FINAL REPORT - BILATERAL COMPARISON ON THE CALIBRATION OF STAINLESS STEEL MASS STANDARDS BETWEEN CENAM-MEXICO AND INTI-ARGENTINA SIM.M.M-S5 (SIM.7.44)

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Introduction
Mass calibration is an important activity for National Metrology Institutes (NMIs), due to the amount of measurements on scientific, industrial and legal activities that have traceability to the national mass standards of each country.

In order to evaluate the stated uncertainty and degree of equivalence between CENAM-Mexico and INTI-Argentina on mass calibration a bilateral comparison was agreed between both laboratories.

An additional objective of this bilateral comparison is to evaluate the degree of equivalence between CENAM-Mexico and INTI-Argentina in mass calibration by subdivision methods.

Subdivision methods are widely used on calibration of weights of the highest accuracy classes, and because of that, it is important for the NMIs to demonstrate their capability of having good results with such methods.

Participant laboratories
The data of the participant laboratories are listed in table 1.

Table 1. Participants of mass comparison

National Institute of Metrology	Acronym	Country	Technical Contact(s)
Centro Nacional de Metrología, km 4.5 Carretera a los Cués, Mpio. El Marqués, Querétaro, México	**CENAM**	**Mexico**	Luis Omar Becerra Jorge Nava Amparo Leticia Luján
Instituto Nacional de Tecnología Industrial Av General Paz 5445, Casilla de Correo 157 B1650WAB San Martín, Buenos Aires Argentina	**INTI**	**Argentina**	Fernando Kornblit Leonardo Carrasco Juan Leiblich

Travelling standards (Weights)
For the bilateral comparison, INTI supplied four stainless steel weights. The volume of the weights was measured at INTI, see table 2.

Table 2. Data of the traveling standards for the SIM mass comparison

Nominal value	Volume cm^3	Uncertainty, k=2 cm^3
1 kg	125,676	0,03 0
100 g	12,567 9	0,004 0
10 g	1,255 4	0,001 5
1 g	0,126 17	0,000 75

Circulation and date of measurements

The travelling standards were measured at participant laboratories according to the dates of table 3.

Table 3. Dates of measurement of the travelling standards

Participant laboratory	Date of measurements
INTI	April, 2005
CENAM	June, 2005

Calibration Methods and Traceability of results reported by participants

For the calibration of the weights, both laboratories used their own facilities, instruments and methods. Each participant laboratory determined mass value and its associated uncertainty for each individual weight.

Both laboratories used subdivision methods for the mass measurement of the travelling standards. These kind of methods are widely used for the calibration of submultiples of the kilogram at the highest accuracy level.

For the buoyancy corrections both laboratories used the CIPM 81/91 equation for the evaluation of the air density and related uncertainty.

In table 4 are listed the calibration methods, the mass standards and the balances used in this bilateral comparison, as well as the source of traceability for the mass values.

Table 4. Calibration methods, mass standards, traceability and balances

Participant laboratories	Calibration Method	Mass standard / Identification	Traceability	Balance
CENAM	Subdivision	1 kg stainless steel / LPN-00-08 1 kg stainless steel / LPN-00-02 1 kg stainless steel / LPM-09	CENAM-Mexico	Mettler Toledo, Max=1 000 g, d = 0.001 mg Mettler-Toledo, Max= 1 100 g, d = 0.01 mg Mettler-Toledo, Max= 110 g, d = 0.001 mg Mettler-Toledo, Max= 5,1 g, d = 0.000 1 mg
INTI	Subdivision	1 kg stainless steel / K30 1 kg stainless steel / k29	INTI-Argentina	Sartorius, Max=1 000 g, d = 0.001 mg Sartorius, Max= 50 g, d = 0.001 mg Sartorius, Max= 5 g, d = 0.000 1 mg

Results

For each traveling standard the participant laboratories measured the mass and calculated the correction and the associated uncertainty.

Corrections and their associated uncertainties reported by participants are listed in table 5.

Table 5. Corrections and associated uncertainties reported by participants.

	CENAM		INTI	
Nominal Value	Correction mg	Uncertainty, k=2 mg	Correction mg	Uncertainty, k=2 mg
1 kg	0,694	0,024	0,745	0,052
100 g	1,592	0,008	1,589	0,01
10 g	-0,002	0,001 8	-0,001	0,002
1 g	0,000 3	0,000 8	0,000 8	0,000 8

Figure 1. Results reported by participant laboratories for the travelling standard of 1 kg of nominal value.

