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TESTING MACHINE CALIBRATION IN COMPRESION SIM COMPARISON UP TO 100 kN

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Abstract – At regional level, Chile is part of the Interamerican Metrology System (SIM) that is the result of the achieved agreements among the 34 member countries of the Organization of American States (OEA) to promote metrology. The SIM consists of five sub regions NORAMET, CARIMET, CAMET, ANDIMET and SURAMET. This last sub region comprises Argentina, Brazil, Chile, Paraguay and Uruguay.

Keywords Force, Triangular Project, SIM, Andimet

1. INTRODUCTION

The development and recognition of Chile's Laboratorio Custodio de Patrones Nacionales de Fuerza (National Force Standards Custodian Laboratory) together with PTB's technical cooperation activities in other Latin American countries have contributed to generate training activities for technicians in third countries providing them knowledge and experiences in the area of this magnitude.

This way an alliance has already been developed that allows the triangular and punctual cooperation with the national institutes of metrology of several Latin American countries (Bolivia, Colombia, Chile, Costa Rica, Ecuador, Panamá, Paraguay, Peru and Uruguay).

In Phase I of the Triangle project between Germany, Chile and Andean Countries a stocktaking of the metrological possibilities in the Andean countries was carried out first for the measurand force. The intended measures to improve the metrological equipment were discussed. The workshop in Santiago 2008 was particularly held for the beginners in the field of material testing machine (MTM) calibration. All participants (Table. 1) used their own equipment and worked on the same MTM, a make of INSTRON, measuring range 50 kN.

A testing machine calibration comparison was carried out among various laboratories from SIM In Phase II the participant circle was extended by additional members of SIM, so that many countries of the South American continent and the Caribbean region were involved from Mexico in the North to Uruguay in the South, in order to compare and to evaluate the results of the calibrations of testing machine. The calibration comparison was carried out for the range of 100 kN in compression.

A testing machine of the SIC force laboratory was prepared for the comparison measurements. The force was generated by a piston-cylinder-system and the force indicator consist of a 100 kN-force transducer in combination with a DK 38 (see pic. 2). The amplifier was adjusted in kN with a resolution of 0,01 kN.

The calibrations was made in conformity with the standard ISO 7500:2004 part 1, the measurement uncertainty was evaluated according to ISO guide "expression of Uncertainty in Measurements" and to the document EA-10/04 "Uncertainty of calibration results in force measurements". The results obtained, the deviation graphs that include the uncertainty for each laboratory are presented in this document As IDIC made tre three calibrations, at the beginning, middle and at the end, the reference value assumed for it, was the average value of these measurements.

From the measurement results obtained by each laboratory, the following parameters are determined: accuracy (q), repeatability (b).and calibration uncertainty (u). The normalized error (En) is evaluated to determine the quality of measurement results between labs. The results obtained, the deviations graphs that include the uncertainty for each laboratory are presented in this document.

This work will allow to gather information about the all participants Comparison Force Calibration Machine to make future works of investigation to reduce the uncertainty in the calibration of customer's standards of National Force Standards Laboratory from each country and declarate yours CMC's capabilities.

The paper presents the main results obtained during the development of phase 2 of this triangular project.

2. PARTICIPANTS

While in the first phase only countries of the Andean States as well as Paraguay, Uruguay, Panama were involved, the number of participants was extended for the last workshop by some members of the SIM. The following countries took part:

	Country	Phase I	Phase II
1	Argentina		■
2	Bolivia	■	■
3	Brasil		■
4	Chile	■	■
5	Colombia	■	■
6	Costa Rica		■
7	Ecuador	■	■
8	Jamaica		■
9	Mexico		■
10	Panama	■	■
11	Paraguay	■	■
12	Peru	■	■
13	Uruguay	■	■

Table 1 Participating Countries

Instituto Nacional de Normalización y Metrología y (INTN), Asunción, Paraguay
Instituto Nacional de Normalización Ecuatoriano (INEN), Quito, Ecuador
Instituto Boliviano de Metrología (IBMETRO), La Paz, Bolivia
Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual, (INDECOPI), Lima, Perú
Centro Nacional de Metrología de Panamá, (CENAMEP), Panamá, Panamá
Superintendencia de Industria y Comercio, (SIC), Bogotá, Colombia
Laboratorio Tecnológico del Uruguay, (LATU), Montevideo, Uruguay
Instituto Nacional de Tecnología Industrial, (INTI), Buenos Aires, Argentina
Instituto Nacional de Metrología, Normalización y Calidad Industrial, (INMETRO), Río de Janeiro, Brasil
Centro Nacional de Metrología (CENAM), Querétaro, México
Laboratorio Nacional de Materiales y Modelos Estructurales Universidad de Costa Rica, (LAMMEC UCR), San José, Costa Rica
Bureau of Standards, (BSJ), Kingston, Jamaica

3. MEASUREMENT EQUIPMENT

Calibration of the used devices

The used force transducers and amplifiers were quite heterogeneous. The amplifiers varied between HMB models DK38, MGCplus, DMP40, SCOUT 55, CONTROLS and last but not least a proving ring as a passive, analogous instrument. All amplifiers work with carrier frequency which depends on the different types (225 Hz, 600 Hz and 4,8 kHz). Some participants used two force transducers because the working range did not cover the full range of the MTM.

