Final Report on GULFMET supplementary comparison GULFMET M.M-S1: Comparison of mass standards in multiples and sub-multiples of the kilogram

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Contents

Abstract

In order to show metrological equivalence in mass standards calibration among National Metrology Institutes (NMIs) of member countries of the “Gulf Association for Metrology” (GULFMET), the first organized supplementary comparison (SC) of mass standards have been carried out under the auspices of the GULFMET. This supplementary comparison of 10 kg, 500 g, 20 g, 2 g and 100 mg stainless steel mass standards was based on the decision of the GULFMET meeting held in 2013. TÜBİTAK-UME (Turkey) acted as pilot laboratory. In this region only two NMIs have the CIPM-MRA signature. These NMIs are SASO-NMCC (Saudi Arabia) and EMI (Abu Dhabi). Therefore, the reference values were calculated with the weighted mean method using these two participating laboratories. Concerning the weight of 100 mg, the weight has not been evaluated in this comparison because the travelling standard was mixed-up at some point during the artefact circulation. The results of EMI and SASO-NMCC are consistent with the reference values within their expanded uncertainties with the coverage factor, $k = 2$.

1. Introduction

The comparison is the first supplementary comparison of GULFMET, comprising nine participants including the pilot laboratory. The objectives of the comparison are to facilitate the demonstration of metrological equivalence between the participating national laboratories in the GULFMET members and to check the validity of quoted calibration measurement capabilities (CMCs) in the field of mass.

From the eight participants in the comparison (i.e. excluding the pilot laboratory) only the results of two of them are presented. Because only two countries are CIPM-MRA signatories in this region. These countries are SASO-NMCC (Saudi Arabia) and EMI (Abu Dhabi). Only the results of these two participating laboratories have been used to determine the reference values and associated uncertainties. Additionally, from the original list of participants (given in Table 1), NIS (Egypt) did not participate in the measurements.

One of the mass standards (100 mg weight piece) has been excluded from the evaluation of the results because there is strong evidence to suggest that the travelling standard was mixed-up at some point during the artefact circulation. Specifically, the standard was measured by the pilot laboratory four times in accordance with specified time schedule and while its mass difference from the nominal value after the third measurement was 0,002 mg with associated uncertainty of 0,000 5 mg this difference after the fourth measurement was determined as -0,014 mg with the same uncertainty. In addition, a significant change in the physical appearance of the weight was observed.

2. Participants

This supplementary comparison of 10 kg, 500 g, 20 g, 2 g and 100 mg stainless steel mass standards was based on the decision of the GULFMET meeting held in 2013 and the organizer was GULFMET. The comparison, piloted by UME, was conducted during 2014 to 2015. Participant detail is given in Tables 1.

Table 1. List of participating laboratories

Laboratory	Address	Contact person /tel/fax/e-mail
TÜBİTAK-UME	TÜBİTAK–Ulusal Metroloji Enstitüsü 41470 Gebze/ Kocaeli-Türkiye	Sevda Kacmaz +90 262 679 50 00 +90 262 679 50 01 sevda.kacmaz@tubitak.gov.tr
Calibration & Metrology Lab (PAI)	Calibration & metrology Lab (PAI)-Kuwait	Amal Al-Azemi +96525302358 +96599812281 Ak.alazmi@pai.gov.kw
Emirates Metrology Institute (EMI)	QCC – Metrology Center, P.O. Box 853, Abu Dhabi, UAE	Dr. Christos Mitsas +971 2 406 6520 +971 2 406 6677 c.mitsas@qcc.abudhabi.ae
Dubai Central Laboratory (DCL)	DCL-Metrology Division, PO.67 DUBAI - UAE	Kazim Almusawi 0097142215555 00971558147998 kakazim@dm.gov.ae
NMCC	SASO/ NMCC – Riyadh - Saudi Arabia P.O 3437 RIADH –11471- Saudi Arabia	Rayan Alyousefi +966114520000 +966505474746 +966114520193 r.alyousefi@saso.gov.sa
Directorate General for Standards and Metrology - OMAN	Directorate General for Standards and Metrology-Oman P.O 550 - Postal Code 100 Muscat	Sakina Almahdi 24774886 24815992 +96892112221 Metlab2000@hotmail.com
Qatar Air Force Calibration Laboratories	Qatar Air force Calibration Laboratories-DOHA-QATAR	Nasser Jattal +97455537747 data1124@hotmail.com
Directorate of Standards and Metrology - Bahrain	BSMD Directorate of standards and metrology P.O 5479	Nabeel Jawad Sultan +97339689464 nsultan@commerce.gov.bh
NIS-Egypt	National Institute for Standards, P.O. Box: 136 Giza, Code: 12211, Egypt	Dr. Alaaeldin A.Eltawil +201000305355/+20233879241 Eltaweel38@yahoo.com

