# SIM.M.F-S4

## FORCE NATIONAL STANDARDS COMPARISON IN THE INTERAMERICAN SYSTEM OF METROLOGY (SIM), 100 kN COMPRESSION

# FINAL REPORT

**Reference**

**Alejandro Savarin – Instituto Nacional de Tecnología Industrial**
**INTI, Argentina**

**Pilot**

**Juan Christian Villarroel Poblete – Instituto de Investigaciones y Control del Ejército**
**IDIC, Chile**

**Participants**

**Ivan David Betancur – Arístides Dájer Espeleta**
**Instituto Nacional de Metrología**
**INM, Colombia**

**July 2019**

**Abstract**

This force comparison was performed between IDIC (Chile), INTI (Argentina) and INM (Colombia), members of the SIM region. Each laboratory used its national standard for the established measuring range. The comparison started in August 2013 and finished in December 2013. This comparison has an overlap with the force steps used in the CIPM Key Comparison CCM.F-K2.a.1, at force points 50 kN and 100 kN.

# Contents

## 1. Introduction

Comparisons between National laboratories are being widely used by the National Institutes of Metrology as one of the main processes for the confirmation of technical competence. At the same time, they allow to know the degree of equivalence between laboratories, constituting a requirement of the Mutual Recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM), for the publication of the Measurement and Calibration Capabilities (CMCs) of each laboratory. The IDIC along with INTI will be in charge of the coordination and evaluation of the comparison program, which will follow this General Procedure.

## 2. Scope of the comparison

In order to compare and evaluate the compatibility of results for the reading taken in one transfer standard (Table 2), the comparison range was selected from 50 kN to 100 kN (starting at 50% of the full force transducer range). The results obtained by the participating laboratories agreed with the analysis of comparability performed by the normalized error equation (Equation 1). The reference value was the corrected value to the KCRV through the comparison CCM.F-K2.a.1 was taken as the reference value

## 3. List of Participants, facilities Used

INTI and INM used a Deadweight Machine (FSM) while IDIC used Reference Force Standard Machines (RFSM). The laboratories standards general information is listed in Table 1, the general information of the laboratories standards is listed and the declared uncertainties are taken from the KCDB databases.

***Table 1. Participating laboratories standards general information***

| Participant | Type of reference standard | Declared range | Reference standard uncertainty ($k$=2, %) | Date of Test |
|---|---|---|---|---|
| INTI (Argentina) | Deadweight Machine | 2 kN – 100 kN | 0,002 | February 2013 |
| INM (Colombia) | Deadweight Machine | 0,1 kN – 100 kN | 0,003 | April 2013 |
| IDIC (Chile) | Force Transfer Standard Machine | 5 kN – 500 kN | 0,05 | May 2013 |

## 4. Transfer Standard

The transfer standard was a compression force transducer. To close the transducer-amplifier loop, a BN100A Bridge Calibrator BN100A was used. Both of them belong to IDIC.

***Figure 1. Force transducer and bridge calibrator***

Basic technical specification:

***Table 2. Comparison equipment***

| Equipment | Model | Serial number | Manufacturer | Range |
|---|---|---|---|---|
| Force transducer | C4 | 023630004 | HBM | 100 kN |
| Bridge Calibrator | BN 100 A | 15140 | HBM | ± 2.5 mV/V |

## 5. Comparison Protocol

### 5.1. Before Calibration

- Prior to calibration, the transducer and BN 100 A should be plugged into the digital amplifier DMP 40 and energized, preferably overnight.
- The transducer should remain in the machine throughout this period in order to reach thermal equilibrium with the compression loading platen.
- The DMP 40 is set up for a 220 V energizing voltage. This can be changed to 110 V by altering the setup in its rear panel
- The DMP 40 must be set to absolute mode, with an energizing voltage of 10 V, and the 0.22 Hz Bessel filter selected.
- “Autocal” should also be on, but take care that readings are not being taken while the instrument is re-calibrating itself or while the filter is still refreshing.
- In order to evaluate the zero drift of the force transducer as the mean of the initial and final zeroes, the final zero reading at a given orientation should be taken prior to rotate the load cell assembly –which may allow to improve the uncertainty, if the zero output is drifting with time.
- The participant laboratories use their own digital amplifier DMP40 for the comparison. All the readings must be obtained in mV/V.