All measuring chains were calibrated in different NMI or accredited calibration laboratories. The force calibration facilities are of different types with different best measurement capabilities which has an effect on the class of the force measuring instruments. Beside the results the date of the calibration was of interest also. It was found that some of the used devices crossed the date of expiry. According to ISO 17025 there was no traceability for these devices.

Table 2 shows the equipment used:

The force transducers (measuring chains) were recalibrated in different force standard machines (FSM) with different measurement uncertainties. The classification of a force transducer is no property of the device but is the result of a measuring.

Without consideration of the status of the involved NMI, the following classification would arise based on the measuring data of the calibration certificates how it is shown in table 2.

Participant	Force Transducer
Argentina	100 kN Z4
Bolivia	200 kN Z4A
Brazil	100 kN C4
Chile	100 kN Z4
Colombia	100 kN Z4
Costa Rica	30 kN E0100/AS
Costa Rica	300 kN E0100/BS
Ecuador	300 kN Prov.Ring
Jamaica	100 kN C18
Mexico	100 kN C3H3

Panama	200 kN Z4A
Paraguay	200 kN Z4A
Peru	50 kN U15
Peru	500 kN U15
Uruguay	200 kN U1

Table 2 Measuring devices

4. RESULTS

The evaluation of the measurement results was made in accordance with ISO 7500-1, appendix D, "Uncertainty of Calibration Results of Force Measuring Systems".

The relative uncertainty is calculated with the formula

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

with k = coverage factor 2

$$u_1 = u_{rep} = \frac{100}{\overline{F}}\sqrt{\frac{1}{n-1}\sum_{1}^{n}\left(F-\overline{F}\right)^2} \quad (2)$$

$$u_2 = \frac{a}{2\sqrt{3}} \quad (3)$$

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

$$u_4 = u_{drift} = \frac{Date_{comp} - Date_{calibr}}{2years} \times 1 \times 10^{-4} \quad (5)$$

The contribution u4 is the same for all participants, the figures vary only on the time difference between the date of calibration and the comparison carried out in Bogotá. The base is 1•10-4. In one case the date of calibration is unknown. So it was estimated that the time difference is 2 years (worst case).

The contribution of the used force transducer (u3) 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 temperature and linear approximation are negligible in this particular case.

The following tables show the results of the testing machine calibration. The original data is mostly in mV/V. For the comparison is all data transferred in kN with the inverse formula based on the calibration results of the force transducers.

Argentina

kN (MTM)	kN mean	q %	b %	a %	U trans	U drift	U %
20	20,16	-0,80	0,005	0,014	0,03	5,01E-05	0,07
40	40,31	-0,77	0,003	0,007	0,03	5,01E-05	0,06
60	60,44	-0,73	0,004	0,005	0,03	5,01E-05	0,06
80	80,58	-0,72	0,002	0,004	0,03	5,01E-05	0,06
100	100,72	-0,72	0,002	0,003	0,03	5,01E-05	0,06

Table 4 Calibration Results Argentina

Bolivia

kN (MTM)	kN mean	q %	b %	a %	U trans	U drift	U %
20	20,16	-0,80	0,005	0,014	0,03	5,01E-05	0,07
40	40,31	-0,77	0,003	0,007	0,03	5,01E-05	0,06
60	60,44	-0,73	0,004	0,005	0,03	5,01E-05	0,06
80	80,58	-0,72	0,002	0,004	0,03	5,01E-05	0,06
100	100,72	-0,72	0,002	0,003	0,03	5,01E-05	0,06

Table 5 Calibration Results Bolivia

Brazil

kN (MTM)	kN mean	q %	b %	a %	U trans	U drift	U %
20	20,14	-0,68	0,089	0,014	0,03	1,58E-09	0,19
40	40,30	-0,74	0,009	0,007	0,03	1,58E-09	0,06
60	60,43	-0,72	0,002	0,005	0,03	1,58E-09	0,06
80	80,57	-0,71	0,004	0,004	0,03	1,58E-09	0,06
100	100,71	-0,70	0,006	0,003	0,03	1,58E-09	0,06

