SIM.M.F-S10

TESTING MACHINE CALIBRATION IN COMPRESSION SIM COMPARISON UP TO 3 000 kN

Final Report

Pilot

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Abstract

A SIM comparison was performed in the field of testing machines calibration. In this case, a bilateral comparison between IDIC and CENAMEP AIP This comparison is registered in the BIPM key comparison database (KCDB) as supplementary comparison SIM.M.F–S10. It was conducted by IDIC (Chile) was the Pilot laboratory for this exercise.
The final report lists data about the indication error, uncertainties declared and the normalized error, obtained by the participating NMIs, as well as degrees of equivalence and levels of measurement agreement.

Contents

1. Introduction

The development and recognition of Chile's Laboratorio Custodio de Patrones Nacionales de Fuerza (National Force Standards Custodian Laboratory), IDIC, have contributed to the creation of training activities for technicians from other countries, providing them with knowledge and experience in this field. In this case, a bilateral comparison with CENAMEP AIP was conducted, following the supplementary comparison SIM.M.F-S1. This comparison aimed to study the reproducibility of the calibration method for testing machines based on ISO 7500-1:2018. The calibrations were performed in accordance with the internationally accepted document Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement (2008) and the standard ISO 17043:2010 Conformity Assessment – General Requirements for Proficiency Testing.
From the measurement results obtained by each laboratory, the following parameters were determined: indication error (q) and calibration uncertainty (u). The normalized error (En) was evaluated to assess the quality of measurement results between the laboratories. The results obtained, along with deviation graphs including the uncertainty for each laboratory, are presented in this document.
This work provides valuable information on the participants in the Force Calibration Machine Comparison to support future research aimed at reducing calibration uncertainty for customers' standards in the National Force Standards Laboratory of each country and declaring their Calibration and Measurement Capabilities (CMCs). The report presents the main results obtained during the testing machine calibration process.

2. Scope of the comparison

The calibration comparison was performed on a testing machine within the range of 300 kN to 2 700 kN. This range was selected because the machine's owner did not want tests conducted near the 3 000 kN limit. Nevertheless, sufficient data were collected for compression forces. The testing machine used for the comparison was a MATEST CYBER PLUS EVOLUTION, from the Elisa Diaz Company force laboratory. The force was generated by a piston-cylinder system, and the force indicator consisted of a 3 000 kN force transducer. The amplifier was configured in kN with a resolution of 0.1 kN.

The comparison covered a range from 300 kN to 2 700 kN. This upper limit was chosen because the machine's maximum capacity is 3 000 kN, and to ensure safe testing conditions, 2 700 kN was set as the final calibration point. These details are presented in Table 1.

Table 1. Comparison equipment

Equipment	Model	Serial number	Manufacturer	Range
Testing Machine	C071N	S/Nº	MATEST	3 000 kN

3. List of Participants, facilities Used

For this comparison IDIC and CENAMEP AIP, used force transducers with scopes up to 3 000 kN, IDIC used as amplifier a DMP40S2 and CENAMEP AIP a Scout55, both with communication filter 0.10 Hz. In table 2 and table 3, below, there are details about the standards and the date of the comparison.

Table 2. Participating laboratories standards general information

Participant	Type of reference standard	Declared range	Reference standard uncertainty in % (*k*=2)	Date of Test
IDIC (Chile)	Force Transducer	300 kN to 3 000 kN	0.042	2019-10-09
CENAMEP AIP (Panamá)	Force Transducer	300 kN to 3 000 kN	0.171	2019-10-09

4. Transfer Standard

Table 3. Transfer Standards.

Participant	Equipment	Model	Serial number	Manufacturer	Range
IDIC (Chile)	Force Transducer	C18	002866YT	HBM	3 000 kN
CENAMEP AIP (Panamá)	Force Transducer	C18	00288MJ6	HBM	3 000 kN

5. Comparison Protocol

5.1. Environmental conditions

All the measurements should be obtained at a temperature of 25ºC ± 2ºC. The force transducers and amplifiers required an environmental conditioning of at least one hour before the start of the calibration. According to the document ISO-7500-1:2018, during the calibration, we cannot exceed the difference between maximum and minimum temperature value of 2 °C. Table 4 shows the data record.

