Proceedings of the 17th International Conference on Force, Mass, Torque and Pressure Measurements,
IMEKO TC3, 17-21 Sept. 2001, Istanbul, Turkey

Force Standards Comparison between Mexico and Brazil

Jorge C. Torres Guzmán*, Daniel Ramírez Ahedo*, Jorge P. Cruz**, Jorge M. E. Saffar***

** Centro Nacional de Metrología (CENAM),Queretaro, Mexico*

*** Instituto Nacional de Metrologia, Normalização e Qualidade Industrial(INMETRO), Xerem, Brasil*

**** Fundação Centro Tecnológico de Minas Gerais (CETEC),Belo Horizonte, Brazil*

Abstract

A force comparison was carried out between Brazil and Mexico, in order to estimate the level of agreement for the realisation of the quantity. The comparison participants were two secondary laboratories (CETEC and IPT/SP) and the national metrology institute (INMETRO) from Brazil and the national metrology institute (CENAM) from Mexico. The comparison was carried from 20 kN to 150 kN, using two load cells as comparison standards, having $1 \cdot 10^{-5}$ relative repeatability each. Resumes of the general guidelines and procedure used for the comparison as well as the results obtained, deviations Figure for each participant laboratory are here included.

1. Introduction

In order to tighten the relationship between Brazil and Mexico and to share force metrology experiences and knowledge, a force comparison was carried out in an split range from 20 kN to 150 kN. This was the first force comparison to be performed between Brazil and Mexico and included only laboratories with dead weight machine and large force metrology experience.

Unfortunately, one Mexican secondary laboratory meeting the characteristics and range for this comparison was unable to participate due to major overhaul of its machine during the period of this comparison.

1.1 Nomenclature

The following terms are to be used in this paper:

NMI - National Metrology Institute

GUM - Guide to the Expression of Uncertainty in Measurement

VIM - International Vocabulary of Basic and General Terms of Metrology

SI - International System of Units

DWM -Dead Weight Force Machines

LM -Lever Force Machine

HM - Hydraulic Force Machine

2. Scope of work

The ISO publication VIM [1] and the SI [2] were used for the comparison and for the writing of this document. The recommendations established in the GUM [3], were followed for the uncertainty evaluation.

2.1. Program Objectives

The comparison included two different measurement ranges:

From 20 kN to 50 kN And from 60 kN to 150 kN.

For this comparison a document including general guidelines and procedure [4] was produced as well as a data sheet [5].

2.2. Comparison Standard

Two different comparison standards were used. Table 1 contains the most relevant information of the transducer used as transfer standard for the range from 20 kN to 50 kN.

Table 2 contains the most relevant information of the transducer used as transfer standard for the range from 60 kN to 150 kN.

Table 1. Comparison standard data, up to 50 kN.

Transducer Type:	Load cell
Range:	5 kN to 50 kN
Accuracy Class:	00
Uncertainty:	$70\ 10^{-6}$ (20 kN to 50kN)
Make:	HBM
Model:	C3 H2
Serial number or Identification:	F 29 685
Owner:	CENAM

Table 2. Comparison standard data, up to 150 kN.

Transducer Type:	Load cell
Range:	20 kN to 200 kN
Accuracy Class:	00
Uncertainty:	$40\ 10^{-6}$ (60 kN to 150kN)
Make:	HBM
Model:	C3 H3
Serial number or Identification:	H 046 55
Owner:	CENAM

The load cells were used with a digital amplifier of the type HBM DK38 or better. Each laboratory used it’s own amplifier, for details see section 3.

2.3. Participating Laboratories

The comparison was held among two NMI´s and included 2 secondary laboratories from Brazil which are listed in table 3.

Table 4 presents the person in charge of the comparison for each laboratory.

The Centro Nacional de Metrología, CENAM, acted as the co-ordinator and pilot laboratory.

Table 3. Participating laboratories.

Laboratory	Laboratory
Instituto Nacional de Metrologia, Normalização e Qualidade Industrial	INMETRO
Fundação Centro Tecnológico de Minas Gerais	CETEC
Instituto de Pesquisas Tecnológicas do Estado de São Paulo	IPT
Centro Nacional de Metrología	CENAM

Table 4. Country and person in charge from each laboratory.

Laboratory	Person in charge	Country
INMETRO	Jorge P. Cruz	Brazil
CETEC	Jorge Saffar	Brazil
IPT	Marisa Pereira	Brazil
CENAM	Daniel Ramírez	Mexico

2.4.General Guidelines

The general guidelines for the comparison were established in the document [4] mentioned in 2.1; this document is based on the Guidelines for key comparisons by Terry Quinn [6]. Only a few relevant aspects of the measurement protocol are mentioned in this paper:

a) General regulations. In this part of the guidelines, several aspects were established such as, responsibilities, participation, schedule of the comparison, logistics and comparison devices to be used.

b) Measurement conditions. The following subjects regarding measurement conditions were also cover in the guidelines: indicating device used, environmental conditions, load cell interaction with the machine and reading time interval.