Table 6 Calibration Results Brazil

Chile

kN (MTM)	kN mean	q %	b %	a %	U trans	U drift	U %
20	20,15	-0,77	0,010	0,014	0,03	5,88E-10	0,07
40	40,29	-0,73	0,003	0,007	0,03	5,88E-10	0,06
60	60,43	-0,71	0,007	0,005	0,03	5,88E-10	0,06
80	80,56	-0,69	0,004	0,004	0,03	5,88E-10	0,06

100	100,70	-0,69	0,004	0,003	0,03	5,88E-10	0,06

Table 7 Calibration Results Chile

Colombia

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,15	-0,76	0,007	0,014	0,03	3,07E-11	0,07
40	40,29	-0,72	0,011	0,007	0,03	3,07E-11	0,07
60	60,43	-0,71	0,008	0,005	0,03	3,07E-11	0,06
80	80,56	-0,69	0,003	0,004	0,03	3,07E-11	0,06
100	100,69	-0,68	0,004	0,003	0,03	3,07E-11	0,06

Table 8 Calibration Results Colombia

Costa Rica

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,18	-0,88	0,071	0,014	0,03	1,05E-10	0,16
40	40,26	-0,65	0,080	0,007	0,12	1,05E-10	0,29
60	60,40	-0,67	0,066	0,005	0,12	1,05E-10	0,27
80	80,55	-0,68	0,039	0,004	0,12	1,05E-10	0,25
100	100,69	-0,69	0,018	0,003	0,12	1,05E-10	0,24

Table 9 Calibration Results Costa Rica

Ecuador

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,11	-0,56	0,000	0,014	0,23	8,93E-09	0,46
40	40,21	-0,52	0,036	0,007	0,12	8,93E-09	0,25
60	60,37	-0,61	0,000	0,005	0,12	8,93E-09	0,24
80	80,45	-0,56	0,036	0,004	0,12	8,93E-09	0,25
100	100,73	-0,72	0,038	0,003	0,12	8,93E-09	0,25

Table 10 Calibration Results Ecuador

Jamaica

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,16	-0,81	0,015	0,014	0,03	2,39E-09	0,07
40	40,31	-0,77	0,011	0,007	0,03	2,39E-09	0,07
60	60,45	-0,75	0,009	0,005	0,03	2,39E-09	0,06
80	80,59	-0,73	0,004	0,004	0,03	2,39E-09	0,06

100	100,72	-0,71	0,003	0,003	0,03	2,39E-09	0,06

Table 11 Calibration Results Jamaica

Mexico

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,15	-0,75	0,018	0,014	0,03	4,61E-10	0,08
40	40,30	-0,74	0,009	0,007	0,03	4,61E-10	0,06
60	60,43	-0,71	0,008	0,005	0,03	4,61E-10	0,06
80	80,56	-0,70	0,009	0,004	0,03	4,61E-10	0,06
100	100,70	-0,69	0,007	0,003	0,03	4,61E-10	0,06

Table 12 Calibration Results Mexico

Panama

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,05	-0,27	0,269	0,014	0,03	1,00E-09	0,54
40	40,24	-0,60	0,038	0,007	0,03	1,00E-09	0,10
60	60,39	-0,64	0,019	0,005	0,03	1,00E-09	0,07
80	80,52	-0,65	0,008	0,004	0,03	1,00E-09	0,06
100	100,65	-0,65	0,004	0,003	0,03	1,00E-09	0,06

Table 13 Calibration Results Panama

Paraguay

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,15	-0,74	0,007	0,014	0,03	1,68E-09	0,07
40	40,29	-0,72	0,007	0,007	0,03	1,68E-09	0,06
60	60,42	-0,70	0,014	0,005	0,03	1,68E-09	0,07
80	80,56	-0,70	0,007	0,004	0,03	1,68E-09	0,06
100	100,69	-0,69	0,004	0,003	0,03	1,68E-09	0,06

Table 14 Calibration Results Paraguay

Peru

kN (MTM)	kN mean	q %	b %	a %	U_{trans}	U_{drift}	U %
20	20,16	-0,77	0,008	0,014	0,03	3,55E-09	0,07
40	40,31	-0,77	0,018	0,007	0,03	3,55E-09	0,07
60	60,48	-0,79	0,028	0,005	0,03	3,55E-09	0,08
80	80,62	-0,77	0,014	0,004	0,03	3,55E-09	0,07

100	100,79	-0,79	0,020	0,003	0,03	3,55E-09	0,07

Table 15 Calibration Results Peru

Uruguay

kN (MTM)	kN mean	q %	b %	a %	U trans	U drift	U %
20	20,15	-0,74	0,029	0,014	0,06	4,63E-09	0,14
40	40,32	-0,79	0,072	0,007	0,03	4,63E-09	0,16
60	60,43	-0,71	0,019	0,005	0,03	4,63E-09	0,07
80	80,56	-0,70	0,044	0,004	0,03	4,63E-09	0,11
100	100,68	-0,67	0,010	0,003	0,03	4,63E-09	0,07

Table 16 Calibration Results Uruguay

5. RESULTS

To calculate the deviations and the uncertainties from the measured data, the following considerations were made:

The laboratories deviations were calculated respect to the mean of the values obtained by the participating primary laboratories (CENAM, INMETRO, INTI and IDIC), namely reference deviation values.