Table 4. Temperature (°C) in participating laboratories during measurements

NMI	Max	Min	Max-Min	Mean
Chile IDIC	25.1	24.3	1.5	24.7
Panamá CENAMEP AIP	25.6	24.4	1.2	25

5.2. Measurement Procedure (Taking readings)

Following a method based in the document ISO-7500-1:2018, we followed step by step statements presented below:

a. The first step is determining the resolution of the testing machine.
b. We need three preloads with the transducer at 0° of position before collect data evaluable.
c. After that, at the same position, 0°, we take the first of three series of measurements in increments discrete force values in a range between 300 kN up to 2 700 kN.
d. Then, it was necessary to rotate the force transducer 120° in position and preload, to take the second series in the same range as first.
e. And finally, we need to add 120° more rotated and another preload, in this case, the transducer rotated 240° of position in total; with the transducer at 240°, we take the third and last series of measurements.

IMPORTANT: For this comparison, the decrements force has not been evaluated.

6. Results

The evaluation of the measurement results was conducted in accordance with ISO 7500-1:2018, Annex C, *Uncertainty of the calibration results of the force-measuring system*. The relative expanded uncertainty is calculated with the equation:

$$U = k\sqrt{\sum_{i=1}^{n} u_i^2} \quad (1)$$

In (1), k=2, complemented the equation as coverage factor.

$$u_1 = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}(q_i - q)^2} \quad (2)$$

In (2), the term is known as repeatability uncertainty, q_i is the relative indication error for each series of measurements, and q represent the relative indication error mean.

$$u_2 = \sqrt{\left(\frac{a}{2\sqrt{3}}\right)^2 + \left(\frac{a_z}{2\sqrt{3}}\right)^2} \quad (3)$$

In (3), the component corresponds to resolution of testing machine, where a is relative resolution, and a_z is the relative resolution at zero force of the machine; in this case, the uncertainty component due a_z is zero.

$$u_3 = u_{trans} = \frac{U_{trans}}{2} \quad (4)$$

In (4), the component corresponds to force transducer calibration, where U_{trans} divided by the *k* factor,   is the relative expanded uncertainty of calibration of the transducer. The contribution of the force transducer (u_3) was calculated with the maximum figure of the class the device was rated. There are certain reasons to do this, because the conditions for calibration and the conditions in use on site are quite different, as there is a different time management, usually different ambient temperature, partial measuring range, etc.

The contributions for different temperatures and linear approximations are negligible in this case. The following tables show the results of the testing machine calibration. The original data is mostly expressed in mV/V. For the comparison all data are converted to kN using the inverse formula based on the calibration results of the force transducer.

Table 5. Results obtained by IDIC.

