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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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.

Country	Institute
Colombia	Instituto Nacional de Metrología (INM)
Costa Rica	Laboratorio Nacional de Materiales y Modelos Estructurales Universidad de Costa Rica (LANAMME-UCR)
Mexico	Centro Nacional de Metrología (CENAM)
Peru	Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI)

Figure 1. Scheme of the comparison round.

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.

Figure 2. Testing machine used for the comparison with a reference force transducer installed in its upper crosshead.

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:

$$u_{resolution} = \frac{a}{2\sqrt{3}} \qquad \text{(A)}$$

$$u_{repeatibility} = \frac{100}{\overline{F}} \sqrt{\frac{1}{n-1}\sum_{1}^{n}\left(F-\overline{F}\right)^2} \qquad \text{(B)}$$

$$u_{standard} = \frac{U_{trans}}{k} \qquad \text{(C)}$$

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.

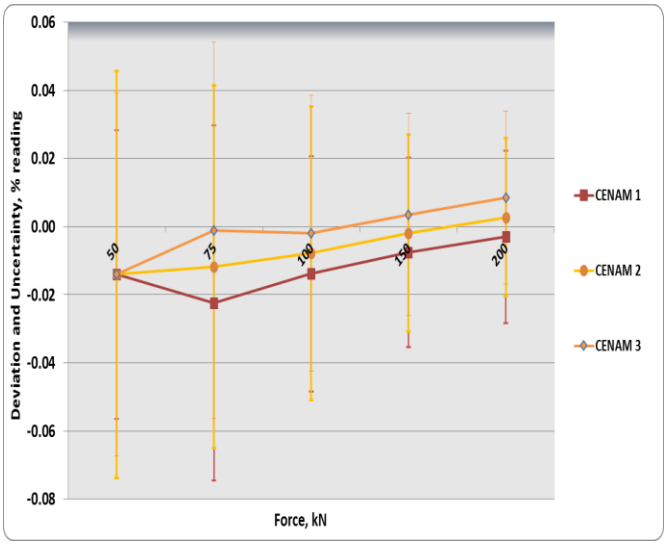

Figure 3. Testing machine CENAM´s three calibrations.

Table 2. Testing machine calibration results obtained by the participating laboratories.

	CENAM 1	INM Colombia	INM Col PTB	INDECOPI	CENAM 2	LANAMME Hum	LANAMME Luis	CENAM 3
				Average Measurements				
kN	kN	kN	kN	kN	kN	kN	kN	kN
50	49.993	49.993	49.996	49.936	49.993	50.022	50.028	49.993
75	74.983	75.000	75.001	74.934	74.991	75.032	75.029	74.999
100	99.986	100.005	100.002	99.918	99.992	100.036	100.060	99.998
150	149.989	150.009	150.001	149.930	149.997	150.060	150.071	150.005
200	199.994	200.020	200.013	199.937	200.005	200.073	200.088	200.017
				Expanded Uncertainties				
kN	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading
50	± 0.042 4	± 0.042 7	± 0.030 9	± 0.125 3	± 0.059 7	± 0.126 4	± 0.123 2	± 0.053 2
75	± 0.052 1	± 0.042 8	± 0.031 0	± 0.122 2	± 0.053 2	± 0.123 8	± 0.122 3	± 0.055 2
100	± 0.034 5	± 0.042 6	± 0.030 8	± 0.072 1	± 0.043 0	± 0.104 1	± 0.102 7	± 0.040 5
150	± 0.027 8	± 0.042 4	± 0.030 5	± 0.058 4	± 0.028 9	± 0.074 6	± 0.071 8	± 0.029 7
200	± 0.025 3	± 0.042 3	± 0.030 4	± 0.052 8	± 0.023 1	± 0.055 8	± 0.052 9	± 0.025 5
				Realtive Deviation (q)				
kN	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading	% Reading
50	-0.014 1	-0.014 6	-0.008 9	-0.128 9	-0.014 0	0.044 1	0.055 3	-0.014 0
75	-0.022 4	0.000 7	0.001 7	-0.088 0	-0.011 8	0.042 6	0.039 3	-0.001 1
100	-0.013 8	0.004 8	0.002 4	-0.082 1	-0.007 9	0.036 1	0.060 0	-0.001 9
150	-0.007 5	0.006 2	0.000 9	-0.046 7	-0.002 0	0.039 8	0.047 1	0.003 5
200	-0.003 0	0.009 8	0.006 5	-0.031 6	0.002 7	0.036 4	0.043 9	0.008 5

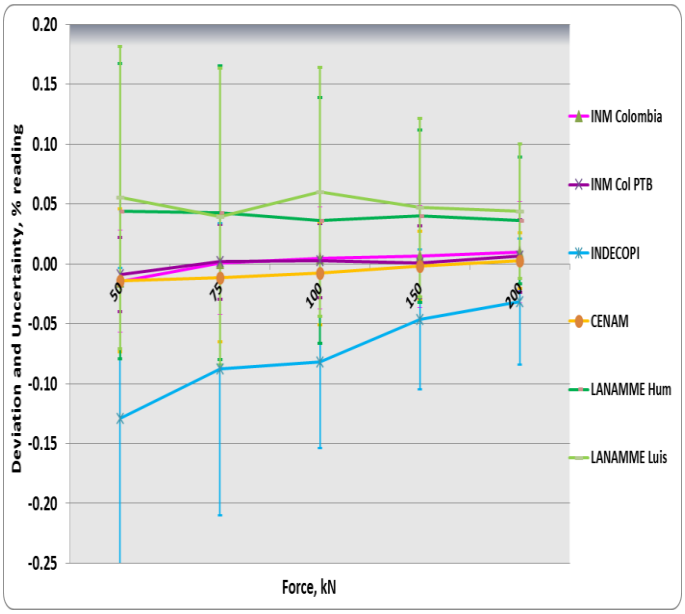

Figure 4. All results obtained by the participating institutes. Including CENAM´s average from the three calibrations made.

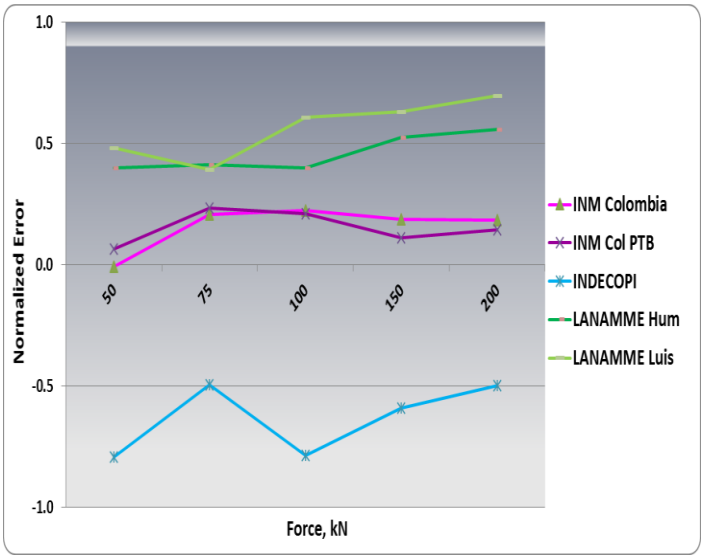

Figure 5. Participating laboratories normalized error values. CENAM provided the reference values.

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 form 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.

[1] ISO 376, "Calibration of force-proving instruments used for the verification of uniaxial testing machines", 2004.

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[3] Evaluation of measurement data — Guide to the expression of uncertainty in measurement; JCGM 100:2008, GUM 1995 with minor corrections.

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