Asia-Pacific Metrology Programme

Final Report

Bilateral Key Comparison 1 kg Stainless Steel Mass Standard (APMP.M.M-K1.1)

10 February 2010

By

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APMP Bilateral Key Comparison of 1 kg Mass Standard

ABSTRACT

This report summarises the results of a bilateral key comparison (APMP.M.M-K1 between the National Measurement Institute of Australia (NMIA) and the National Metrology Centre, Agency for Science Technology & Research (NMC, A-STAR) using a 1 kg stainless steel mass standard.

The objective of the comparison is to demonstrate the metrological equivalence between the two laboratories. The results of the comparison will be used to support the improved Calibration and Measurement Capability (CMC) declaration of NMC, A-STAR to fulfil the requirements of the CIPM MRA[I].

The NMIA has taken part in both CCM.M-K1 and APMP.M.M-K1, and is the pilot and linking laboratory for this bilateral comparison. The comparison commenced on 29 September 2008 and concluded on 15 December 2008. A stainless steel 1 kg OIML Class E1 standard mass was used as the travelling artefact and was transported between the laboratories by courier and by hand-carrying. The APMP.M.M.K2 technical protocol was adopted as the protocol for this comparison.

The comparison results together with their assigned uncertainties show good agreement between NMIA and NMC, A-STAR and with the key comparison reference value (KCRV) of the CCM.M-K1. It also shows that NMC, A-STAR has the measurement capability at the OIML E_1 level. The deviation from the KCRV of the CCM.M-K1 for NMC, A-STAR through this comparison was + 0.033 mg with an uncertainties of 0.049 mg.

[I] Comité international des poids et mesures Mutual Recognition Arrangement

1 INTRODUCTION

The bilateral key mass comparison using a 1 kg stainless steel standard was conducted between the National Measurement Institute of Australia (NMIA) and the National Metrology Centre of the Agency for Science Technology & Research (NMC, A-STAR).

The comparison was piloted by NMIA, which participated in the key comparison CCM.M-K1, and was able to act as the link laboratory to the CCM Key Comparison Reference Value (KCRV). The bilateral comparison was registered as an official key comparison under the designation APMP.M.M-K1.1.

A 1 kg stainless steel weight of OIML class E1 was used as the transfer standard for the comparison. The measurement results have been evaluated by NMIA and are incorporated in this report.

2 OBJECTIVE

The objectives of this bilateral comparison are:

- To demonstrate metrological equivalence of NMC, the national laboratory of Singapore and to support its calibration and measurement capabilities (CMC) at the 1 kg level.
- To determine the degree of equivalence of NMC, A-STAR with NMI, Australia that had previously taken part in CCM.M-K1.
- To enable the degrees of equivalence of NMC to be determined using the link to the CCM Key Comparison Reference Value found in CCM.M–K1.

3 DETAILS OF THE PARTICIPANTS

Participant details including affiliation, name and e-mail address of the contact person are listed as follow:

Details	Pilot Lab	Participating Lab
NMI	National Measurement Institute of Australia (NMIA)	National Metrology Centre, Agency for Science Technology & Research (NMC, A-STAR)
Address	Bradfield Road Lindfield, New South Wales Australia	1 Science Park Drive Singapore 118221 Singapore
Contact Person	Kitty Fen (Ms)	Lee Shih Mean
Email	kitty.fen@measurement.gov.au	lee_shih_mean@nmc.a-star.edu.sg

Table 1 : Participating Laboratories

4 DESCRIPTION OF ARTIFACT & REFERENCE STANDARDS

A 1 kg stainless steel mass standard (serial no.: 19029026) of OIML class E1, signified as (A) in this report, belonging to NMC was chosen to be the travelling artefact. The artefact was first monitored in the NMC for a period of 3 months before the start of the bilateral comparison.

