

FORCE STANDARDS BILATERAL COMPARISON BETWEEN NMISA (SOUTH AFRICA) AND CENAM (MEXICO).

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Abstract: This paper details a force bilateral comparison between the National Metrology Institute of South Africa (NMISA) and Centro Nacional de Metrologia (CENAM, Mexico). A single 50 kN Force Transducer was used as the artefact. Measurements were conducted in compression mode in the range of 10 kN to 50 kN. The characteristics of the two standard machines used and the procedure of the comparison are briefly discussed. The values of measurements and the associated uncertainties for each laboratory are reported as well as the degree of equivalence between the two national force laboratories.

Keywords: Force, bilateral comparison, force standard machine.

1. INTRODUCTION

The agreement of measurement systems is vital for scientific collaborations and for facilitation of international trade. National measurements institutes (NMIs) of countries around the world are usually tasked with maintenance of measurements systems and standards. To prove agreement of measurements, it is important for NMIs to compare their measurement standards with each other on regular basis.

Inter-laboratory comparison (ILC) is the organization performance and evaluation of measurements or tests on the same or similar items by two or more laboratories or inspection bodies in accordance with predetermined conditions [1]. A successful participation of an NMI in an ILCs can prove technical competence as well as provide evidence to support measurement capabilities claimed by the NMI.

After an international assessment found that NMISA has not been participating in any key comparisons in the last decade, due to a lack of international key comparisons and the limitations of the force laboratory, it was suggested to participate in a bilateral supplementary comparison.

NMISA approached CENAM to do a bilateral comparison in the range of 10 kN – 50 kN. It was agreed upon that the bilateral will use a single 50 kN HBM, type C4 Force Transducer which was provided by NMISA (figure 1).



Figure 1: The 50 kN HBM, type C4 Force Transducer used for the bilateral.

NMISA was to use a comparator machine with an overall overestimated calibration measurement capability of 0,03 % ($k = 2$ at approximately 95 % level of confidence) and a standard load cell with uncertainty of generated force of 0,015 % (in the range 10 - 50 kN) in the bilateral comparison. The force was hydraulically applied to two transducers back to back. The one transducer would be the standard while the other would be the unit under test (UUT), in this case the 50 kN transfer standard. CENAM used their dead weight force standard machine to calibrate the UUT. The relative uncertainty of the Dead weight machine is 0,002 5 %. The bilateral was carried out during July and August 2016 and it was the first force comparison between South Africa and Mexico.

2. BILATERAL COMPARISON GENERAL GUIDELINES AND PROCEDURE

The procedure covers the technical protocol to be followed during measurement of the force transducer. Table 1 summarises key aspects of the comparison protocol.

Table 1: Comparison procedure

Readings positions	0°, 90°, 180°, 270° and 360°
Force Steps	10 kN to 50 kN in 10% steps.
Number of preloads (at maximum force)	3 at 0°, 1 at all other positions.
Readings cycles	3 cycles at 0° position, one cycle in all other positions.
Digital Amplifier	Each laboratory used its own digital amplifier (DMP40 for NMISA and DMP 41 for CENAM).
Reading Units	mV/V

The technical protocol is based on ISO 376:2011 document for calibration of force proving instruments [2].

The environmental temperature near the UUT and relative humidity of the air were monitored and recorded. The UUT and accompanying devices were allowed to reach the local environmental temperature for establishing thermal equilibrium, when already connected to the amplifier.

3. THE CHARACTERISTICS OF THE TWO STANDARD MACHINES

NMISA: With the NMISA dead weight (DW) machine being refurbished, the Force laboratory used the comparator machine to participate in the bilateral.

The comparator machine function on the principle of force application by means of a hydraulic press, where two transducers are pressed against one another back to back.

