FINAL REPORT OF THE FORCE SUPPLEMENTARY COMPARISON AT SIM (SIM.M.F-S5), COMPRESSION TESTING MACHINES CALIBRATION, UP TO 200 kN

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1CENAM, Mexico; 2INM, Colombia; 3INDECOPI, Peru; 4LANAMME-UCR, Costa Rica.

Abstract
CENAM, through the Force and Pressure Division, organized a comparison on testing machines calibration, in compression mode. The participating laboratories were SIM National Institutes of Metrology from Colombia, Peru and Costa Rica, where CENAM, Mexico was the pilot and reference laboratory. The results obtained by the laboratories are presented in this paper as well as the analysis of compatibility.

Key Words: Force, compression-testing machines, international comparison.

1. Introduction.
CENAM organized a comparison on testing machines calibration, in compression mode. The participating laboratories are SIM National Institutes of Metrology from Colombia, Peru and Costa Rica, where CENAM, Mexico was the pilot and reference laboratory.

2. Objective.
To determine the compatibility of compression testing machines calibration results among the participating laboratories.

3. Development.
The comparison was carried out from May to July 2013. CENAM calibrated the transfer standard initially, at the middle and at the end of the comparison, figure 1.

Table 1. Participating Institutes, in alphabetical order according to its Country name.

<table>
<thead>
<tr>
<th>Country</th>
<th>Institute</th>
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<tbody>
<tr>
<td>Colombia</td>
<td>Instituto Nacional de Metrología (INM)</td>
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<tr>
<td>Costa Rica</td>
<td>Laboratorio Nacional de Materiales y Modelos Estructurales Universidad de Costa Rica (LANAMME-UCR)</td>
</tr>
<tr>
<td>Mexico</td>
<td>Centro Nacional de Metrología (CENAM)</td>
</tr>
<tr>
<td>Peru</td>
<td>Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI)</td>
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</table>

For this comparison, a force transducer (200 kN, HBM, C3H3 model, class “00” according ISO 376 [1]), was incorporated to a compression testing machine. It was mounted upside down at the upper crosshead of the machine. When mounting the force transducer we take care to align the vertical axis of the force transducer to the vertical axis of load application in the testing machine.

The machine readings, with this special arrangement, were taken on an HBM amplifier; model DMP 40, in mV/V signal. The values in kN were obtained by means of an equation of the transfer system (transducer – amplifier).

All the equipment used for this comparison, testing machine, force transducer and amplifier are property of CENAM.
The compression testing machine calibrations performed by the participating laboratories were made according to the ISO 7500-1:2004 [2] written standard. The evaluation of data for uncertainty in measurement estimation was made following the recommendations of the Guide to the Expression of Uncertainty in Measurement (GUM) 2008 [3].

The minimum contributions considered for the estimated uncertainty of the testing machine calibration [4] were:

(A) Resolution of the reference transducer,
(B) Repeatability of the transference system,
(C) Uncertainty of the calibration standard used.

The following contributions were not considered:

Temperature: the temperature variations were less than 0.4 °C, and all transducers used have internal temperature compensation system.

Interpolation: no estimated interpolation was performed between the results obtained.

Drift: it was not considered the drift due to the stability of the reference transducer (the drift value was less than 0.006 % of the reading).

The recommended equations for uncertainty in measurement estimation were:

\[
 u_{\text{resolution}} = \frac{a}{2\sqrt{3}} \quad \text{(A)}
\]

\[
 u_{\text{repeatability}} = \frac{100}{F} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (F_i - F)^2} \quad \text{(B)}
\]

4. Results.

The participation of each laboratory included different complete sets of measurements as follows:

INM – Colombia made two full calibrations. For the first calibration INM used the traceability information from their own reference standards of force (INM-Colombia); for the second calibration INM used the traceability information from the PTB-Germany force primary standards.

INDECOPI – Peru made one calibration.

LANAMME-UCR - Costa Rica made two calibrations. In both calibrations, LANAMME-UCR used the same force transducer with traceability to PTB, Germany. The difference between the two calibrations performed was the metrologist. In each calibration, a different metrologist made the measurements.

CENAM made three calibrations, one at the beginning of the comparison round, another at the middle and the last one at the end of the comparison round (as shown in Figure 1). The results of CENAM’s calibrations are presented at Figure 3.

![Figure 3. Testing machine CENAM’s three calibrations.](image-url)
Table 2. Testing machine calibration results obtained by the participating laboratories.

<table>
<thead>
<tr>
<th></th>
<th>CENAM 1</th>
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<th>INM Col PTB</th>
<th>INDECOPI</th>
<th>CENAM 2</th>
<th>LANAMME Hum</th>
<th>LANAMME Luis</th>
<th>CENAM 3</th>
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<tr>
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Figure 3. Average measurements and expanded uncertainties.

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<td>±0.042 7</td>
<td>±0.039 9</td>
<td>±0.125 3</td>
<td>±0.059 7</td>
<td>±0.126 4</td>
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<td>±0.062 8</td>
<td>±0.061 0</td>
<td>±0.122 2</td>
<td>±0.052 2</td>
<td>±0.122 8</td>
<td>±0.122 3</td>
<td>±0.055 3</td>
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<tr>
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<td>±0.064 6</td>
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<td>±0.072 1</td>
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<td>±0.023 1</td>
<td>±0.055 8</td>
<td>±0.052 9</td>
<td>±0.025 3</td>
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Figure 4. All results obtained by the participating institutes. Including CENAM’s average from the three calibrations made.

5. Discussions.

In figure 4, it can be seen that the results reported from LANAMME Costa Rica, with the same transducer but different metrologist, are very similar between them in deviation and in estimated uncertainty.

The same Figure 4 shows homogeneity in the calibration results from INM Colombia, with the same transducer and the same metrologist but using different traceability. Also, from the two calibrations performed by INM Colombia, it can be determined that between the calibration traceable to their own reference standards and the ones traceable to the PTB (Germany) primary standards there are differences less than 6x10^{-5} in the error reported and in the expanded uncertainties of measurement the difference is less than 1.2x10^{-4}.

Figure 5 show the normalized error values from the participating National Institutes with respect to the reference values provided by CENAM (average value from the three calibrations made by CENAM). We can see that the participants who have direct traceability to primary measurement systems (dead weight force machines) have lower values of the normalized error, hence smaller deviations.

6. Conclusions.

The results of this comparison prove consistency of measurements among the participating laboratories with the reference values provided by CENAM Mexico.
An extra value from the comparison was that the laboratories had ideas and experiences that may be used to improve their measurement and calibration procedures and introduce them in future exercises of this type.

7. References.