

**FORCE SUPPLEMENTARY COMPARISON**

**SIM.F.S.XX (1 000 kN)**

**Pilot Laboratory**

Instituto Nacional de Metrología de Colombia, (INM)

Instituto Nacional de Tecnología Industrial, (INTI)

INTI

Force Laboratory

(Version 2)

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**Table of Contents:**

[1.- Participants laboratories 3](#_Toc144717396)

[2.- General Information 4](#_Toc144717397)

[3.- Measurement device 4](#_Toc144717398)

[4.- Transport of devices and schedule 5](#_Toc144717399)

[5.- Preparation of measurement 6](#_Toc144717400)

[6.- Measurement protocol 6](#_Toc144717401)

[7.- Measurement results, uncertainty, and evaluation 7](#_Toc144717402)

[8.- Results evaluation 8](#_Toc144717403)

[9.- References: 8](#_Toc144717404)

[Appendix A 8](#_Toc144717405)

# 1.- Participants laboratories

Reference Laboratory: National Institute of Standards and Technology (NIST) – Maryland - USA

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# 2.- General Information

This force supplementary comparison will be carried out between the *National Institute of Standards and Technology* (NIST) of USA as the reference laboratory, the *Instituto Nacional de Tecnología Industrial* (INTI) of Argentina and *Instituto Nacional de Metrología* (INM) of Colombia as the pilot laboratories, the Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO) of Brazil, the *Centro Nacional de Metrología* (CENAM) of México, the *Instituto de Investigaciones y Control del Ejército* (IDIC) of Chile, the *Instituto Ecuatoriano de Normalización* (INEN) of Ecuador, and the *Laboratorio Costarricense de Metrología* (LACOMET) of Costa Rica.

This supplementary comparison will be carried out in conjunction with the key comparison SIM.F.K.XX (1000 kN).

For this comparison, INM will provide one force transducer with 1000 kN as nominal force value.

# 3.- Measurement device

For this comparison, it was selected one reference force transducer with the following characteristics:

Table 1. Details of the measurement device

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Manufacturer** | **Model** | **Serial** | **Capacity** | **Picture** |
| HBM | C18 | 00283N54 | 1000 kN |  |

Fitting pads (load button and thrust piece) and the connection cable are provided by the laboratory. Each laboratory must check that all load transfer surfaces, both transducer and the reference machine used are clean and in good conditions before mounting and measuring. The transducer must be carefully mounted, paying special attention to its alignment in the machine before starting the measurements.

Each laboratory will use its own DMP40/DMP41 amplifier. They will be operated according to the following setup:

* Supply voltage: 110 / 220-240 V at 50/60 Hz
* Excitation voltage: 5 V at 225 Hz
* Measuring range: 2.5 mV/V
* Low-pass filter: 0,22 Hz Bessel[[1]](#footnote-1).
* Resolution: 0.000001 mV/V
* Measurement mode: Absolute
* Auto-calibration: On[[2]](#footnote-2)
* Measuring channel: Defined by each laboratory[[3]](#footnote-3)

*Note: If you need to use a different amplifier, it will be necessary to ensure that its configuration is compatible with the previous setup.*

In addition, an HBM BN100A calibrator device will be sent with the force transducer to control de Laboratory amplifier(s) used.

# 4.- Transport of devices and schedule

The comparison is organized in a two-loop. Each laboratory will have one month to make its measurements and to prepare for transportation to the next participant. The schedule was designed to fit within the preferences of the laboratories for scheduling the measurements and any changes to the schedule, after the start of the circulation, will be discussed and agreed upon among the participants and the TC-F (Technical Committee - Force) chairman. The reference laboratory, NIST, NIST will make three measurements to check the stability of the Travelling Standard, and the reference value will be the average of these three measurements.

Once a participant has completed their measurements and is ready to ship the traveling standards the next scheduled participant along with the pilot institute should be notified. All items should be inspected and packed into the original carrying case and sent to the next participant promptly to avoid delay.

The devices will be shipped in watertight cases. The measurement scheme will be:

Table 1.- Planning of the measurements and declared uncertainties.

|  |  |
| --- | --- |
| **Laboratory** | **Date** |
| NIST – Initial Measurement | August 2023 |
| CENAM | October 2023 |
| INM | September 2023 |
| IDIC | December 2023 |
| NIST – Mid measurement | January 2024 |
| INTI | February 2024 |
| INMETRO | March 2024 |
| LACOMET | April 2024 |
| INEN | May 2024 |
| NIST – Final measurement | June 2024 |

*Please see the key comparison SIM.F.K.XX protocol in order to obtain more mandatory information.*

# 5.- Preparation of measurement

After receiving the transducers, all devices will be kept at laboratory conditions. The following minimum time intervals are recommended before measurement:

*7 days since the devices traveled by air, 3 days in the laboratory facilities, 24 h in the laboratory where the measurements will be made, as close as possible to the machine to be used, 12 h mounted in the measurement position and connected to the digital amplifier to be used.*

The measurement temperature range is 20.0 ºC ± 1.0 K*.*

The measurement protocol must be carried out without interruptions in each mounting position. Between the ending of one mounting position and the start of the next, it should not take more than 5 minutes. If this time is exceeded, it is recommended to carry out at least one additional preload without being recorded.