The physical working of the comparator consists mainly of a mechanical frame and a hydraulic system. The hydraulic system comprises of an electric hydraulic power pack, hydraulic piston and a stepper motor coupled to the Budenberg pressure balance. Both the power pack and the Budenberg pressure balance feed into the piston to generate force within the comparator machine. Reference force transducers of different capacities are attached to the upper coupling of the mechanical frame and can be used to measure the force generated by the machine. Controlling the comparator is done by manually feeding the piston with the power pack for large applications of force and with the pressure balance for smaller more sensitive and fine applications of force. Due to the limitations of the comparator machine, the force can never be held at a specific point because of oil leakage. Thus, the application of force can never be stopped and is regulated to only a crawl when close to nominal force point. To capture the nominal force point, a 0,9 Hz Basel filter for quick response on the amplifier and a camera on burst mode are used.



Figure 2: The comparator force machine at NMISA.

CENAM: Contrary to the comparator system used by NMISA, CENAM participate in the bilateral using a 49 kN DW force machine. The Morehouse DW machine consist of a yoke on which an assembly of different combinations of weights can be suspended to apply force directly on the

instrument being calibrated. The grouping of weights used for calibration consists out of two sets of weights of different masses. These sets comprise of nine weights each which can be loaded individually on the yoke. The first set of mass pieces weighs 50 kg per weight while the second set of mass pieces weighs 500 kg per weight. With the yoke, which also weighs 50 kg, the whole yoke-mass piece assembly results in a maximum load of 49,033 kN of total force that can be applied to the UUT. The yoke and mass pieces' positions and movements are pneumatically controlled. This allows for different forces to be applied to the UUT by using different combinations of the mass pieces loaded on to the yoke. The DW machine allows for calibration measurements to be done in tension as well as compression.



Figure 3: The 49,033 kN capacity Morehouse DW machine at CENAM.

4. RESULTS & EVALUATION CRITERIA

Uncertainty analysis: It was the responsibility of each laboratory to calculate their own expanded relative measurement uncertainty, which will consider all uncertainty contributors effecting their calibrations in their own laboratory. Figure 4 and Figure 5 shows all the uncertainty contributors for CENAM and NMISA measurements. In both laboratories, the standard ISO 376 was used as guideline in calculation of these results.

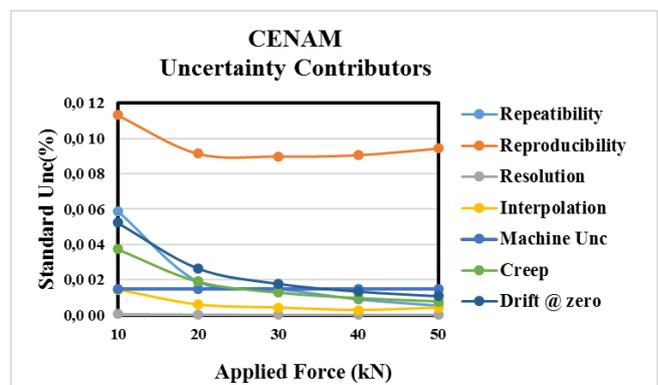


Figure 4: Measurement uncertainty contributors for CENAM.

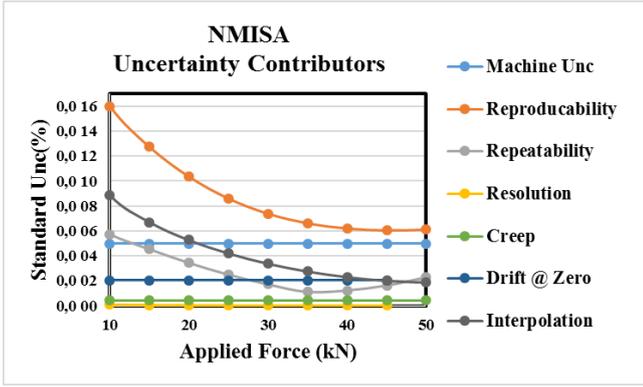


Figure 5: Measurement uncertainty contributors for NMISA.

