AFRIMETS

Supplementary Comparison

on

Calibration of Setting Rods

(AFRIMETS.L-S2.2.n02)

Renamed from (AFRIMETS.L-S5)

(2019-2022)

Final Report

2024

Prepared by: *Dr.Eng. Ahmed ElMelegy*

Giza, Egypt

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Abstract

National Metrology Institutes from 8 African countries, namely Egypt, Nigeria, Kenya, Tanzania, Zambia, Zimbabwe, Botswana, and Mauritius have participated in an international supplementary comparison on the calibration of setting rods. This comparison was a part of larger supplementary comparison between 13 African countries for the calibration of hand measuring instruments. This larger comparison which was carried out during the period between December 2019 – December 2022 has been piloted by NIS, Egypt and has been registered in BIPM-KCDB database on December 2019 with the identifier AFRIMETS.L-S5. The artifacts have been prepared by NIS, Egypt and measured before sent to circulate between all participant countries in round-robin scheme and returned back again for NIS, Egypt where a final measurement was made for stability check. The main purpose of these comparisons is to support submission of CMCs for calibration of hand length measuring instruments in BIPM-KCDB.

1. Introduction

In December 2019, the Egyptian National Institute of Standards (NIS), Egypt has initiated a comparison for the calibration of length hand measuring instruments which is considered the standard activity in most African metrology institutes. It was not possible to conduct comparison for the calibration all length hand measuring instruments, so a number of 6 hand measuring instruments have been selected, which are external micrometer, caliper, dial gauge, setting rods, feeler gauges, and Pin gauges. The comparison was carried out during the period from December 2019 to December 2022 and was piloted by NIS, Egypt. The comparison has been registered in BIPM-KCDB database on December 2019 by the identifier AFRIMETS.L-S5 and was given the internal AFRIMET identifier AFRIMETS L11. The comparisons were carried out according to the protocol approved by all participants before initiating the comparison. The artifacts have been prepared and measured by NIS, Egypt before they were circulated between all participant countries in round-robin scheme and returned back again for NIS, Egypt where a final measurement was made for stability check. The main purpose of these comparisons is to support submission of CMCs for calibration of hand length measuring instruments in BIPM-KCDB.

In this report, 8 African countries, namely Egypt, Nigeria, Kenya, Tanzania, Zambia, Zimbabwe, Botswana, and Mauritius have participated in an international supplementary comparison on the calibration of setting rods. Three setting rods which have nominal lengths of 50 mm, 75 mm, 125 mm are prepared by NIS, Egypt for the comparison.

2. Participants

8 African countries, namely Egypt, Nigeria, Kenya, Tanzania, Zambia, Zimbabwe, Botswana, and Mauritius have participated in an international supplementary comparison on the calibration of setting rods. NIS, Egypt was acting as the pilot laboratory. The rest of the 13 countries which are Morocco, Ghana, Ethiopia, Malawi, and South Africa did not participate in the setting rod comparison. The list of participants of this comparison are listed in the following table with their details:

Table 1 shows the participants NMIs in the setting rod comparison

N.	Participant	Correspondence	E-mail Address Phone number	Address
1	NIS (Pilot) (Egypt)	Osama Terra (Organizer)	Osama.terra@gmail.com +201141172900	Tersa Street, Haram, Giza, Egypt. P. code: 12211, P.O. Box: 136 Giza
		Ahmed Elmelegy (Pilot lab.)	ahmedme3@yahoo.com +201112145450	
2	NMI/SON (Nigeria)	Bede Obayi	beobayi@yahoo.com	52, Lome Crescent, Zone 7, Wuse, Abuja
3	KEBS (Kenya)	Calvin Bore	borec@kebs.org +254 20 6948 359	Dimensional Laboratory, Kenya Bureau of Standards, P.O. Box 54974 - 00200, Nairobi, Kenya.
4	TBS (Tanzania)	Joseph James Angela Charles	mahillajj@yahoo.co.uk joseph.mahilla@tbs.go.tz angela.charles@tbs.go.tz Tel.: + 255 22 2450206	Morogoro/Sam Nujoma Roads, Ubungo, P.O. Box 9524 Dar-es-Salaam
5	ZMA (Zambia)	Daniel Mutale	dmmutalezs@gmail.com +260 955135366	Zambia Metrology Agency Plot # 4526 Lechwe House Freedom Way, Lusaka, Zambia. P.O.Box: 30989 Lusaka
6	SIRDC- NMI (Zimbabwe)	Burnhard Gandah	bgandah@sirdc.ac.zw burnhardg@gmail.com Tel: +263 778330014	1574 Alpes Road, Technology Drive Hatcliffe P.O. Box 6640 Harare
7	BOBS (Botswana)	Modiriemang Kame Pamidzani Ntima	kame@bobstandards.bw Ntima@bobstandards.bw Pamidzani.ntima@gmail.com Tel. (+267) 3903200 Tel. (+267) 72607660	Private Bag B0 48 Gaborone
8	MSB (Mauritius)	Tomeswar Pryam Vaneeda Ramasawmy Pallut	tpryam@msb.intnet.mu vramasawmy@msb.intnet.mu +230 433 3648	Mauritius Standards Bureau Villa Road, Moka Postal code – 80805 Mauritius

3. Form of Comparison

The comparison is made according to round robin scheme. All artifacts including the setting rods are calibrated first at NIS, Egypt then shipped to the next country in the timetable, and so on. Malawi withdrew from the comparison since they were not ready by that time. Since not all countries participated in the 6 calibration activities, participants will differ from one report to the others. For setting rods, only 8 countries participated (shown in blue in figure 1).

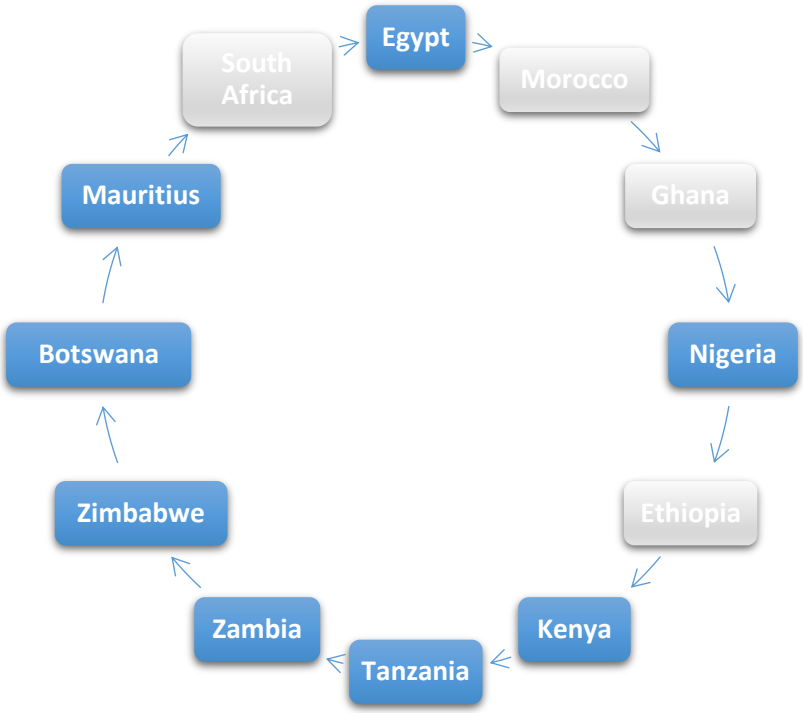


Figure 1: The transportation sequence and measurements of the artifacts.

4. Timetable

The sequence of transferring the standards was made according to the protocol. However, delays occur due to the Covid-19 pandemic which took place at the start of the comparison in 2020. Table 2 shows the comparison planned timetable of the protocol. A delay of around one and half year almost from the planned time table.