## 5.2. Environmental conditions

All the measurements should be obtained at a temperature of 20 ºC ± 2 ºC. The transfer standard must be conditioned in the calibration laboratory for at least 12 hours to homogenize its temperature to that of the laboratory. In case there are corrections for the effect of calibration temperatures that differ from the nominal value, the relative uncertainty estimates associated with these values were determinate from analysis of the linear fit results. Table 3 shows the data record.

***Table 3. Temperature (°C) in participating laboratories during measurements***

| NMI | Max | Min | Max-Min | Mean |
|---|---|---|---|---|
| **Argentina INTI** | 21,6 | 20,7 | 0,9 | 21,2 |
| **Colombia INM** | 20,0 | 19,6 | 0,4 | 19,7 |
| **Chile IDIC** | 20,2 | 19,9 | 0,3 | 20,1 |

## 5.3. Initial conditions for reading

The reading of the transfer standard for an applied force is the difference between the indicator signal when it is loaded minus the indicator signal when the load has not been applied. That is, the actual signal zero when the standard has no load This value of zero reading without the applied load must be recorded as soon as the transfer standard has arrived at the participant laboratory.

## 5.4. Measurement Procedure (Taking readings)

a. The transfer standard must be measured in eight different positions relative to the axis of the machine, that is: 0°, 60º, 90º, 120°, 180º, 240°; 300º and 360º.

b. One preload and one series of measurements (as shown for 60º in Figure 2 is carried out at all positions: 60º, 90º, 120°, 180º, 240°; 300º and 360º).
c. In order to minimize the influence of creep, the relative long reading period of six (6) minutes was selected according to the standard machine.
d. A diagram which describes the procedure to take the readings is shown in Figure 2.
e. The forces applied to the transfer standard are 50 kN and 100 kN.

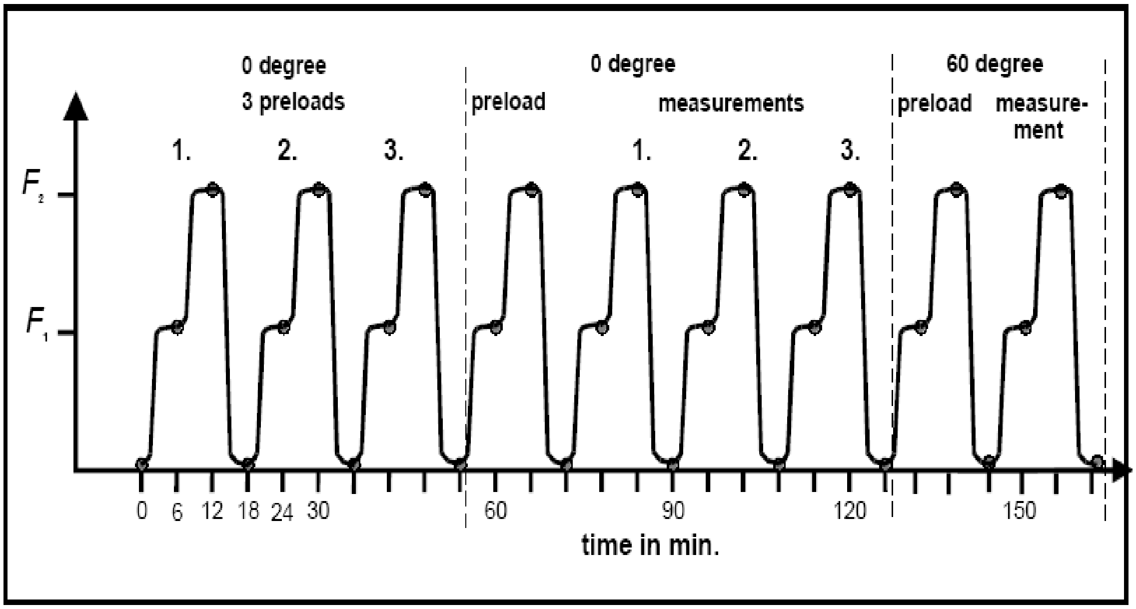



***Figure 2. Loading scheme with F1 = 50 kN and F2 = 100 kN***

## 5.5. Criteria for taking readings and force increments

The pilot laboratory will be in charge if making the analysis of the measurement results. The results will be error, uncertainty and compatibility of results of each laboratory with the reference values provided by the linking laboratory to CIPM comparison (INTI).