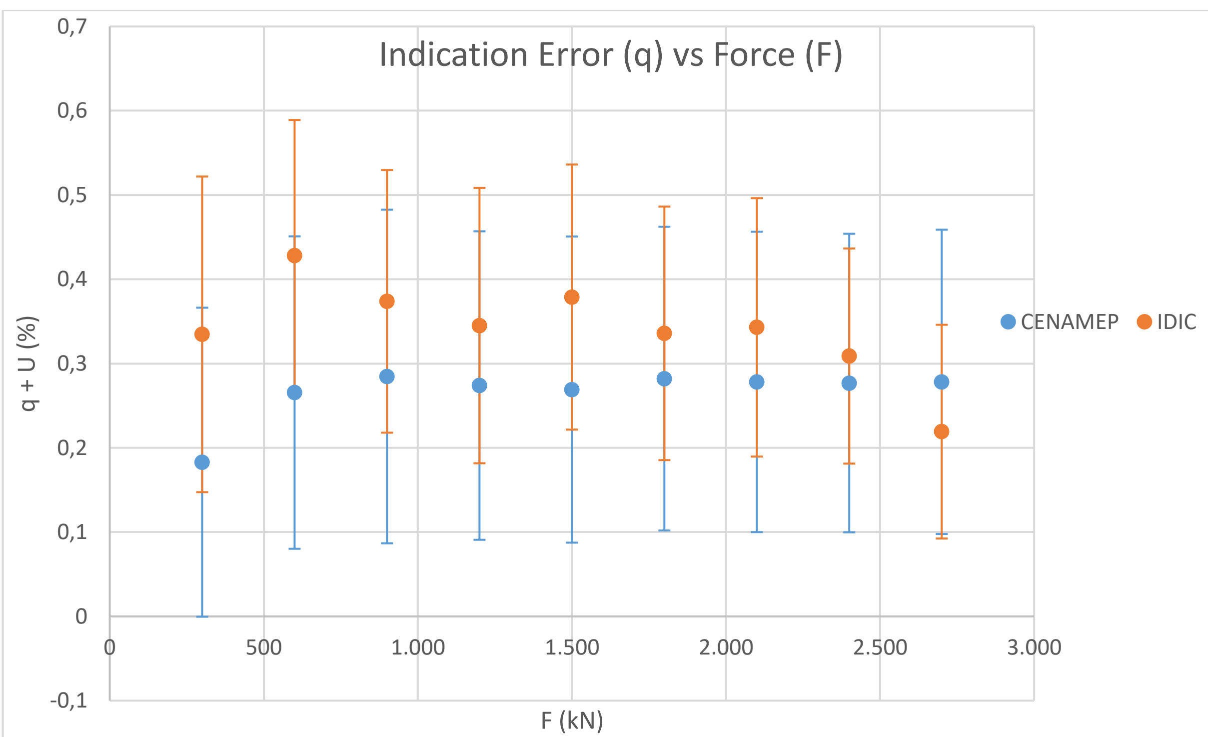
Nominal Values	IDIC's Results	
kN	q (%)	U (%)
300	0.33	0.19
600	0.43	0.16
900	0.37	0.16
1 200	0.35	0.16
1 500	0.38	0.16
1 800	0.34	0.15
2 100	0.34	0.15
2 400	0.31	0.13
2 700	0.22	0.13

Table 6. Results obtained by CENAMEP AIP.

Nominal Values	CENAMEP's Results	
kN	q (%)	U (%)
300	0.18	0.18
600	0.27	0.19
900	0.28	0.20
1 200	0.27	0.18
1 500	0.27	0.18
1 800	0.28	0.18
2 100	0.28	0.18
2 400	0.28	0.18
2 700	0.28	0.18

The calculated uncertainties were primarily based on three contributing factors: relative repeatability, relative resolution, and the calibration results of the transducer. The results are presented relative to the corresponding nominal force value applied. In Figure 1, all results are shown as the relative indication error along with its associated uncertainty. For improved clarity, the curves are slightly shifted around the measured force steps. The extensions at the measured points represent the calculated uncertainties, corresponding to Tables 4 and 5.

Fig. 1. Results of comparison.



Clearly it sees, that CENAMEP AIP is the measurements blues and IDIC the measurements orange. The degree of equivalence among the results of the measurements made by the participating laboratories was evaluated using the normalized error equation according to the expression:

$$En = \frac{q_{CENAMEP} - q_{IDIC}}{\sqrt{U_{CENAMEP}^2 + U_{IDIC}^2}} \quad (5)$$

Where:
En –normalized error.
$q_{CENAMEP}$ –indication error by CENAMEP.
q_{IDIC} –indication error by IDIC as reference.
$U_{CENAMEP}$ –CENAMEP's expanded uncertainty.
U_{IDIC} –IDIC's expanded uncertainty as reference.