3. Description of the travelling standard

For this comparison the travelling standards were five mass standards having the following nominal values: 10 kg, 500 g, 20 g, 2 g and 100 mg. UME provided the travelling standards, whose characteristics are shown in Table 2.1 & 2.2.Each of the travelling standard met OIML specifications for the properties [1] of weights of accuracy Class E1.

Table 2.1. Density and volume of the travelling standards and their uncertainties

nominal value	density ρ (kg/m^3)	uncertainty u_ρ (kg/m^3)	volume V (cm^3)	uncertainty u_V (cm^3)
10 kg	8039,7	1,5	1243,8	0,2
500 g	8044,9	1,3	62,151	0,005
20 g	8057	5	2,4824	0,0016
2 g	8042	29	0,2487	0,0009
100 mg*)	8600	172	-	-

*) **density assumed**

Table 2.2. Magnetic susceptibility and magnetization of the travelling standards and their uncertainties

nominal value	magnetic susceptibility χ	uncertainty u_χ	magnetisation M (μT)	uncertainty u_M
10 kg	0,00346	0,004	0,05	0,5
500 g	0,00408	0,004	0,09	0,5
20 g	0,00343	0,004	0,15	0,5
2 g	0,00445	0,012	0,41	0,5
100 mg	-	-	-	-

4. Time schedule

Each participating laboratory had 4 weeks to receive the weights, carry out measurements and send to the next laboratory. For the transportation purposes a special wooden box was provided by UME. Transportation was carried out by different shipping companies individually chosen by each participant. Deviations from the planned time schedule were observed mainly due to the delays in customs clearance as well as dispatching the travelling standards between participants. The time schedule was as follows:

Table 3. Time schedule

Order	Country	Date
1	TÜBİTAK-UME TURKEY	15.12. 2013 to 15.01. 2014
2	DCL - UAE	15.02.2014 to 15.03.2014
3	DGSM- OMAN	15.03.2014 to 15.04. 2014
4	EMI - UAE	15.04. 2014 to 15.05. 2014
5	TÜBİTAK-UME TURKEY	15.05. 2014 to 15.06.2014
6	PAI - KUWAIT	15.06.2014 to 15.07.2014
7	QATAR	15.07.2014 to 15.08.2014
8	BSMD - BAHRAIN	15.08.2014 to 15.09.2014
9	NMCC - KSA	15.09.2014 to 15.10. 2014
10	TÜBİTAK-UME TURKEY	15.10. 2014 to 15.11. 2014
11	NIS-EGYPT	03.06. 2015 to 16.10.2015
12	TÜBİTAK-UME TURKEY	16.10.2015 to 30.11. 2015

5. Summary of results reported by the participants

5.1. Values of mass and uncertainty

The results and uncertainties provided by two participating laboratories for each of the nominal mass values are shown in Table 4. Each result is shown as the difference between the mass determined by the participant (m) and the nominal mass value (m_o), in mg. The uncertainties (u_c) are given in mg at k=1.

Table 4. Reported results for the travelling standards from participants, shown as the difference between mass, m, and nominal mass, m_0, and standard uncertainty u_c (k=1).