Specifications for the artifact are as shown in Table 2:

Parameters	Technical Specifications
Nominal Value	1 kg
Serial No.	19029026
Accuracy Class	OIML Class E1
Material	Stainless Steel
Volume at 20 °C (± Standard Uncertainty, k = 1)	124.893 cm^3 (± 0.010 cm^3)
Volume Expansion Coefficient	0.000045 K^{-1}

Table 2 : Specifications of the Artefact (A)

The details of the reference standards used for this comparison are as shown in Table 3:

Parameters	NMIA	NMC, A*STAR
Nominal Value	1 kg	1 kg
Serial No(s).	(1) Stan (2) Chy2	83700
Accuracy Class	NMIA Mass secondary standard	OIML Class E1
Material	Stainless Steel	Stainless Steel
Shape	Cylinder with flat knob	OIML Knob
Volume at 20 °C (u_{vol}, k = 1)	(1) (127.726 ± 0.015) cm^3 (2) (126.955 ± 0.015) cm^3	(124.893 ± 0.010) cm^3
Volume Expansion Coefficient	0.000045 K^{-1}	0.000048 K^{-1}
Date of Last Calibration	27 Oct 08 to 6 Nov 08	3 Aug 2007
Traceability Linkage (Year)	PI44 (BIPM in 2005)	BIPM (2007)

Table 3 : Details of the Reference Standards Used

5 CIRCULATION SCHEDULE

The artefact was sent from NMC, A-STAR to NMIA for the initial and final measurement in Oct 2008 and Dec 2008 respectively. The artefact was transported by courier service in the first round (Oct

2008) and hand carried in the second round (Dec 2008). The detail itinerary and circulation schedule is shown in Table 4.

Dates	Circulation Schedule
October 2008	Mass standard sent by courier to NMIA
	Measurement by NMIA (pilot lab)
November 2008	Mass standard sent by courier to NMC, A-STAR
	Measurement by NMC
December 2008	Mass standard hand-carried to NMIA
	Measurement by NMIA (pilot lab)
	Mass standard hand-carried to NMC, A-STAR
January - February 2009	Compile & submit report

Table 4 : Circulation Schedule

6 MEASUREMENT METHOD and UNCERTAINTY OF MEASUREMENT

The technical protocol of the Asia-Pacific Metrology Programme (APMP) Mass Comparison APMP.M.M-K2 is adopted for this bilateral comparison.

In the comparison, NMIA used the Mettler-Toledo automatic comparator HK1000MC (standard deviation 2 μg, resolution 1 μg) while NMC A*Star used the Mettler-Toledo comparator AT1006 (standard deviation of 2 μg, resolution 1 μg) for their measurements. Both laboratories used substitution method in the form of ABA weighing cycle and carried out their measurements in air and hence buoyancy corrections were taken into account.

For the uncertainty of measurement, both laboratories followed the International Organisation for Standardization “Guide to the Expression of Uncertainty in Measurement”, (1993) for their uncertainty estimation. They included the uncertainty of the weighing process, uncertainty of the reference weight, the uncertainty of the air buoyancy correction and the uncertainty of the comparator.

7 MEASUREMENT RESULTS

The true and conventional mass deviation of the artefact A from 1 kg was determined and the result of the bilateral comparison is shown in Table 5 and plotted in Figure 1.

Meas. No.	Lab	Date	True Mass Deviation (mg)	Conventional Mass Deviation (mg)	Uncertainty k = 2 (mg)
1	NMIA	Oct 2008	+ 0.104	+ 0.234	0.029
2	NMC, A-STAR	Nov 2008	+ 0.131	+ 0.260	0.029
3	NMIA	Dec 2008	+ 0.103	+ 0.233	0.029

