Final Report
Supplementary Comparison SIM.M.M-S18

CALIBRATION OF CONVENTIONAL MASS OF A 20 kg WEIGHT

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Content

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1 Introduction

This report describes the results of a supplementary comparison between two National Metrology Institutes (NMIs) from Sistema Interamericano de Metrología (SIM), which was carried out to compare the degree of equivalence in conventional mass calibration of a 20 kg mass standard.

By mutual agreement, the NMIs from Mexico and Panama, i.e., Centro Nacional de Metrología (CENAM) and the Centro Nacional de Metrología de Panamá (CENAMEP – AIP) respectively, agreed to carry out a bilateral comparison in calibration of conventional mass of mass standard of 20 kg to compare the degree of equivalence between the two NMIs.

Mr. Aldo Quiroga from INACAL – Peru was invited as referee for reviewing and analyzing the participant results and, pointing out possible typing errors or mistakes in the results of the two NMIs.

A 20 kg OIML class F_1 [1] one-piece stainless-steel weight was used as the traveling standard for this comparison. CENAMEP-AIP Panama provided the weight.

The traveling standard was characterized by CENAM-Mexico in its density/volume and in its magnetic properties.

2 List of participant NMIs

The participant laboratories and their respective technical contacts are listed below:

- Centro Nacional de Metrología (CENAM) / Mexico.
  - Luis Omar Becerra
  - Luis Manuel Peña
  - Sandra Ramírez
- Centro Nacional de Metrología de Panamá (CENAMEP AIP).
  - Saul García
  - Edwin Aizpurua

All the participant laboratories are NMIs belonging to SIM and signatories of the CIPM MRA.

3 Traveling standard weight

The travelling standard used was a weight of class OIML F_1 and the property of CENAMEP AIP. Its shape, material and identification are shown in Table 1.

Nominal value	Identification	Accuracy class	Material	Shape
20 kg	1570102	F_1	Stainless steel	Cylindrical knob

Table 1. Physical characteristics of weight.

In May 2018 the volume and the magnetic properties of the weight were measured at CENAM. The results are shown in Table 2.

Nominal value	**Volume (20 °C)**	**Uncertainty ($k = 2$)**
20 kg	2 542.72 cm^3	0.49 cm^3
	Magnetic Susceptibility (χ)	**Permanent Magnetization ($\mu_0 M$)**
	< 0.07	< 8

Table 2. Volume with its expanded uncertainty and magnetic properties of the traveling standard

During the circulation between the participant laboratories, volume and magnetic properties of the weights were not measure by any participant.

4 Circulation Schedule

The traveling standard was circulated according to the schedule shown in Table 3. CENAM started the measurements in May 2018, after such measurements, CENAMEP began the measurements in August 2018.

After the measurements, CENAMEP and CENAM sent their results to INACAL, who checked the consistency of these results; once consistency was checked, INACAL notified CENAMEP to continue with the analysis of reported results by the participants and to write the comparison report. The objective of this process was to ensure a “blind” comparison between the participants.

NMI	Date of arrival	Date of departure
CENAMEP AIP	----	16/03/2018
CENAM	20/03/2018	07/06/2018
CENAMEP-AIP	07/06/2018	----

Table 3. Schedule of circulation during the comparison

5 Surface damages of the traveling standard

Each participant laboratory examined and registered the surface condition of the traveling standard at both reception and departure, using the established forms to record all the visible marks, scratches or damages that could happen on the weight during the circulation.

No progressive damage was reported on the traveling standard during the circulation.

Image 1. The travelling standard

6 Procedures and Measurement Methods

The participant laboratories determined the conventional mass and their associated uncertainty for the travelling standard, using their own facilities, instruments, and procedures according to the best capability of the laboratory.

Air density was determined from environmental measurements using the CIPM-2007 formula, in order to correct the air buoyancy effect [2].

The resolution of the weighing instruments used by participant laboratories are shown in Table 4.

	CENAM	CENAMEP
20 kg	0.1 mg	5 mg

Table 4. Resolution of the weighing instruments used by NMIs

The resolution of instruments used by participant laboratories for measuring the environmental conditions during the calibration is shown in Table 5.

	CENAM	CENAMEP
TEMPERATURE t / °C	0.1	0.1
RELATIVE HUMIDITY h / %	0.1	0.1
BAROMETRIC PRESSURE p / Pa	0.1	0.1

Table 5. Resolution of devices for environmental conditions measurements used by NMIs

Table 6 shows the traceability of the 20 kg reference mass standard used by the participant laboratories, to indicate the possible correlation of the traceability source of the standard.

	CENAM	CENAMEP
20 kg	BIPM (Internal calibrations at CENAM from 1 kg up to 20 kg)	PTB

Table 6. Mass traceability of NMIs

Table 7 shows the dates of calibration of the mass standards. An overdue calibration could introduce a drift that may affect the results of the calibration.

The date indicated in Table 7, regarding the CENAM calibration, refers to the date on which CENAM calibrated the 20 kg mass internally.

	CENAM	CENAMEP
20 kg	2016	2018

Table 7. Dates of last calibration of mass standards of NMIs

7 Results of the measurements

The direct comparison method was used by CENAM and CENAMEP. Table 8 shows the mass correction value calculated by each participant laboratory and its associated uncertainty with a coverage factor equal to 1 (k =1).