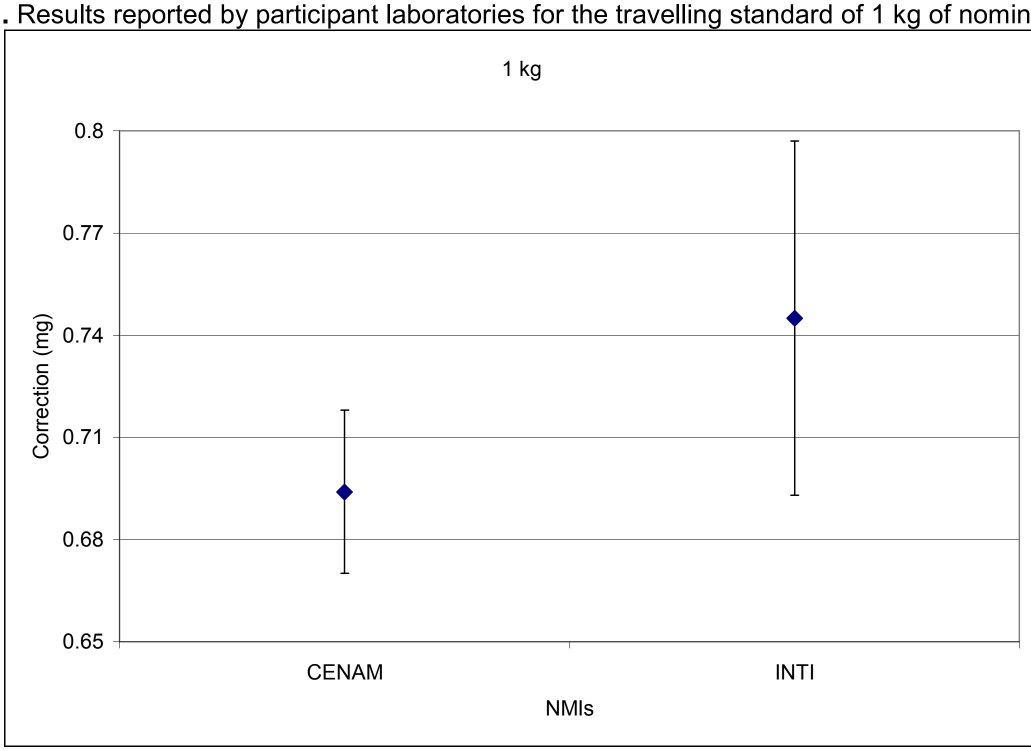


Figure 2. Results reported by participant laboratories for the travelling standard of 100 g of nominal value.