Table 2 shows the comparison time table at the protocol

Activity	Start Date	End date	Remarks
First calibration at NIS, Egypt	25 November 2019	10 December 2019	
Delivery to LPEE/LNM, Morocco	11 December 2019	31 December 2019	

Calibration at LPEE/LNM, Morocco	1 January 2020	15 January 2020	
Delivery to GSA, Ghana	16 January 2020	5 February 2020	
Calibration at GSA, Ghana	6 February 2020	20 February 2020	
Delivery to NMI/SON, Nigeria	21 February 2020	10 March 2020	
Calibration at NMI/SON, Nigeria	11 March 2020	25 March 2020	
Delivery to NMIE, Ethiopia	26 March 2020	15 April 2020	
Calibration at NMIE, Ethiopia	16 April 2020	30 April 2020	
Delivery to KEBS, Kenya	1 May 2020	20 May 2020	
Calibration at KEBS, Kenya	21 May 2020	5 June 2020	
Delivery to TBS, Tanzania	6 June 2020	26 June 2020	
Calibration at TBS, Tanzania	27 June 2020	12 July 2020	
Delivery to MBS, Malawi	13 July 2020	3 August 2020	Withdrawn
Calibration at MBS, Malawi	4 August 2020	20 August 2020	
Delivery to ZABS, Zambia	21 August 2020	10 September 2020	
Calibration at ZABS, Zambia	11 September 2020	30 September 2020	
Delivery to SIRDC/NMI, Zimbabwe	1 October 2020	20 October 2020	
Calibration at SIRDC/NMI, Zimbabwe	21 October 2020	5 November 2020	
Delivery to BOBS, Botswana	6 November 2020	26 November 2020	
Calibration at BOBS, Botswana	27 November 2020	12 December 2020	
Delivery to MSB, Mauritius	13 December 2020	2 January 2021	
Calibration at MSB, Mauritius	3 January 2021	18 January 2021	
Delivery to NMISA, South Africa	19 January 2021	9 February 2021	
Calibration at NMISA, South Africa	10 February 2021	28 February 2021	
Delivery to NIS, Egypt	1 March 2021	20 March 2021	
Calibration at NIS, Egypt	21 March 2021	5 April 2021	
Final Chance for Submitting the Results	6 April 2021	20 April 2021	
Pre-Draft A	21 April 2021	20 June 2021	

5. Description of the artifact:

NIS artifact is three setting rods as shown in figure 2 that has nominal lengths of 50 mm, 75 mm, 125 mm.

Figure 2: photograph of setting rods (similar one)

6. Calibration method used by each participant

Different methods are used by each participant for the calibration of setting rods. The used methods by each participant are summarized in table 3

Table 3 methods used for calibration of setting rods by each participant

	Participant	Method used for calibration of setting rods
1	NIS (Egypt)	1 µm Comparator & Reference gauge blocks
2	NMI/SON (Nigeria)	NMI Vernier caliper of range 0-300 mm
3	KEBS (Kenya)	Universal measuring machine SIP 414M
4	TBS (Tanzania)	Standard Universal Length Machine
5	ZMA (Zambia)	Height Measuring Machine
6	SIRDC- NMI (Zimbabwe)	Gauge Blocks & Dial Comparator
7	BOBS (Botswana)	Trimos (not clear)
8	MSB (Mauritius)	Reference Micrometers and setting rods

7. Calibration results

The following table (table 4) shows the results for all participant in rod setting calibration comparison. The results of each participant and the calibration uncertainty for the calibration of the three setting rods are shown as a single row in table 4.

Table 4. Calibration results by each participant.