From figure 4 and 5, it can be observed that the biggest uncertainty contributor for both laboratories is the reproducibility of the results while the resolution of the comparison standard (force transducer and digital amplifier) is the smallest uncertainty contributor for both laboratories.

Table 2 shows the calculated mean deflection with its corresponding calculated expanded relative uncertainty for each normalised applied force.

Table 2: Expanded relative Uncertainties.

Force kN	Value Comparison (CENAM is reference)				
	NMISA mV/V	CENAM mV/V	Difference mV/V	Exp. Unc. (k=2)	
				NMISA	CENAM
10	0,399643	0,399711	0,000068	0,046%	0,029%
15	0,599464	0,599575	0,000112	0,038%	0,023%
20	0,799286	0,799447	0,000161	0,031%	0,020%
25	0,999111	0,999327	0,000215	0,026%	0,020%
30	1,198940	1,199213	0,000273	0,023%	0,019%
35	1,398775	1,399107	0,000332	0,021%	0,019%
40	1,598615	1,599008	0,000393	0,020%	0,019%
45	1,798463	1,798916	0,000453	0,020%	0,019%
50	1,998319	1,998832	0,000512	0,020%	0,019%

Evaluation of Results: To compare the measurement results, the Normalised Error Equation is used. The Normalized Error, designated as E_n , is used as a statistical evaluation of proficiency testing results where the uncertainty in the measurement result is included.

$$E_n = \frac{x_{Lab} - x_{Ref}}{\sqrt{U_{Lab}^2 + U_{Ref}^2}} \quad (1)$$

Where:

x_{Lab} = Measurement result of participating lab, NMISA.

x_{Ref} = Measurement result of reference lab, CENAM.

U_{Lab} = Expanded Uncertainty of Measurement (95%) of participating lab, NMISA.

U_{Ref} = Expanded Uncertainty of Measurement (95%) of reference lab, CENAM.

Normalised errors values in the range of -1 and +1, are considered to prove equivalence of measurements. Values greater than 1 or lower of -1 indicate that the difference between the measurements performed by the two laboratories may be significant, as it cannot be explained by the combination of the uncertainties.

From the uncertainties associated with the values obtained by the two NMIs as shown in Table 2, the E_n values are calculated and plotted in Figure 6.

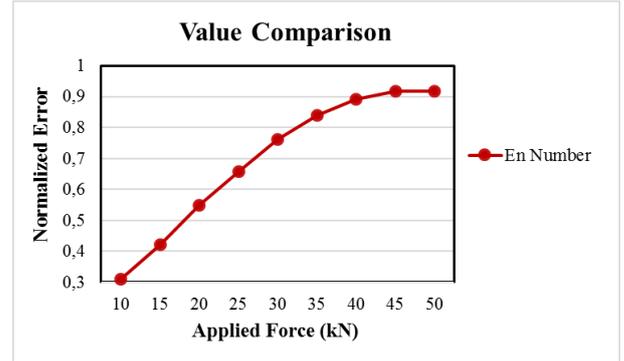


Figure 6: Value Comparison (absolute Normalised Error)

All the force points at which the comparison was performed has resulting E_n values less than 1, proving agreement of measurements and giving confidence in the claimed uncertainties of the force standards at these values.

5. CONCLUSION

NMISA and CENAM agreed to participate in a bilateral comparison of force standards in the range of 10 kN-50 kN. NMISA used a hydraulic comparator force machine while CENAM used a deadweight force machine. The normalized error equation was proposed as a method of assessing comparability of force measurement between the two laboratories. In general, the outcome of this bilateral comparison provide evidence to support the uncertainty claims of the two laboratories.

6. REFERENCES

- [1] ILAC P9:06/2014 – ILAC Policy for Participation in Proficiency Testing Activities.
- [2] Metallic materials - Calibration of force-proving instruments used for the verification of uniaxial testing machines; BS EN ISO 376, 2011.