	10 kg		500 g		20 g		2 g	
Participant	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg
EMI	-6,6	0,97	0,15	0,063	0,003	0,005	0,0015	0,0027
NMCC	-7,48	0,64	0,225	0,054	0,0003	0,003	0,0006	0,0013

6. Stability of the travelling standards

The travelling standards were measured at UME according to time schedule given in Table 3. In order to check the mass changes during the comparison as is seen in Table 5. The results are shown as the difference in mg between the mass determined by UME (*m*) and the nominal mass value (*mo*), together with the associated uncertainty (u_c) at *k*=1. The weights were stable within the uncertainty of measurement except the weight of 100 mg.

Table5. Results obtained by pilot laboratory, UME, for each of the travelling standard shown as the difference between mass, *m*, and nominal mass, m_0, and standard uncertainty u_c (*k*=1).

Date	**10 kg**		**500 g**		**20 g**		**2 g**	
	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg	m-m_o / mg	u_c / mg
January 2014	-7,0	0,35	0,136	0,01	0,002	0,001	0,0010	0,0009
June 2014	-6,9	0,35	0,140	0,01	0,002	0,001	0,0012	0,0009
November 2014	-6,6	0,35	0,138	0,01	0,001	0,001	0,0010	0,0009
November 2015	-6,8	0,35	0,142	0,01	0,002	0,001	0,0010	0,0009

7. Calculation of reference mass value and uncertainty and data consistency

For the purposes of this comparison the reference value m_{ref} has been taken to be a weighted mean [2] of the reported mass values of two participants. The reference value m_{ref} was calculated as:

$$mref = \frac{m_A/u^2(m_A) + m_B/u^2(m_B)}{1/u^2(m_A) + 1/u^2(m_B)} \qquad (1)$$

while the uncertainty [3] of the reference value $u(m_{ref})$ was determined from given below equation

$$1/u^2\left(m_{ref}\right) = 1/u^2(m_A) + 1/u^2(m_B) \qquad (2)$$

The four reference values and their associated uncertainties are shown in Table 6.

Table 6. Reference values and associated uncertainties (*k*=1)

nominal value	reference value, m_{ref} mg	uncertainty, *u*(*mref*) mg
10 kg	-7,21	0,53
500 g	0,193	0,041
20 g	0,001	0,0025
2 g	0,0008	0,0012

7.1. Mass difference and uncertainty between participants and reference value

The mass difference of the reference value and each participant is calculated from

$$\Delta m_{A,ref} = m_A - m_{ref} \quad (3)$$

The uncertainty of the difference between the reference value and a participant's measurement is generally made up of the following components:

- The uncertainty of the participant's measurement, $u(m_A)$

- The uncertainty due to the drift or instability of the transfer standard, u_d (neglected)

The uncertainty of the reference value, $u(m_{ref})$

$$u^2(\Delta m_{A,ref}) = u^2(m_A) - u^2(m_{ref}) \quad (4)$$

$$U(\Delta m_{A,ref}) = 2u(\Delta m_{A,ref}) \quad (5)$$

Since the uncertainty of the drift or instability of the transfer standards is in negligible level, the uncertainty of the drift or instability of the transfer standards has not been included. If the measurement m_A was not included in the reference value then the uncertainty is calculated from

$$u^2(\Delta m_{A,ref}) = u^2(m_A) + u^2(m_{ref}) \quad (6)$$

Measurements were tested for discrepancies through

$$|\Delta m_{A,ref}| > 2u(\Delta m_{A,ref}) \quad (7)$$

The differences between two participating laboratories and the reference value, together with their associated uncertainties, are given in Table 7 and shown graphically in Figure 1.

Table 7. Differences between participants' results and reference value, Δm, and associated k=2 uncertainties, $U(\Delta m)$ and E_n number.

		EMI	**NMCC**
10 kg	Δm / mg	0,61	-0,27
	$U(\Delta m)$ / mg	1,62	0,70
	E_n	0,38	0,38
500 g	Δm / mg	-0,043	0,032
	$U(\Delta m)$ / mg	0,096	0,070
	E_n	0,45	0,45
20 g	Δm / mg	0,002	-0,001
	$U(\Delta m)$ / mg	0,009	0,003
	E_n	0,23	0,23
2 g	Δm / mg	0,0007	-0,0002
	$U(\Delta m)$ / mg	0,0048	0,0011
	E_n	0,15	0,15