All readings must be recorded in the measurement protocol. The 0.22 Hz Bessel filter will be used, unless there is a problem related to it, in which case a 0.1 Hz or 0.45 Hz Bessel filter will be used instead. For this reason, it is recommended to pay special attention that the force is stable and there are no disturbances at least 30 s before recording the value, including the autocalibration of the amplifier.

The air temperature near the force transducer in ºC will be recorded with each measured value, excluding preloads. The relative humidity in % and the air pressure in hPa will be recorded at the beginning and at the end of measurements.

A verification of the amplifier(s) using the BN100A will be performed before starting the measurements and upon completion of the measurements.

The thrust piece will be mounted so that the mark made on it is aligned with the cable connector. When the transducer is rotated, clockwise viewed from above, the thrust piece will rotate with it to keep the mark aligned with the cable connector.

# 6.- Measurement protocol

The following measurement schedule was agreed:

All pre-loadings and measurement series are carried out in the same time interval, which is three minutes between taking values. This time includes the time needed to change the load and its stabilization. The value is taken just before starting the load change.

The measurements are carried out in the following force steps:

0, 200 kN, 400 kN, 500 kN, 800 kN, 1000 kN

The measurement sequence is as follows:

0º Preload at 1000 kN (Three times)

0º 0, 200 kN, 400 kN, 500 kN, 800 kN, 1000 kN, *800 kN, 500 kN, 400 kN, 200 kN, 0* (Twice)

90º Preload at 1000 kN (Once)

90º 0, 200 kN, 400 kN, 500 kN, 800 kN, 1000 kN, 0 (Twice)

180º Preload at 1000 kN (Once)

180º 0, 200 kN, 400 kN, 500 kN, 800 kN, 1000 kN, 0 (Twice)

270º Preload at 1000 kN (Once)

270º 0, 200 kN, 400 kN, 500 kN, 800 kN, 1000 kN, 0 (Twice)

The measurement data must be recorded raw in the “*SC\_SIM-1MN\_Protocol.xslx*” spreadsheet "*raw\_data*" tab, which will be delivered by the pilot laboratory. There will be another tab where laboratories using reference comparison machines RT-FCM can enter the raw values received from their amplifiers and the calculated force value of their reference machine. This is done to trace calculation errors during the analysis of this comparison.

# 7.- Measurement results, uncertainty, and evaluation

Deflections are calculated from the readings. Each deflection value is defined as the reading at the force step minus the corresponding zero reading before applying the force step.

Measurement results are calculated from the original readings. The measurement result is the mean deflection calculated from the eight measured values in four mounting positions of the force transducer.

The measurement uncertainty is calculated for the mean deflection measured from the transducer.

The reference value (NIST) will be corrected linearly in time due to the temporal drift that is part of the loop in which each laboratory measures.

Only ascending runs will be part of the mean values. No temperature correction will be performed because the thermal coefficient of the transfer transducer is unknown. The DMP40/DM41 amplifiers will be corrected based on the measurements taken with the BN100A.

The uncertainties to be considered by each laboratory will be based in Euramet cg/04 guide. The sources to consider will be:

* Laboratory CMC, as declared in Table 1.
* Reproducibility.
* Resolution.
* Amplifier checks using BN100A (Instability of the BN100A itself).
* Temperature.
* Long term drift. A rectangular distribution will be taken.

The following parameters will be indicated in the report but will not be quantified within the measurement uncertainty:

* Repeatability.
* Reversibility.
* Linearity, through the differences obtained using a third-degree interpolation curve with or without an intercept term.

*Note: The uncertainty due to temporal drift will be considered within the loop value corresponding to each laboratory. A rectangular probability distribution will be used because the loop time will exceed three months.*

# 8. Results evaluation

After taking the measurements and completing the spreadsheet, it will be sent to NIST within the 15 days after performing the measurement. Once INM and/or INTI have submitted their measurement data to NIST, they will be able to start receiving data from the other laboratories to initiate the analysis process.

INTI and INM will carry out the evaluation of this comparison.