Table 5 : Results of Comparison

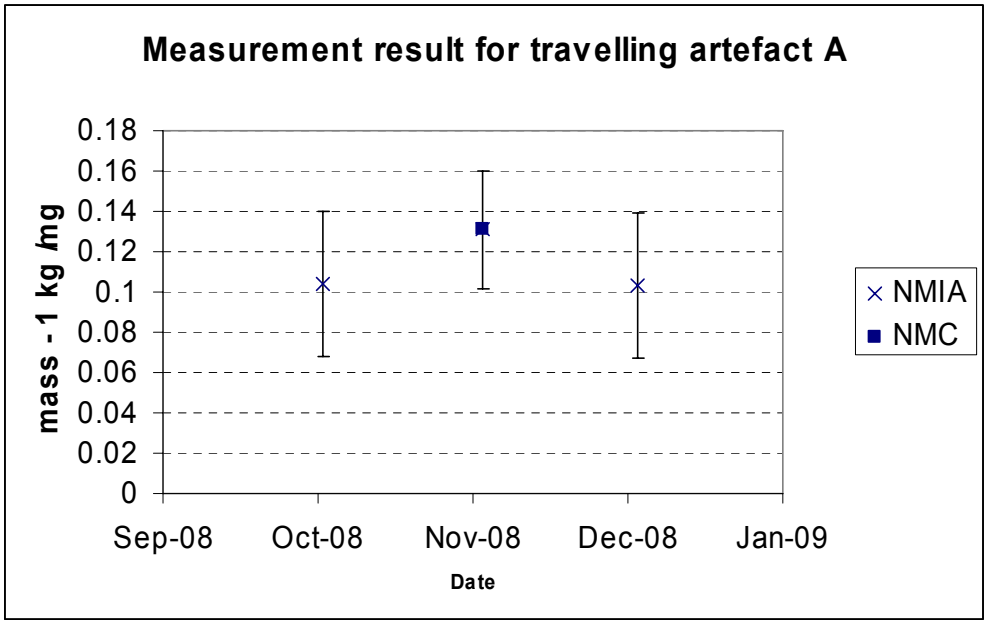

Figure 1: Mass Deviation of Artefact (A) from 1 kg Measured by NMIA and NMC, A-STAR

The stability of the travelling 1kg artefact (A) was assessed by NMIA by measuring the mass values of the artefact as well as one of NMIA's reference standards (Chy2) before and after the measurement loop. The result is shown in Table 6.

Nominal mass	Mass change dm between Oct to Dec 2008 (μg)	
	Travelling Artefact (A)	NMIA standard (Chy2)
1 kg	-1	0

Table 6 : Mass Change of the Travelling Standard and Reference Standard as Measured by NMIA during the Comparison

From the measurement, no evidence of instability was found. The uncertainty of the stability of the artefact during Oct to Dec 2008 was calculated using Equation (1):

$$u_d = \sqrt{\frac{(m_{NMI2} - m_{NMI1})^2}{12}} \quad (1)$$

Where :

m_{NMIA1} : Mass measurement by NMIA in Oct 2008
m_{NMIA2} : Mass measurement by NMIA in Dec 2008

8 ANALYSIS & LINKAGE TO CCM.M-K1

The analysis follows the method used in the APMP comparison APMP.M.M-K1 [1] [2] for linkage to the key comparison reference value (KCRV) obtained in the CCM 1 kg key comparison CCM.M-K1. The aim of the analysis is to estimate the degree of equivalence for the participating laboratory; NMC, A-STAR through the link laboratory NMIA.

From the *Final Report on CIPM key comparison of 1 kg standards in stainless steel (CCM.M-K1)* [3]:

$$\text{NMIA (previous CSIRO)} - \text{KCRV} = (5 \pm 29)\ \mu g \qquad (2)$$

Where :

The number following the symbol ± is the expanded uncertainty determined with a coverage factor k = 2.

This result is interpreted as the mass value assigned by NMIA to the mass of the 1 kg travelling standard is 5 µg greater than the KCRV. This difference from the KCRV was determined in the course of the key comparison CCM.M-K1. The KCRV for CCM.M-K1 was estimated using the median value of the results of the participating laboratories for the mass of the 1 kg travelling standards.

The equation describing each comparison measurement for artifact (A) can be written as :

$$m_A(Lab_i)_p - m_o = \Delta_i - (m_o - m_A) + e_{i,p} \qquad (3)$$

Where :

$m_A(Lab_i)_p$	:	p^{th} value assigned to artifact (A) by laboratory i
m_o	:	Nominal mass of the artifact
m_A	:	Mass of artifact (A)
Δ_i	:	Bias of laboratory i
$e_{i,p}$	:	Random error associated with the measurement.

Similarly, the equation for the result of the link laboratory is

$$m_{cx}(Lab_i) - K = \Delta_i - (K - m_{cx}) + e_i \qquad (4)$$

Where :

$m_{cx}(Lab_i) - K$	:	Measured deviation between the link laboratory i and the KCRV at m_o
m_{cx}	:	Median mass values of the CCM.M-K1 travelling standards
K	:	Key comparison reference value
e_i	:	Random error associated with the measurement

The known values are $m_x(Lab_i)_p - m_o$ and $m_c(Lab_i) - K$. To solve these equations, a constraint is required and we choose $K - m_c = 0$; so that the value obtained for Δ_i from the solution is the expected deviation of the laboratory's result from the KCRV.

