A COMPARISON IN CONVENTIONAL MASS MEASUREMENTS SIM.M.M-S6 – FINAL REPORT

Francisco García[1], Orlando Pinzón[2], Saúl García[2], Raúl Hernández[1], Fernando Leyton[1]
[1]CESMEC-LCPN-M (Red Nacional de Metrología), Centro de Estudios, Medición y Certificación de Calidad, CESMEC S.A., Av. Marathon 2595, 781-0552 Macul, Chile, Phone: 56-2-3502185.
fgarcia@cesmec.cl; rhernandez@cesmec.cl; fleyton@cesmec.cl
[2]Centro Nacional de Metrología de Panamá AIP, Edificio 215, Ciudad del Saber, Clayton, Ciudad de Panamá, República de Panamá, Phone: 507-5173100. opinzon@cenamep.org.pa;

Abstract: The present document reports the results of a bilateral comparison in the calibration of mass standards that was carried out between CESMEC (Chile) and CENAMEP AIP (Panamá).

This comparison was carried out in the following nominal values:

200 mg, 1 g, 50 g, 200 g, 1 kg, 2 kg, and 10 kg.

1. INTRODUCTION

In July 2009 CENAMEP AIP and CESMEC agreed to execute a bilateral within the CIPM MRA Appendix B [1,2] framework.

A measurement protocol was agreed [3] and reported to the SIM Mass & Related Quantities Metrology Working Group on September 2009. The SIM.M.M-S6 code was assigned [1].

2. COMPARISON PROCESS

2.1. General Guidelines

The following relevant aspects were stated in the protocol:

- Measurements were done after the acclimatization time as specified in [3] for class E_1.
- The participating laboratories measured the conventional mass of the artifacts according to [3].
- No washing was performed. Before measurements, dust particles were removed from the surface of the standard by a soft brush.
- All weighing were performed in air. Uncertainties were estimated and combined according to [4] and the specific requirements of [3].
- The standards were transported by a courier service.
- Measurement method was direct comparison to a reference weight of the same nominal value with a buoyancy correction applied.

2.2. Comparison Objects

The test objects have the nominal values and densities stated in Table 1.

***Table 1**. Density of the comparison objects.*

Nominal Value	Density	Expanded uncertainty of the density value $(k = 2)$
10 kg	7950	140
2 kg	7950	140
1 kg	7950	140
200 g	7950	140
50 g	7950	140
1 g	7950	140
200 mg	8600	170

The weights were manufactured by Häfner Gewichte GmbH and their magnetic properties were measured by CESMEC using method B.6.4 of [3]. It was confirmed that the magnetic properties met the requirements for OIML Class E_2 [3].

The weights are always sold by the manufacturer with their conventional mass values within tolerance and in order to make this comparison more challenging to the participant laboratories, some of them were adjusted at the mechanical workshop of CESMEC.

2.2 Comparison round

The circulation of the weights was done in one way, that means, no measurements were executed to estimate the drift of the weights. However, there is evidence that shows that at the measurement uncertainty levels of the participant laboratories there is not significant effect due to travel conditions [5,6,7].

Table 2. *Participant laboratories and measurement standards.*

Laboratory/ Country	Institute that calibrated the standards used for this comparison	Last calibration date
CESMEC S.A. / Chile	PTB	2007-05
CENAMEP AIP / Panamá	INTI (10 kg) NIST (200 mg- 2 kg)	2008-09 (10 kg) 2008-05 (200 mg - 2 kg)

3. RESULTS

Results as reported by each laboratory for each nominal value and the expanded uncertainty ($k = 2$) are presented in Table 3.