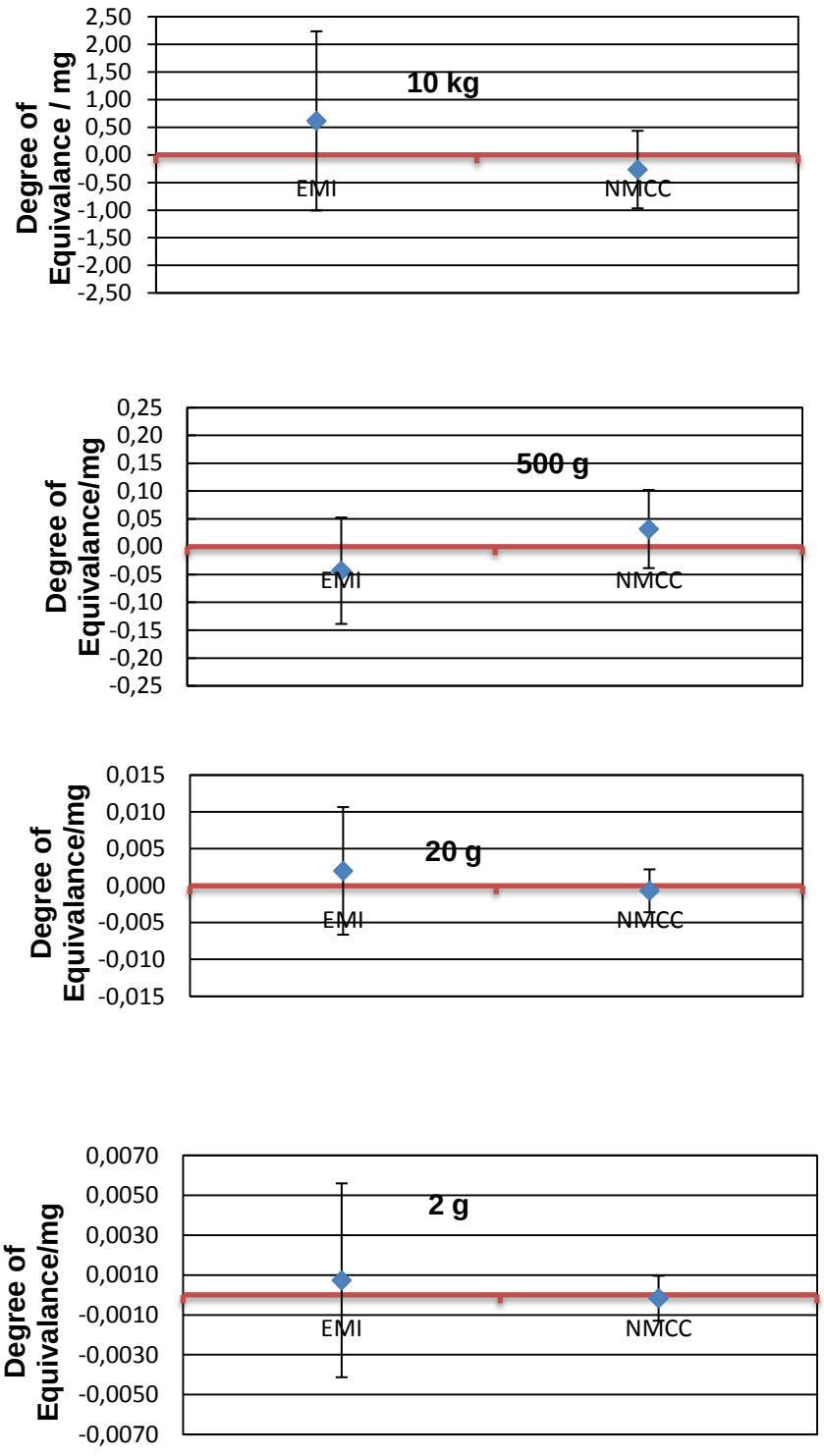

Figure1. The differences between each participant and the reference value, together with their associated uncertainties

8. Conclusion

This comparison was the first such exercise organized and executed in the GULFMET region and even though for some participants it was their first participation, it can generally be concluded that it has served its purpose successfully while identifying potential improvement actions. Difficulties were encountered mainly in adhering to the agreed time schedule with respect to travelling standard transport and timely reporting of the requested information to the pilot laboratory.