The results should be in accordance with the ISO Guide to the Expression of Uncertainty in Measurement, ISO-IECOIML-BIPM.

## 6. Results

### 6.1. Corrections

The average values compared are corrected. This correction is performed using the initial and final average zero, and then, it is corrected by the indication of the BN100A. It is not corrected by drift because there is no clear behavior.
The Reference value of INTI is corrected to the KCRV, according to CCM.F-K2.a.1.The next tables show the results for the two nominal values 50 kN and 100 kN for the participants

***Table 4. Corrected values to 50 kN***

| 50 kN | Corrected value for zero | Corrected value BN100A | Deviation from INTI |
|---|---|---|---|
| | mV/V | mV/V | mV/V |
| INTI | 1,000018 | 1,000022 | --- |
| INM | 1,000060 | 1,000061 | 0,000039 |
| IDIC | 1,000297 | 1,000307 | 0,000285 |

***Table 5. Corrected values to 100 kN***

| 100 kN | Corrected Value for zero | Corrected Value BN100A | Deviation from INTI |
|---|---|---|---|
| | mV/V | mV/V | mV/V |
| INTI | 2,000257 | 2,000272 | --- |
| INM | 2,000355 | 2,000364 | 0,000092 |
| IDIC | 2,000754 | 2,000760 | 0,000488 |

### 6.2. Uncertainty

There is an expanded relative uncertainty value for each mean deflection obtained in each participating laboratory, which is calculated in the same way, with contributions due to the applied force:

- The reproducibility of the readings

$$u_{rep} = \frac{S}{\bar{X} * \sqrt{3}}$$ *Equation 2*

Where: $S$ *is the standard deviation*

$\bar{X}$ *is the average value at the applied force*

- Resolution of the digital amplifier

$$u_{res} = \frac{r}{\bar{X} * \sqrt{3}} \qquad \textit{Equation 3}$$

Where: $r$ *is the resolution of the digital amplifier DMP40 ($r = 0.000001\ mV/V$)*
$\bar{X}$ *is the average value at the applied force*

- Temperature: this uncertainty is the difference between the average temperature for each laboratory and the reference temperature (20°C) (using a temperature coefficient of $10 \cdot 10^{-6}$ / ºC, provided by the manufacturer).

$$u_T = \frac{|T_l - 20°C| * 10}{1000000} \qquad \textit{Equation 4}$$

Where: $T_l$ *is the average temperature*

- Drift: taking $u_{drift} = 12 * 10^{-06}$
- Standard: CMC declared by each laboratory with *k* = 1, Table 1.

Temperature uncertainty is considered in all laboratories, while uncertainty due to drift is considered in all laboratories except in the reference.

***Table 6. Corrected values and expanded uncertainty***

| 50 kN | Corrected value to KCRV | $U$ $k$ = 2 |
|---|---|---|
| | mV/V | $1 \cdot 10^{-6}$ |
| INTI | 1,000037 | 31,7 |
| INM | 1,000061 | 39,1 |
| IDIC | 1,000307 | 500,8 |

***Table 7. Corrected values and expanded uncertainty***

| 100 kN | Corrected value to KCRV | $U$ $k$ = 2 |
|---|---|---|
| | mV/V | $1 \cdot 10^{-6}$ |
| INTI | 2,000310 | 32,1 |
| INM | 2,000364 | 39,0 |
| IDIC | 2,000760 | 500,8 |

## 7. Analysis

The degree of equivalence between the results of the measurements made by the participating laboratories was evaluated using the normalized error equation according to the following expression:

$$E_n = \frac{E_{lab} - E_{ref}}{\sqrt{U_{lab}^2 + U_{ref}^2}}$$

$E_n$ -Normalized error

$E_{lab}$ -Laboratory's estimated relative deviation

$E_{ref}$ –Reference value (deviation of the pilot laboratory)

$U_{lab}$ –Laboratory's expanded uncertainty

$U_{ref}$ –Reference's expanded uncertainty

According to the normalized error equation model, if -1 $\leq En \leq +1$ the results of the laboratories are compatible, and if -1 $> En > +1$ the results are not compatible. (ISO / IEC-17043: 2010).