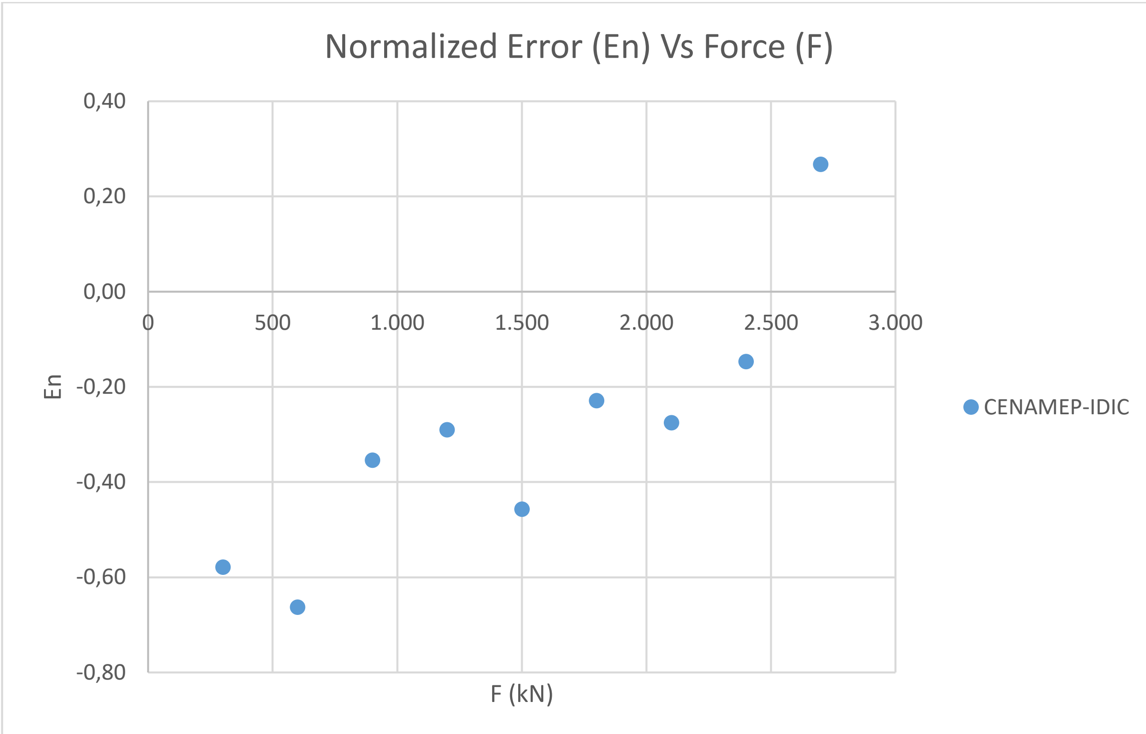
Following, table 7 shows the results corresponding the normalized error calculated in (5).

Table 7. Normalized error per point of measurement.

Nominal Values	CENAMEP-IDIC
kN	**En**
300	-0.58
600	-0.66
900	-0.35
1 200	-0.29
1 500	-0.46
1 800	-0.23
2 100	-0.28
2 400	-0.15
2 700	0.27

And the chart below, in Fig. 2, shows how the behavior of En is.

Fig. 2. Results of Normalized Error.



7. Conclusions

- A good correlation was found in the relative deviation of the machine's force indicator. In conclusion, all results can be considered reliable and comparable, as according to ISO 17043:2010, a normalized error $|En| \leq 1$ indicates method consistency and satisfactory performance.

- This work provides valuable information about the participants in the Force Calibration Machine Comparison, facilitating future research aimed at reducing uncertainty in the calibration of customers' standards at the National Force Standards Laboratory of each country.

- Based on the results from the comparability analysis using the normalized error equation, it can be concluded that excellent agreement was achieved among the measurements performed by all participants across the entire comparison range.

8. References

[1] SIM.M.F-S1, Testing Machine Calibration in Compression SIM Comparison up to 100 kN. 2010.
[2] ISO-7500-1, Metallic Materials-Calibration and verification of static uniaxial testing machines. Feb-2018.
[3] ISO-376, Metallic Materials-Calibration of force proving instruments used for the verification of uniaxial testing machines. Jun-2011.
[4] ISO/IEC 17043, Conformity Assessment-General requirements for proficiency testing. Feb-2010.
[5] Evaluation of measurement data – Guide to expression of uncertainty in measurement. 2008.