Nominal value	20 kg	
	Conventional Mass Correction Value, mg	Standard uncertainty $u(m_c)$, (k =1) mg
CENAM	-12	1.2
CENAMEP	-9	6,6

Table 8. Mass correction values and standard uncertainties reported for the nominal value of 20 kg.

It was not considered necessary to carry out a second measurement by CENAM since there were only two participating laboratories and the measurements between CENAM and CENAMEP were carried out at very close times, so that the uncertainty due to instability of the traveling standard was assumed to be negligible.

The results reported by the participant laboratories, as well as the uncertainty analysis, were made according to "*Guide to the expression of Uncertainty in Measurements*" GUM [3].

8 Analysis of the results between CENAM and CENAMEP

The aim of the comparison is to demonstrate the equivalence of the results provided by CENAMEP with the values of the CENAM.

8.1 Consistency between CENAM and CENAMEP

The method for the evaluation of consistency is described as follows [4].

$$E_n = \frac{\Delta x_{\mathrm{CENAMEP}} - \Delta x_{\mathrm{CENAM}}}{\sqrt{U^2(\mathrm{CENAMEP}) + U^2(\mathrm{CENAM})}}$$

Where:

E_n normalized error of the results

$\Delta x_{\mathrm{CENAMEP}}$: conventional mass correction value measured by CENAMEP AIP

$\Delta x_{\mathrm{CENAM}}$: conventional mass correction value measured by CENAM

$U^2(\mathrm{CENAMEP})$: expanded uncertainty of conventional mass calculated by CENAMEP AIP

$U^2(\mathrm{CENAM})$: expanded uncertainty of conventional mass calculated by CENAM

Table 9 shows the values of normalized error for conventional mass correction values reported by the participants.

Nominal value	20 kg
Normalized error, E_n, in conventional mass	0.2

Table 9. Normalized error between the measurements of CENAM and CENAMEP

9 Conclusions

According to the results of this supplementary comparison, it is possible to conclude:

- There is a consistency of the measurements in conventional mass correction values for 20 kg weights between CENAM and CENAMEP-AIP.
- CENAMEP AIP stated uncertainties equal to one-third of the corresponding maximum permissible error for weights of class OIML F_1 which is the maximum value for the expanded uncertainty recommended in OIML R111 for F_1 weights.

10 References

[1] OIML R 111-1 Edition 2004. ”Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3 Part 1: Metrological and technical requirements”. Organisation Internationale de Métrologie Légale.

[2] A Picard et al, “Revised formula for the density of moist air (CIPM-2007)” 2008 Metrologia 45 149. DOI 10.1088/0026-1394/45/2/004.

[3] JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurements

http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

[4] Wöger, W., “Remarks on the E_n – Criterion used in Measurement comparisons”. Internationale Zusammenarbeit PTB – Mitteilungen 109 1/99

11 ANNEX A

Uncertainty contributions values reported by the participant laboratories for mass and conventional mass correction estimated values:

Nominal value 20 kg	CENAM	CENAMEP	Unit	CENAM	CENAMEP	Unit	CENAM	CENAMEP
Influence Quantity	Mean value	Mean value		Standard uncertainty (mg)	Standard uncertainty (mg)		Contribution to the uncertainty in conventional mass (mg) (See Note 1)	Contribution to the uncertainty in conventional mass (mg) (See Note 1)
Value of Reference Mass standard	20.000 02	20.000 007 70	kg	0.76	5	mg	0.76	5
Instability of the reference mass standard	0.00	1.88	mg	0.12	1.09	mg	0.12	1.09
Density of the reference mass standard	7 950.7	8 000	kg/m^3	1.3	30	kg/m^3	-0.38	0.07
Density of the mass under test	7 865.58	7865.58	kg/m^3	0.76	0.76	kg/m^3	0.062	0.004
Air density	0.947 98	1.184 45	kg/m^3	0.000 57	0.000 79	kg/m^3	0.016	0.17.
Mass difference	-3.967	-16.5	mg				----	-----
Resolution of the balance	0.1	5	mg	0.041 mg	1.44 mg	mg	0.041	1.44
Repeatability	0	1.7	mg	0.13 mg	1.7 mg	mg	0.13	1.70
Reproducibility	0	----	mg	0.68	3.6	mg	0.68	3.6
Eccentricity	0	----	mg	0.43	0	mg	0.43	See Note 2

Table A.1. Uncertainty contributions reported by the participant laboratories for the 20 kg nominal value weight.

Note 1: All contributions, including those the density of the mass standard, the density of the traveling standard and the air density, are given in mg.

Note 2: CENAMEP AIP has considered that the uncertainty of repeatability includes the uncertainty due to eccentricity.

12 ANNEX B

Environmental conditions during the measurements

20 kg	Temperature, t / °C	Barometric pressure, p / Pa	Relative humidity h / %	Air density, ρ / kg/m^3
CENAM	22.63 to 22.84 ± 0.15	80 642 to 80 938 ± 16	31.5 to 39.17 ± 1	0.945 81 to 0.947 98 ± 0.000 58
CENAMEP	21.34 to 21.63	100 600 to 100 700	52.7 to 53.9	1.1831 to 1.185 28

Table B.1. Environmental conditions during the measurement of 20 kg weight