Tables 8 y 9 show the results of the measurements made by the participating laboratories. The values obtained from the application of the normalized error equation method are also included in the last column.

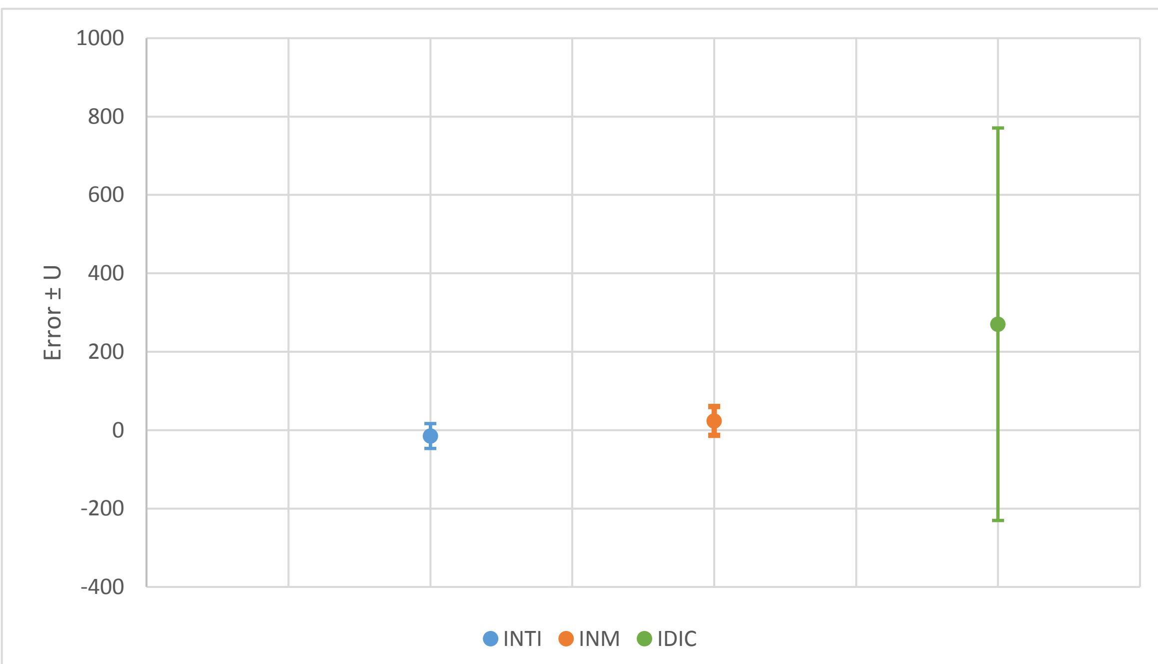
***Table 8. Normalized Error to 50 kN***

| 50 kN | Corrected Value to KCRV | *U* *k*=2 | Relative deviation KCRV | $E_n$ |
|---|---|---|---|---|
| | mV/V | $1 \cdot 10^{-6}$ | $1 \cdot 10^{-6}$ | |
| INTI | 1,000037 | 31,7 | -15 | ---- |
| INM | 1,000076 | 39,1 | 24 | 0,77 |
| IDIC | 1,000322 | 500,8 | 270 | 0,57 |