For each nominal value, Figure 1 shows that the differences between two participating laboratories and the reference value, together with their associated uncertainties. Consequently, the results of EMI and SASO-NMCC were consistent with the reference values within their expanded uncertainties with the coverage factor, $k = 2$.

9. References

[1] OIML R-111 “Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3 Part 1: Metrological and technical requirements”, 2004 E.

[2] M. G. Cox: The evaluation of key comparison data, Metrologia, 2002, 39, 589-595.

[3] Guide to the Expression of uncertainty in measurement, 1995.

Appendix A

- The results of the measurement of the participants who are not signatories of CIPM-MRA are given in table A1 and table A2.
- QATAR AIR FORCE didn't calculate true mass value of the transfer standard, the situation was reported, but the laboratory did not make the calculation and also E_n values were not determined.
- PAI calculated the uncertainty of the true mass value and the conventional mass value of the transfer standards by a very large difference, but there was no response from participant.

Table A1. Reported results for the travelling standards from participants, shown as the difference between mass *m*, and nominal mass, m_0, and standard uncertainty u_c (*k*=1).

Participant	**10 kg**		**500 g**		**20 g**		**2 g**	
	$m-m_o$ / mg	u_c / mg	$m-m_o$ / mg	u_c / mg	$m-m_o$ / mg	u_c / mg	$m-m_o$ / mg	u_c / mg
BSMD-MOIC	-0,8	9,9	-0,376	0,4	-0,006	0,008	0,003	0,005
DCL	-1,7	2,6	0,430	0,14	0,019	0,013	-0,000	0,006
PAI	-9,0	3,77	0,096	0,2	-0,004	0,020	-0,004	0,010
QATAR AIR FORCE	-	-	-	-	-	-	-	-

Table A2. Reported results for the travelling standards from participants, shown as the difference between conventional mass, m_c, m_0 and standard uncertainty u_c (*k*=1).

Participant	10 kg		500 g		20 g		2 g	
	$m-m_o$ / mg	u_c / mg	m_c-m_o / mg	u_c / mg	m_c-m_o / mg	u_c / mg	m_c-m_o / mg	u_c / mg
BSMD-MOIC	6,6	9,9	0,04	0,4	0,015	0,008	0,005	0,005
DCL	0,7	2,6	0,53	0,14	0,024	0,013	0,000	0,006
PAI	-1,6	12,15	0,51	0,61	0,017	0,031	0,0031	0,0026
QATAR AIR FORCE	-1,5	11,0	3,4	0,24	0,036	0,012	-0,0030	0,010

The reference values of GULFMET M.M-S01 were used to determine the degree of equivalence of the participants. The differences between participants' results and reference value, $\Delta mref$, with associated *k*=2 uncertainties, $U(\Delta mref)$ and E_n number are calculated by Equation (1) and show in Table A3.

$$E_n = \left| \frac{m_{ref} - m_A}{\sqrt{U_{ref}^2 + U_A^2}} \right| < 1 \qquad (1)$$

Table A3. Differences between participants' results and reference value, $\Delta mref$, and associated *k*=2 uncertainties, $U(\Delta mref)$ and E_n number.

		BSMD-MOIC	**DCL**	**PAI**
10 kg	Δm / mg	-6,41	-5,51	1,79
	$U(\Delta m)$ / mg	19,81	5,23	7,56
	E_n	0,32	1,05	0,24
500 g	Δm / mg	0,569	-0,237	0,097
	$U(\Delta m)$ / mg	0,801	0,283	0,402
	E_n	0,71	0,84	0,24
20 g	Δm / mg	0,007	-0,018	0,005
	$U(\Delta m)$ / mg	0,016	0,026	0,040
	E_n	0,43	0,69	0,12
2 g	Δm / mg	-0,0022	0,0008	0,0048
	$U(\Delta m)$ / mg	0,0100	0,0120	0,0200
	E_n	0,22	0,07	0,24