Variance due to the instability of the travelling standard, correlations between the CCM.M-K1 and this comparison for the link laboratory and the use of air density formula [4] are all accounted for in the matrix analysis. The recalibration of the primary standard of mass, Pt-Ir copy no. 44 and the changes of the enviromental sensors at the link laboratory after the CCM.M-K1 reduced the correlated uncertainties between the CCM.M-K1 and this comparsion. The uncertainty of the reference value 2.2 μg (k = 1) was used in the calculation.

The results are shown in Table 7 & 8. Table 7 and Figure 2 gives the deviations from the KCRV for both laboratories, together with the associated uncertainties. Table 8 gives the difference in assigned mass values between NMIA and NMC and its uncertainty at 1 kg.

Lab	Difference from KCRV (mg)	Expanded uncertainty U (mg)
NMIA	0.005	0.030
NMC, A-STAR	0.033	0.049

Table 7 : Deviation from the KCRV (Key Comparison Reference Value of CCM.M-K1) in mg and Associated Expanded Uncertainty U (k=2) in mg for NMIA and NMC

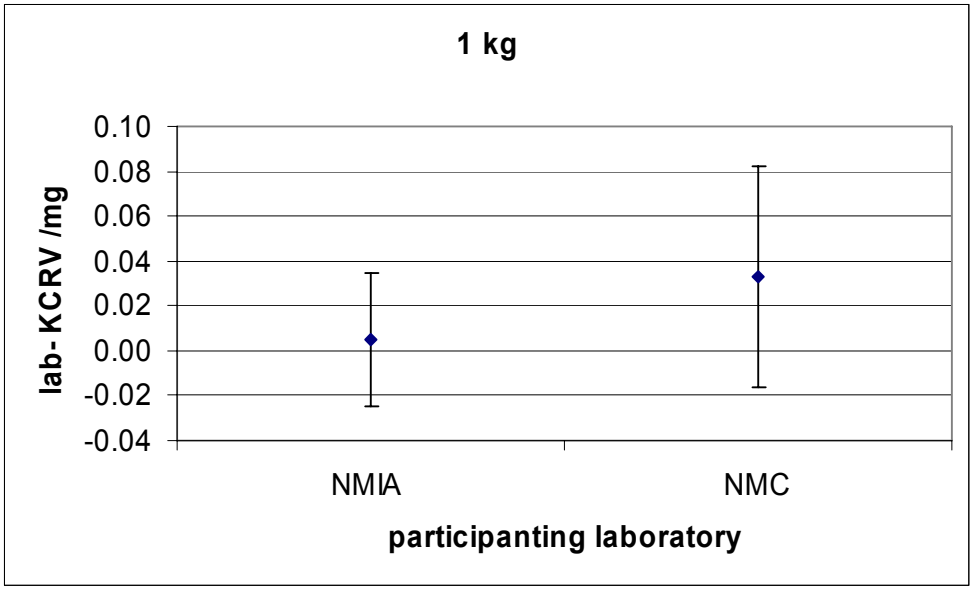

Figure 2: Mass Values Assigned by NMIA and NMC with Bars Representing Expanded Uncertainties (Zero Value Corresponds to the KCRV of CCM.M-K1)

NMIs	Difference in Assigned Mass (mg)	Expanded Uncertainty (k=2) (mg)
NMC - NMIA	0.028	0.049

Table 8 : Difference in Assigned Mass Value between NMIA and NMC, A-STAR and the Expanded Uncertainty for 1 kg (True Mass) in mg

9 CONCLUS ION

The comparison has determined the degree of equivalence between NMIA and NMC, A-STAR and with the key comparison reference value (KCRV) of CCM.M-K1. The overlapping uncertainties assigned to the results from the two laboratories as shown in Figure 2 illustrated a good level of consistency. NMC, A-STAR has demonstrated its measurement capability at the OIML E1 level.

10 REFE RENCES

[1] CM Sutton (Metrologia, Vol 41, 272-277, 2004)
[2] Lars Nielson (Danish Institute of Fundamental Metrology Report DFM-99-R39)
[3] Final report on CIPM key comparison of 1 kg standards in stainless steel (CCM.M-K1)
[4] Picard et al (Metrologia 45, 149-155, 2008)