Table 3. *Results as reported by each participant on July 2,2010*

Laboratory	Conventional mass value	Expanded Uncertainty of the conventional mass value ($k = 2$)	Measurement date
CENAMEP	10 kg – 5 mg 2 kg – 4,3 mg 1 kg – 4, 5 mg 200 g – 2,51 mg 50 g – 1,61 mg 1 g – 0,621 mg 200 mg + 0,007 mg	16 mg 3,0 mg 0,5 mg 0,10 mg 0,03 mg 0,010 mg 0,006 mg	2010-03 2010-03 2010-03 2010-03 2010-03 2010-03 2010-05
CESMEC (Pilot)	10 kg + 2,1 mg 2 kg – 2,2 mg 1 kg – 3,7 mg 200 g – 2,36 mg 50 g – 1,57 mg 1 g – 0,619 mg 200 mg + 0,009 mg	16 mg 3,0 mg 0,5 mg 0,10 mg 0,03 mg 0,010 mg 0,006 mg	2009-08 2009-08 2009-08 2009-08 2009-08 2009-08 2010-05

This report was submitted for publication to a metrology congress. On August 17, 2010, at the end of the review process, one referee noticed that the uncertainty contribution of each variable $\left|\frac{\partial m_{\mathrm{ct}}}{\partial x_i}\boldsymbol{u}(\boldsymbol{x_i})\right|$ was different from one laboratory to the other, although the standards and comparators were similar (ANNEX A). The Pilot laboratory reviewed the records and in August 2020 found that there was a mistake in its own calculations that was due to a bad selection of the test weights material, Figure 1; instead of “stainless steel”, “German silver” was selected or “stainless” was not selected. The Pilot Laboratory will apply the “non-conforming” work procedure.

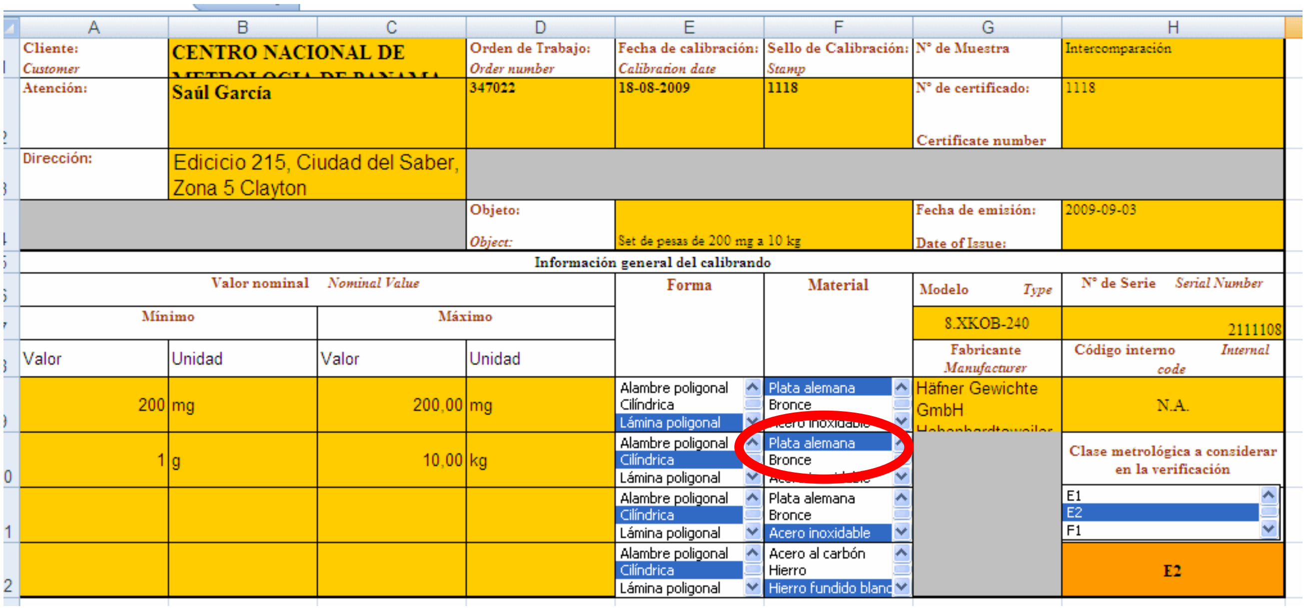

Figure 1

After selecting the right material for the test weights (and using the right density values) the new mass values are those given in Table 4.