The values to be compared will be the mean value between the initial and final measurements obtained at NIST corrected by temporal drift, this is the loop value, versus the mean value obtained at each laboratory. The normalized error will be used as an indicator of the results quality.

The goal is to have the initial calculations within 3 months after the completion of the measurements, followed by Draft A within 6 months, and Draft B within 9 months.

# 9 References

[1] CCEM Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons, 2007 (available on the BIPM website: http://www.bipm.org/utils/common/pdf/CC/CCEM/ccem\_guidelines.pdf)

[2] Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement (GUM), JCGM 100, First edition, September 2008 (available on the BIPM website: <http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf>)

[3] EA Publication EA-4/02, Expression of the Uncertainty of Measurement in Calibration

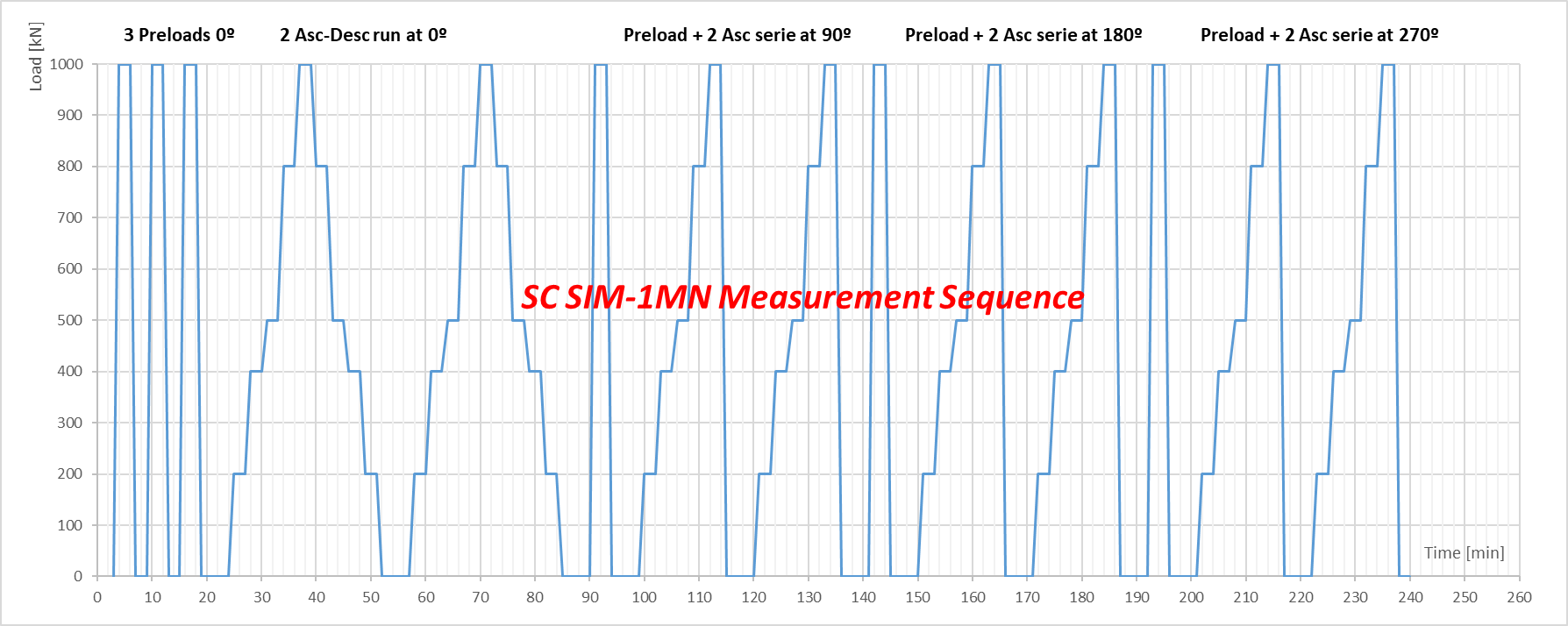
[4] ISO / IEC 17043 “Conformity assessment — General requirements for proficiency testing”, International Standardization Organization”, 2010

[5] EURAMET. (2022). *Guidelines on the Uncertainty of Force Measurements EURAMET Calibration Guide No. 4 Version 3.0 (02/2022).*

[6] CIPM MRA-G-11 − Measurement comparisons in the CIPM MRA, 2021

# Appendix A

The measurement sequence is exemplified in the following picture.



1. Depending on electrical and/or mechanical influences, another filter frequency could be chosen by the laboratory. [↑](#footnote-ref-1)
2. It is also allowed to perform the auto-calibration just after taking the value. [↑](#footnote-ref-2)
3. Only the transducer under measurement will be connected to the DMP40/DMP41 amplifier in the channel selected. [↑](#footnote-ref-3)