The uncertainties calculated were based mainly, on four contributing elements; the standard used by the laboratory (according to the values reported in the BIPM data base), rel. reproducibility, rel. resolution, calibration result of the force transducer drift between date of calibration and.

The results are presented relative to the corresponding nominal force value applied.

In Fig 1 all results are shown in an x-y-error-diagram. For better clearness the particular curves are shifted around the measured force steps. The extensions at the measured points represent the calculated uncertainties in correspondence with the tables 4 to 16.

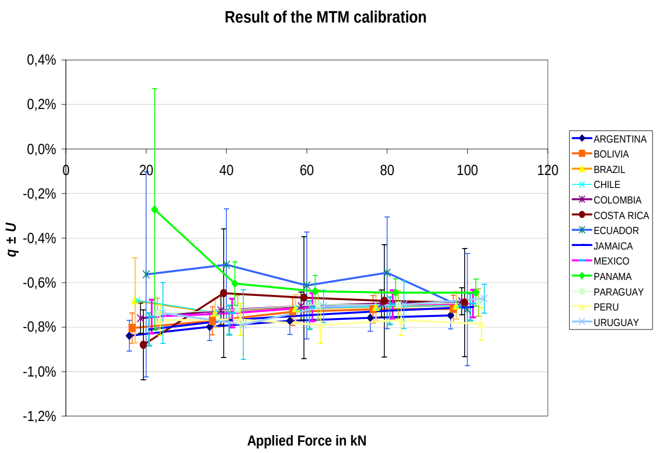

Fig. 1 Calibration Results of all Participants

The most readings were in mV/V. This comes from the calibration of the force transducer which is usually made in mV/V. For the comparison of the machine calibration it is unsuitable and all results are recalculated in kN based on the inverse function which is given in the particular calibration certificates.

The degree of equivalence among the results of the measurements made by the participating laboratories was evaluated using the normalized error equation acccording to the expression

$$e_n = \frac{E_{ref} - E_{lab}}{\sqrt{(U_{ref})^2 + (U_{lab})^2}} \qquad (6)$$

Where,

e_n - normalized error
E_{lab} - laboratory's estimated relative deviation
E_{ref} - mean value reference deviation calculated from the deviations of the primary laboratories = (eCENAM + eINMETRO + eINTI) / 3
U_{lab} - laboratory's expanded uncertainty
U_{ref} - Combined expanded uncertainty of the primary participating laboratories (according to equation 7).

$$U_{ref} = \frac{\sqrt{U^2_{CENAM} + U^2_{INMETRO} + U^2_{INTI}}}{\sqrt{3}} \qquad (7)$$

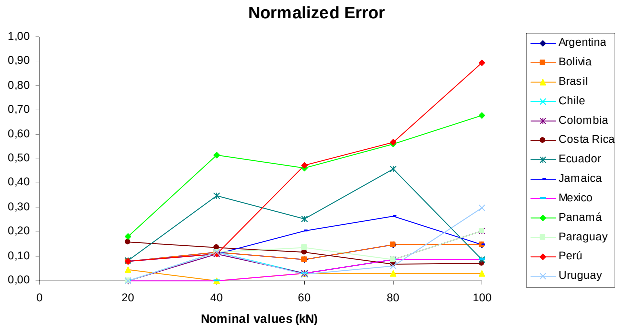

Fig. 2 Normalized Error of Results of all Participants

6. CONCLUSION AND DISCUSSION

The result of this workshop is not directly comparable with the result of the first workshop held in Santiago because of several reasons:

The MTM-types and the measuring ranges are different
The machines have different properties
The used equipment was different

The investigated machine could be classified as a testing machine class 1. Apart from a few single one-offs all results including the measurement uncertainty lie inside the limits of ± 1%.

A good correspondence was found in the relative deviation of the force indicator of the machine. In conclusion it can be said that all results are reliable and comparable.

This work will allow to gather information about the all participants Comparison Force Calibration Machine to make future works of investigation to reduce the uncertainty in the calibration of customer's standards of National Force Standards Laboratory from each country.

From the results of the analysis of comparability, normalized error equation, it can concluded that excellent agreement exist among the measurements carried between all participants in all range for this comparison.

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