2.5. Measurement Procedure

The reading and force step criteria were agreed and the main points of the measurement procedure are here described.

a) In order to evaluate and minimise the parasitic components [7], the transfer standard was measured in five different positions relative to the standard machine axis, in 0°, 90°, 180°, 270° and 360°;

b) In the 0° position, the load cell was preloaded three times to 100% of the range of measurement, during 90 s. Between preloads a pause of 180 s was made;

c) Then, two series of readings in ascending order were taken 180 s after the last preload and in the same mounting position (0°);

d) After these 2 series, transfer standard was rotated 90° and was preloaded only once to 100% of the measurement range. Three minutes after unloading the cell, two series of measurements were taken in ascending order;

e) For the positions of 180° and 270°, the procedure of measurement was similar to that used for 90°. For the last position (360°), only one series of measurements was taken.

2.5.1 Force Steps and Readings Criteria

The forces applied by the standards, in the range of measurement and according to the restrictions of the loads, were determined with the following criteria:

For the range from 20 kN to 50 kN.

a) Starting at 20 kN increments of 5 kN were made until the maximum value of 50 kN was reached; the force was held for 60 s at each measurement point before the reading was taken;

b) The same number and values of forces were applied in each series of measurement;

c) Readings were taken in mV/V.

For the range from 60 kN to 150 kN.

d) The first 2 reading points were 60 kN and 70 kN. Then, 20 kN increments were made until the maximum value of 150 kN was reached; the force was held for 60 s at each measurement point before the reading was taken;

e) The same number and values of forces were applied in each series of measurement;

f) Readings were taken in mV/V.

3. Participating Laboratory Standards

Table 5 presents the standard type and the amplifier used by each laboratory. INMETRO (Brazil´s NMI) used a DWM from 60 kN up to 110 kN and a LM (connected to the DWM) for the range up to 150 kN.

Table 5. Type of standard and amplifier used by each laboratory.

Laboratory	Standard type	Amplifier
INMETRO	DWM up to 110 kN LM up to 150 kN	DMP40
CETEC	DWM for 20 kN to 50 kN HM for 60 kN to 150 kN	DK38
IPT	DWM	DK38
CENAM	DWM	DMP40

4. Results

The results of the measurements made by the participating laboratories were entered into the data file provided for the comparison [5] and sent to the co-ordinating laboratory.

The resulting Figures, showing the estimated deviation of the measurements made on the transfer standards by each laboratory, are presented in this section. In an attempt to increase clarity in the Figures, lines for each laboratory connect the measured points. In Figure 1, the relative deviations for each laboratory for the range up to 150 kN are plotted. The deviations are respect to INMETRO and CENAM average measurements and to the reading.

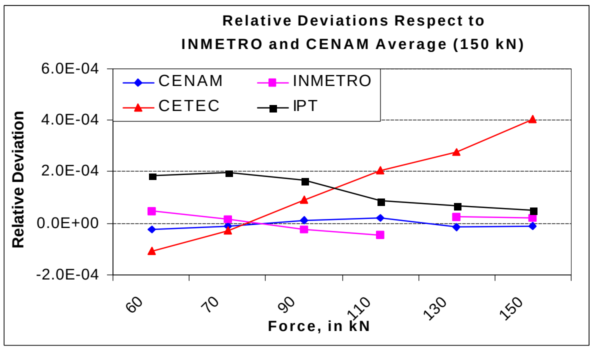

Figure 1. Relative deviations for the range 60 kN to 150 kN.

The results obtained for the measurement range from 20 kN to 50 kN are shown in Figure 2, which includes the same information as Figure 1.

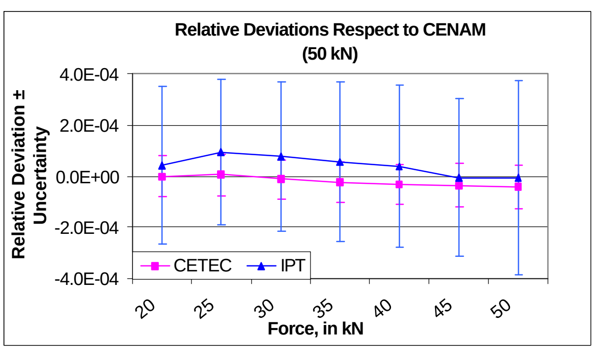

Figure 2. Relative deviations of the range 20 kN to 50 kN.

Due to a logistics problem (from the part of the pilot laboratory), INMETRO was unable to perform the measurements for this range.

5. Discussion

The higher compared range results (presented in Figure 1) show a small deviation between INMETRO and CENAM, within 20 10^{-6}. IPT obtained measurement results with relative deviations less than 200 10^{-6} (with respect to the average of INMETRO and CENAM results), and better results are observed from 110 kN to 150 kN (where the relative deviation is less than 60 10^{-6}). CETEC results presented a larger deviation in the 110 kN to 150 kN range, relative to the average, but it is important to realise that for this range they used an HM.

The lower compared range results, shown in Figure 2, present very small deviations between CETEC and CENAM, within 45 10^{-6}. IPT obtained measurement results with deviations less than 90 10^{-6} (relative to CENAM), and very small deviations can be seen from 40 kN up to 50 kN where deviations are less than 40 10^{-6}.