	Institute, Country	Nominal 50	U, mm	Nominal 75	U, mm	Nominal 125	U, mm
1	NIS (Egypt) (Pilot)	50.000	0.0015	75.000	0.0015	125.000	0.0015
2	NMI/SON (Nigeria)	50.000	0.0663	75.000	0.0543	125.000	0.0493
3	KEBS (Kenya)	49.9991	0.0016	74.9996	0.0016	124.9997	0.0016
4	TBS (Tanzania)	50,0012	0.002	74,9996	0.002	125,0009	0.002
5	ZMA (Zambia)	50.001	0.002	75.003	0.003	125.002	0.004
6	SIRDC- NMI (Zimbabwe)	49.9995	0.0020	74.9999	0.0030	125.0000	0.0040
7	BOBS (Botswana)	50.000	0.0078	75.000	0.0078	125.000	0.0079
8	MSB (Mauritius)	50.001	0.004	75.000	0.004	125.009	0.004
1	NIS (Egypt) (After)	49.999	0.0015	75.000	0.0015	125.001	0.0015

8. Traceability

Reference for the calibration of the setting rods should be traceable to SI unit of length though unbroken traceability chain. The following table demonstrates the traceability of the measurement of each participant that are deduced from the calibration report.

Table 5. Traceability of calibration results by each participant.

Nr.	Participant	Traceability
1	NIS (Egypt)	To SI units of length through NIS primary length standard (He Ne 633 laser)
2	NMI/SON (Nigeria)	Not mentioned
3	KEBS (Kenya)	(for probe) To SI units of length through NMISA standards (for Scale – Laser interferometer) To SI units of length through TUBITAK UME standards
4	TBS (Tanzania)	Not mentioned
5	ZMA (Zambia)	To SI units of length through NMISA standards
6	SIRDC- NMI (Zimbabwe)	To SI units of length through NMISA standards
7	BOBS (Botswana)	To SI units of length through NMISA standards
8	MSB (Mauritius)	To SI units of length through setting rods calibrated in South Africa by ROSS Calibration Services CC.

The status of some NMIs having traceability through NMISA standards did not affect the analysis of comparison results.

9. Analysis of the results

9.1. Transportation Stability

Drifts of the artifact's values can occur during the transportation of the artifacts and handling over the long period of comparison. Therefore, a stability check must be performed to assure that this change will not affect

the comparison results. The instability of the artifacts is assessed according to the following equation:

$$\Delta_{ins} = \left| x_{NIS_2} - x_{NIS_1} \right|$$

where, x_{NIS_2} is the measurement of the pilot (NIS, Egypt) after the comparison and x_{NIS_1} is the measurement of the pilot before the comparison. The instability of each artifact during the transportation will add additional contribution to the uncertainty of the reference value:

$$u_{ad}(x_i) = \frac{\Delta_{ins}}{2\sqrt{3}}$$

Additional criteria are applied to ensure the stability of the results which is:

$$\Delta_{ins} \leq 0.9\sqrt{u_{CRV}^2 + u_{min}^2}$$

where, the u_{CRV} is the uncertainty in the comparison reference value and u_{min} is the uncertainty of the participant with the lowest uncertainty.

Therefore, the total combined uncertainty for each participant after adding the uncertainty due to the stability will be

$$u_a^2(x_i) = u^2(x_i) + u_{ad}^2(x_i)$$

Table 6. Stability measurement for each artifact

Nominal length, (mm)	Δ_{ins} (mm)	$u_{ad}(x_i)$, mm	$0.9\sqrt{u_{CRV}^2 + u_{min}^2}$ mm	Status
50	**0.0010**	**0.0003**	**0.0016**	**Fulfilled**
75	**0.0000**	**0.0000**	**0.0016**	**Fulfilled**
125	**0.0010**	**0.0003**	**0.0016**	**Fulfilled**