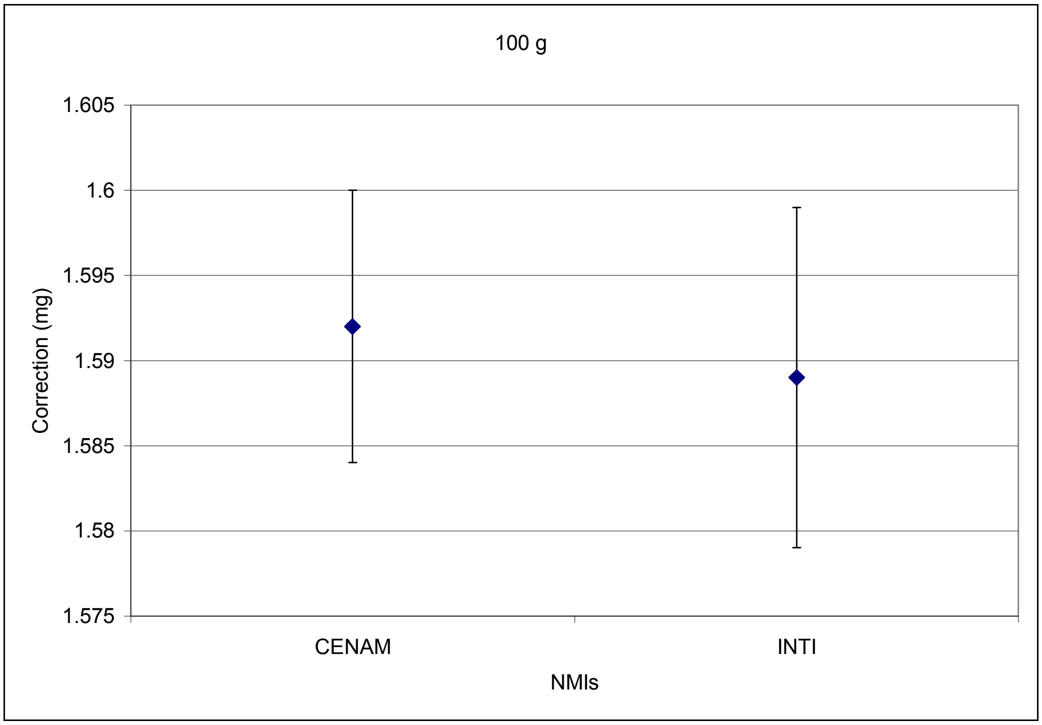


Figure 3. Results reported by participant laboratories for the travelling standard of 10 g of nominal value.

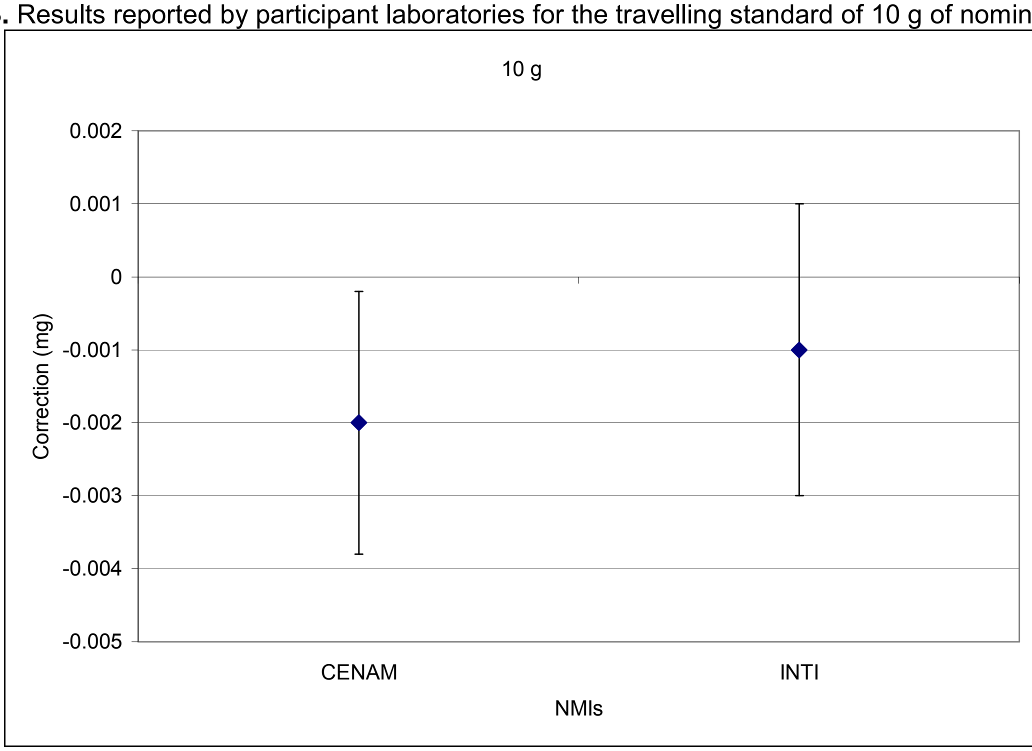
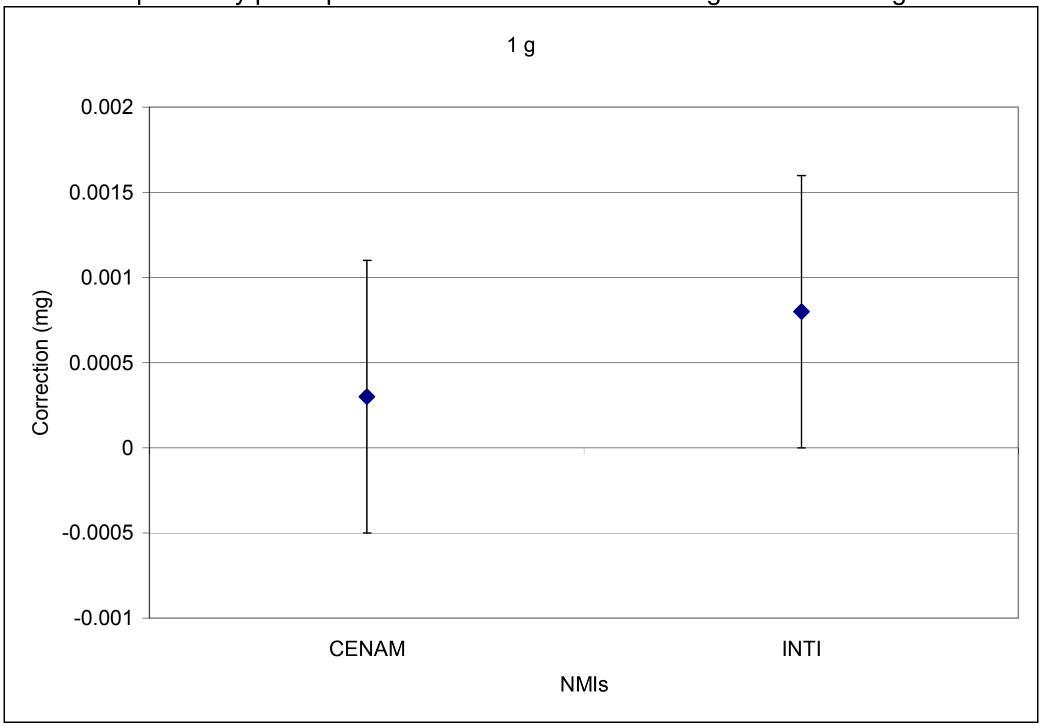