Table 4. *Corrected Pilot results*

Laboratory	Conventional mass value		Expanded Uncertainty of the conventional mass value ($k = 2$)	Measurement date
CENAMEP	10 kg 2 kg 1 kg 200 g 50 g 1 g 200 mg	– 5 mg – 4,3 mg – 4,5 mg – 2,51 mg – 1,61 mg – 0,621 mg + 0,007 mg	16 mg 3,0 mg 0,5 mg 0,10 mg 0,03 mg 0,010 mg 0,006 mg	2010-03 2010-03 2010-03 2010-03 2010-03 2010-03 2010-05
CESMEC (Pilot)	10 kg 2 kg 1 kg 200 g 50 g 1 g 200 mg	– 5 mg – 3,7 mg – 4,4 mg – 2,51 mg – 1,61 mg – 0,619 mg + 0,009 mg	16 mg 3,0 mg 0,5 mg 0,10 mg 0,03 mg 0,010 mg 0,006 mg	2009-08 2009-08 2009-08 2009-08 2009-08 2009-08 2010-05

4. DISCUSSION

The degrees of equivalence are given by the pair of value: d_{ij} and $U(d_{ij})$ where:

$$d_{ij} = m_{\text{ct}}^{(i)} - m_{\text{ct}}^{(j)} \tag{1}$$

$m_{\text{ct}}^{(i)}$ is the conventional mass value of the test weight determined by the laboratory i

- $i = p$ for CENAMEP, Panamá.
- $i = c$ for CESMEC, Chile and

$$U(d_{ij}) = 2\sqrt{\left(u^2\left(m_{\text{ct}}^{(c)}\right) + u^2\left(m_{\text{ct}}^{(p)}\right)\right)} \tag{2}$$

Where $u(m_{\text{ct}}^{(c)})$ and $u(m_{\text{ct}}^{(p)})$ represent the uncertainty of the conventional mass of the equipment under test determined by Chile and Panamá respectively.

And the level of measurement agreement is given by the quotient E_n,

$$E_n = \frac{d_{ij}}{U(d_{ij})} \tag{3}$$

which is also called normalized error:

Table 5 contains the values of degrees of equivalence (E_n) and levels of measurement agreement among participants that can be obtained from Table 3. For all nominal values $|E_n| \leq 1$, except for 1 kg and 200 g (note that the high E_n here are due to the error noted In Section 3 above).

Table 5. *Degrees of equivalence and levels of measurement agreement from Table 3.*

Nominal Value	d_{ij}/ mg	$U(d_{ij})$/ mg	E_n
10 kg	-7	17	-0,4
2 kg	-2,1	3,2	-0,7
1 kg	-0,8	0,7	-1,1
200 g	-0,15	0,14	-1,1
50 g	-0,04	0,04	-0,9
1 g	-0,002	0,014	-0,1
200 mg	-0,002	0,008	-0,2

Table 6 contains the corrected values for the degrees of equivalence and levels of measurement agreement among participants that can be obtained from Table 4. For all nominal values $|E_n| \leq 1$,

Table 6. *Degrees of equivalence and levels of measurement agreement from Table 4.*

Nominal Value	d_{ij}/ mg	$U(d_{ij})$/ mg	E_n
10 kg	0	17	0,0
2 kg	-0,6	3,2	-0,2
1 kg	-0,1	0,7	-0,1
200 g	-0,00	0,14	0,0
50 g	0,00	0,04	0,0
1 g	-0,002	0,014	-0,1
200 mg	-0,002	0,008	-0,2

5. CONCLUSIONS

It is possible to conclude that this comparison results support CENAMEP's current CMCs declaration in the KCDB [9]. Also provides evidence that CENAMEP is able to reach confident results with smaller uncertainties than those currently declared in the KCDB [9] and CENAMEP may consider expanding the scope of its CMC to include a declaration at 10 kg.

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