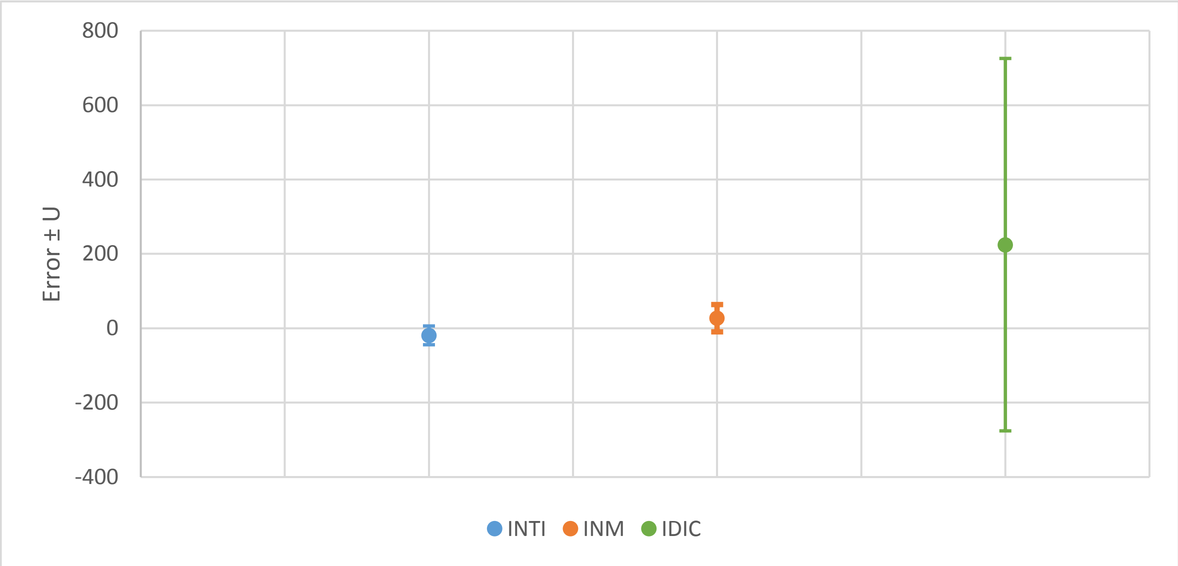
***Table 9. Normalized Error to 100 kN***

| 100 kN | Corrected value to KCRV | *U* *k*=2 | Relative deviation KCRV | $E_n$ |
|---|---|---|---|---|
| | mV/V | $1 \cdot 10^{-6}$ | $1 \cdot 10^{-6}$ | |
| INTI | 2,000310 | 32,1 | -19 | ---- |
| INM | 2,000364 | 39,0 | 27 | 0,91 |
| IDIC | 2,000760 | 500,8 | 225 | 0,49 |

***Graph 1. Uncertainty and Error at 50 kN***



***Graph 2. Uncertainty and Error at 100 kN***




## 8. CONCLUSIONS

- ✓ The approved technical approaches in the area of professional of participant laboratories by means of the understanding and real use of standards ISO 376:2011.
- ✓ It is verified that is another group trained professional group with domain in the area of calibration of force inside in SIM region.
- ✓ Consolidate it regional working net that allows reinforcing the working structure of the Interamerican Metrology System SIM.
- ✓ A good correspondence was found in the relative deviation of the force indicator. In conclusion it can be said that all results are reliable and comparable.
- ✓ From the results of the analysis of comparability, normalized error equation, it can be concluded that excellent agreement exist among the measurements carried between all participants in the whole range for this comparison.
- ✓ IDIC and INM have good agreement with INTI for the both force measuring range from 50 kN up to 100 kN.
- ✓ The uncertainties declared and the results shown support the CMCs declared in Appendix C of the CIPM MRPA published in the KCDB by participating laboratories.

## REFERENCES

[1] Alejandro Savarin, Nieves Medina, Andy Knott "Final Report Force Key Comparison CCM.F-K2.a.1 (50 kN and 100 kN)".

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[4] Torres-Guzman J. C., Sawla A., Ramirez Ahedo D. A., "Force Standards Comparison between PTB (Germany) and CENAM (Mexico)", Joint International Conference on Force, Mass, Torque, Hardness and Civil Engineering Metrology, IMEKO TC3/TC5/TC20, Celle, Germany. September 2002.

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