Figure 4. Results reported by participant laboratories for the travelling standard of 1 g of nominal value.



Degree of equivalence between participants

The degree of equivalence among participant laboratories was calculated as the difference between the values reported by participants.

$$D_{CENAM-INTI} = X_{CENAM} - X_{INTI} \quad (1$$

with the expanded uncertainty as follows,

$$U(D_{CENAM-INTI}) = 2\sqrt{u^2(X_{CENAM}) + u^2(X_{INTI})} \quad (2$$

For the above formula, the correlation between results reported by CENAM and INTI are considered not significant.

From this difference and corresponding uncertainty, the normalized errors were calculated for each nominal values as follows,

$$En = \frac{|D_{CENAM-INTI}|}{U(D_{CENAM-INTI})} \quad (3$$

In the table 6 are listed the degrees of equivalence between CENAM and INTI for the measurements done in this bilateral comparison.

Table 6. Degree of equivalence between CENAM and INTI

Nominal Value	Diff. CENAM-INTI $D_{CENAM-INTI}$ mg	Expanded uncertainty, k=2 $U(D_{CENAM-INTI})$ mg	Normalized Error En
1 kg	-0,051	0,057	0,89
100 g	0,003	0,013	0,23
10 g	-0,001 0	0,002 7	0,37
1 g	-0,000 5	0,001 1	0,44

Conclusions

The main objectives of this SIM bilateral comparison were:

- to evaluate the stated uncertainty offered by CENAM-Mexico and INTI-Argentina on the calibration of mass standards by subdivision methods and,
- to evaluate the degree of equivalence between CENAM-Mexico and INTI-Argentina in the calibration of mass standards by subdivision methods.

In order to reach such objectives, two weights of stainless steel were measured in both laboratories from April to June, 2005.

For the measurements each laboratory used their own facilities, equipments, mass standards and procedures.

The traceability of the measurements done by the laboratories are to CENAM's prototype and for INTI's national mass standard.

From results reported by participants (see table 5), there were calculated the degree of equivalence between participants in the scope range of this bilateral comparison as well as the normalized errors, results are reported in table 6.

From data of table 6, it can be noted that results reported by both participants are consistent within the reported uncertainty. The largest normalized error calculated for this comparison was 0.89, which was calculated for 1 kg.

Acknowledge

The technical contacts of participant laboratories wish to thank to **Francisco García** of CESMEC-Chile for acting as a third laboratory which received results from both participants and checked consistency before to share the results with CENAM and INTI.

Reference

[1] JCGM 100:2008 - Evaluation of measurement data — Guide to the expression of uncertainty in measurement -