Table 7. correction of combined uncertainties for each participant

	Institute, Country	Nominal 50	$u_a(x_i)$, mm	Nominal 75	$u_a(x_i)$, mm	Nominal 125	$u_a(x_i)$, mm
1	NIS (Egypt) (Pilot)	50.000	0.0008	75.000	0.0008	125.000	0.0008
2	NMI/SON (Nigeria)	50.000	0.0332	75.000	0.0272	125.000	0.0247
3	KEBS (Kenya)	49.9991	0.0009	74.9996	0.0008	124.9997	0.0009
4	TBS (Tanzania)	50,0012	0.0010	74,9996	0.0010	125,0009	0.0010
5	ZMA (Zambia)	50.001	0.0010	75.003	0.0015	125.002	0.0020
6	SIRDC- NMI (Zimbabwe)	49.9995	0.0010	74.9999	0.0015	125.0000	0.0020
7	BOBS (Botswana)	50.000	0.0039	75.000	0.0039	125.000	0.0040
8	MSB (Mauritius)	50.001	0.0020	75.000	0.0020	125.009	0.0020

9.2. Reference value of the comparison

The CRV (comparison reference value) was calculated using the weighted mean method according to the equation:

$$x_{CRV} = \sum_{i=1}^{N} w_i \, x_i$$

Where w_i is the weights and is calculated by the equation:

$$w_i = \frac{u_a^{-2}(x_i)}{\sum_{i=1}^{N} u_a^{-2}\,(x_i)}$$

and where u_a^2 is the uncertainty contribution of each participant including the uncertainty due to the stability analysis:

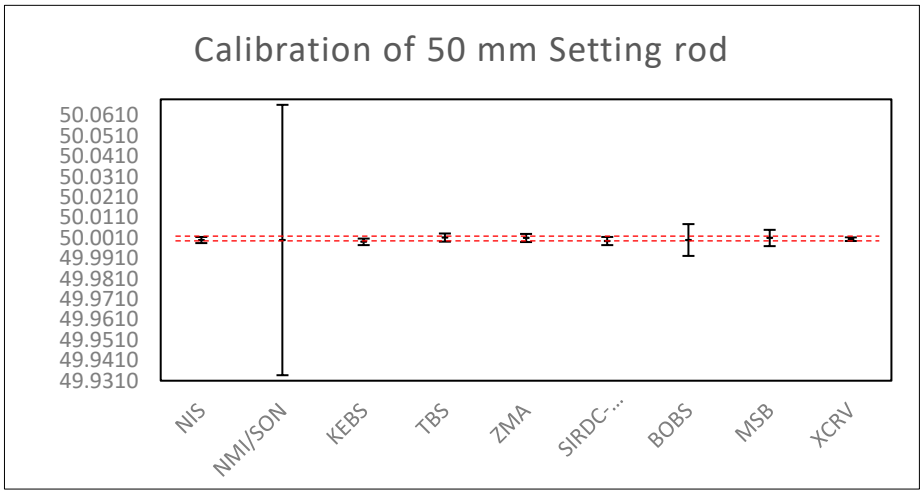
The standard uncertainty in the CRV value is calculated according to the following equation:

$$u(x_{CRV}) = \frac{\sqrt{\sum_{i=1}^{N} \frac{u^2\,(x_i)}{u_a^4\,(x_i)}}}{\sum_{i=1}^{N} u_a^{-2}\,(x_i)}$$