It would be rather adventurous to conclude the state of agreement among the laboratories from the observation of deviations in Figures 1 and 2. To obtain a better perspective of the comparison results, the laboratories declared uncertainties are included (see table 6).

Table 6. Uncertainty associated to force measurement as declared by each laboratory.

Laboratory	Range	Expanded uncertainty, relative to the reading
INMETRO	DWM up to 110 kN LM up to 150 kN	20×10^{-6} 100×10^{-6}
CETEC	DWM for 20 kN to 50 kN HM for 60 kN to 150 kN	50×10^{-6} 550×10^{-6} to 230×10^{-6}
IPT	DWM	200×10^{-6}
CENAM	DWM	20×10^{-6}

Following Figures, 3 and 4, show the relative deviations results including the force measurement associated uncertainties. The uncertainties shown include (at least) the declared laboratory standard uncertainty (table 6), repeatability and resolution.

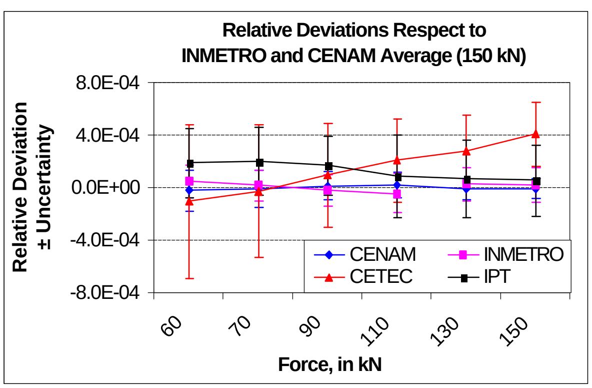

Figure 3. Relative deviations and uncertainties for the range 20 kN to 50 kN.

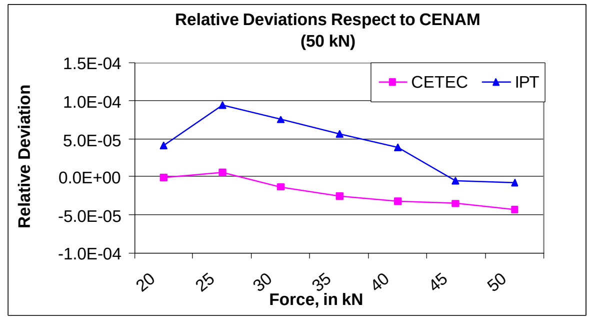

Figure 4. Relative deviations and uncertainties for the range 60 kN to 150 kN.

6. Conclusion

In this comparison, two national laboratories (INMETRO and CENAM) and two secondary laboratories (CETEC and IPT) compared their force standards by means of two electronic transducers (load cells) using different digital amplifiers. Two different ranges were compared, from 20 kN to 50 kN and from 60 kN to 150 kN.

According to the results and the information given in the Figures 1 and 4, INMETRO and CENAM have full agreement.

CETEC and CENAM have full agreement for the range from 20 kN to 50 kN and a small difference in one point (150 kN) in the range from 60 kN to 150 kN (where the HM is used). CETEC and INMETRO have also a full agreement, no disagreement exist between them at 150 kN.

IPT and CENAM have a very good agreement. In Figure 1 the deviation seems large, but when uncertainties are included, Figure 4, this deviation can be regarded as insignificant. IPT and INMETRO have full agreement, having similar considerations for 110 kN.

Acknowledgements

INMETRO is grateful to Ademir Rodrigues das Chagas for performing the measurements. CETEC acknowledges Eunice Marta Ferreira Marques for her work on this comparison.

We also wish to thank, besides the person in charge mentioned in table 1, the contributing metrologist from IPT/SP Walter Link.

7. References

[1]. *International Vocabulary of Basic and General Terms in Metrology*; BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML; 1993.

[2]. *The International System of Units (SI)*; Bureau International des Poids et Mesures. BIPM; 1998.

[3]. *Guide To The Expression Of Uncertainty In Measurement*; ISO TAG 4 WG 3. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML; 1995.

[4]. Torres Guzmán J. C., Ramírez Ahedo D., *General Guidelines and Procedure for* the: Comparison of Force Standards up to 150 kN, within the Interamerican Metrology System (SIM). 1999.

[5]. Ramírez Ahedo D., Torres Guzmán J. C, *Data Sheet for*: Force Standards up to 150 kN. 1999.

[6]. Quinn T. J. *Guidelines for key comparison carried out by Consultative Committees*. 1997.

[7]. Sawla, A.; Peters, M.; Yaniv, S.; *Intercomparison of force standard machines of the National Institute of Standards and Technology, USA and the Physikalisch-Technische Bundesanstalt*, FRG, PTB- Bericht MA-20, 1991.

Contact Person for Paper:

Dr. Jorge Torres Guzmán
Centro Nacional de Metrología
km 4,5 carretera a Los Cués, El Marqués, Queretaro C.P. 76 241, Mexico
Tel. (52) 4 211 0572,
Fax (52) 4 211 0578,
e-mail jtorres@cenam.mx