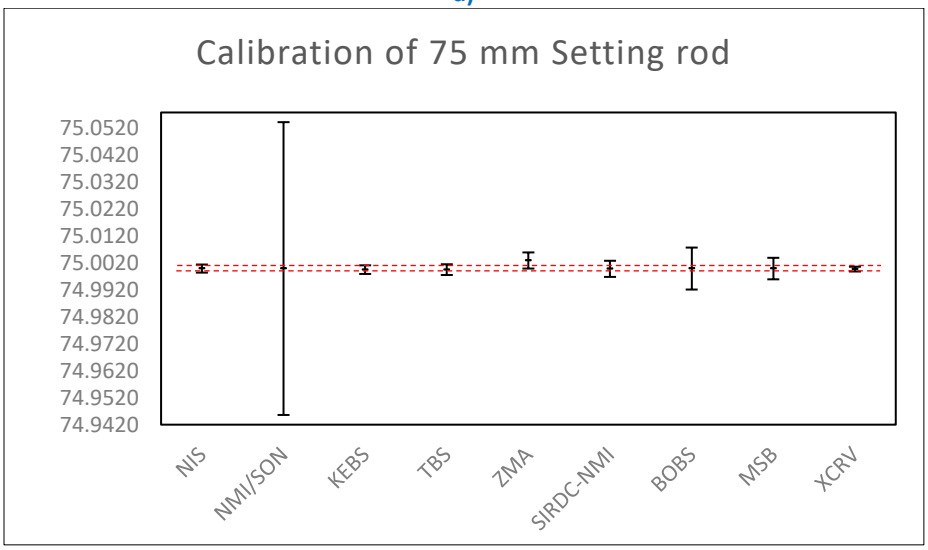
Calculation of the CRV and its uncertainty are given in table 8 and figure 2. The calculation is made after removing the inconsistent data according to section 9.3

Table 8. Comparison CRV and its uncertainty

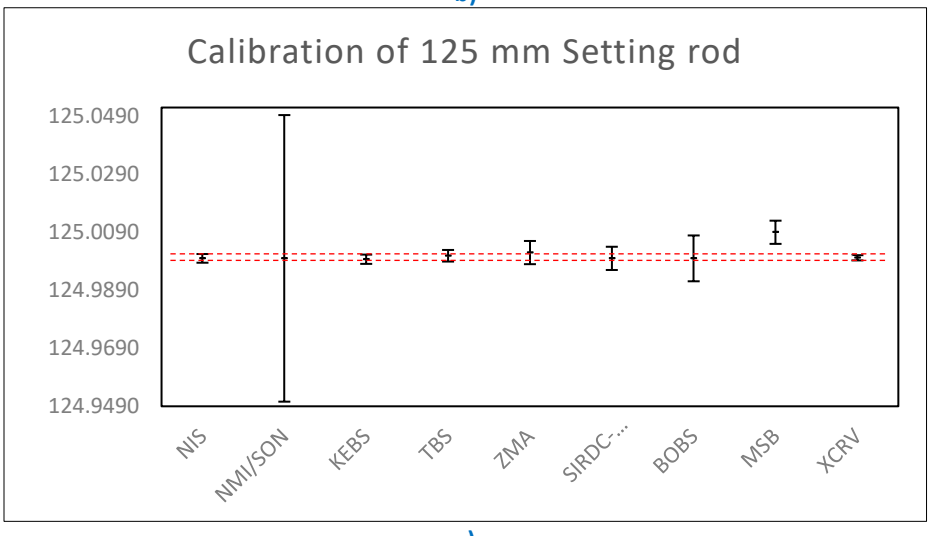
Nominal length (mm)	CRV value (length) (mm)	Expanded Uncertainty (@ *K*=2), (mm)
50	**50.00040**	**0.000886**
75	**74.9998**	**0.000885**
125	**125.00020**	**0.000903**



a)



b)



c)

Figure 3. The results of the participants in comparison with the CRV and it's uncertainty (expanded), a, b & c.

9.3. Consistency check of the results

Before calculating the CRV and its uncertainty a consistency of the comparison results must be examined. To determine the consistency of comparisons results Chi-square value χ^2_{obs} is calculated according to the following equation:

$$\chi^2_{obs} = \sum_{i=1}^{n} \frac{(x_i - x_{CRV})^2}{u_a^2(x_i)} \qquad 3$$

For the data to be consistent, the following condition must satisfy

$$\Pr\{\chi^2(v) > \chi^2_{obs}\} < 0.05 \qquad 4$$

Where v is the degrees of freedom which is the number of participants minus one and P_r denotes "probability of" and $\chi^2(v)$ is the inverse of the chi-square cumulative distribution function with degree of freedom specified by v for the probability of 0.05 (corresponding to the 95 % level of confidence). In this case, the participant with the highest value of χ^2_{obs} is excluded from the next round of evaluation and a new reference value, reference standard uncertainty, and chi-squared values are calculated again without the excluded laboratory. If the consistency check did not fail then y was accepted as the x_{CRV} and the $u(x_{CRV})$ are accepted. The number of participants N=8, therefore, the degrees of freedom υ = N-1 = 7. From the Chi-Square table at 95 % confidence level, we obtain $\chi^2_{0.05}$= 14.07.

Table 9: Consistency check (Not satisfied)

Nominal length (mm)	χ^2_{obs}	$\chi^2_{0.05}$ (υ=7)	**Consistency** $\chi^2_{obs} \leq \chi^2_{0.05}$ **?**
50	**3.887**	**14.07**	**Satisfied**
75	**4.402**	**14.07**	**Satisfied**
125	**19.610**	**14.07**	**Not Satisfied**

- The results from the following participants are removed before calculating the CRV and its uncertainty for the data to be consistent
  - Participant MSB @ (125 mm)

After removing these results from the CRV calculation: υ = 6 in the consistency check.

Table 10: Consistency check (satisfied)

Nominal length (mm)	χ^2_{obs}	$\chi^2_{0.05}$ (υ=6)	Consistency $\chi^2_{obs} \leq \chi^2_{0.05}$?
125	**1.666**	**12.59**	**Satisfied**

9.4. Performance Evaluation

The purpose of the evaluation of performance methods is to provide a normalized performance evaluation so that all results are comparable and the performance of each participant can be measured. In such calibration schemes, the performance of the participants is evaluated by measuring whether the results of the participants are within the uncertainty of the CRV. The performance is evaluated using the normalized error number E_n, where;

$$E_n = \frac{(x_i - x_{CRV})}{\sqrt{U_{a_i}^2 + U_{\mathrm{CRV}}^2}}$$

Where; x_i and U_{a_i} are the result and its corresponding adjusted expanded uncertainty of each participant, respectively. x_{CRV} and U_{CRV} are the CRV and its expanded uncertainty, respectively. E_n is interpreted as follows:

$|\boldsymbol{E_n}| \leq \mathbf{1} \rightarrow$ **Satisfactory performance**

$|\boldsymbol{E_n}| > 1 \rightarrow$ Unsatisfactory performance

Table 11. Evaluation of performance for the participants using E_n

Nominal length (mm)	$\|\boldsymbol{E_n}\|$							
	NIS	**NMI/SON**	**KEBS**	**TBS**	**ZMA**	**SIRDC-NMI**	**BOBS**	**MSB**
50	0.2	0.0	0.7	0.4	0.3	0.4	0.1	0.1
75	0.1	0.0	0.1	0.1	1.0	0.0	0.0	0.0
125	0.1	0.0	0.3	0.3	0.4	0.0	0.0	2.1

10. Conclusion:

- The results from 8 National Metrology Institutes from Egypt, Nigeria, Kenya, Tanzania, Zambia, Zimbabwe, Botswana, and Mauritius have participated in an AFRIMET supplementary comparison on the calibration of setting rods. The comparison reference value has obtained from the results using the weighted mean method after performing consistency check of the results using the Chi-square method. The Normalized error number En is used to evaluate the performance of all participants. All results are found satisfactory except Mauritius (MSB) at 125 mm is found unsatisfactory (En>1).

List of References

[1] Guide to preparation of Key Comparison Reports in Dimensional Metrology (GD3), A Lewis, T Coveney 30 Nov 2020.

[2] Measurement comparisons in the CIPM MRA, Guidelines for organizing, participating and reporting, CIPM MRA-G-11

[3] M. G. Cox, “The evaluation of key comparison data”, metrologia, 39, 589-595, 2002.