

AFRIMETS

Supplementary Comparison

on

Calibration of Caliper

(AFRIMETS.L-S6.1.n03)
Renamed from (AFRIMETS.L-S5)

(2019-2022)

Final report

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Final report: Calibration of Caliper

Abstract

National Metrology Institutes from 11 African countries, namely Egypt, Morocco, Ghana, Nigeria, Ethiopia, Kenya, Zambia, Zimbabwe, Botswana, Mauritius and South Africa have participated in an international supplementary comparison on the calibration of caliper. 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.

Final report: Calibration of Caliper**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, feeler gauge, setting rods 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, 11 African countries, namely Egypt, Morocco, Ghana, Nigeria, Ethiopia, Kenya, Zambia, Zimbabwe, Botswana, Mauritius and South Africa have participated in an international supplementary comparison on the calibration of caliper. A caliper of 300 mm range is prepared by NIS, Egypt for the comparison.

Final report: Calibration of Caliper**2. Participants**

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

Table 1 shows the participants NMIs in caliper 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	LPEE/LNM (Morocco)	Lhossain Mechkour	mechkour@lpee.ma Tel : +212 5 22 48 87 94	km 7, Route d'El Jadida, Casablanca – Maroc
3	GSA (Ghana)	Paul Date	date_105@msn.com Tel.: + 233 302 500065	P.O. Box MB 245 Okponglo, Legon-Madina Road, Accra
4	NMI/SON (Nigeria)	Bede Obayi	beobayi@yahoo.com	52, Lome Crescent, Zone 7, Wuse, Abuja
5	NMIE (Ethiopia)	Tadesse Gergiso Birhan Tesfaye	tdsgrs@gmail.com bire31@yahoo.com Tel : +251 116 67 19 69	B67, 1405 Street, Woreda 6, Bole Sub city, Addis Ababa, Ethiopia. P.O. Box: 5722 Addis Ababa
6	KEBS (Kenya)	Calvin Bore	borec@kebs.org +254 20 6948 359	Dimensional Laboratory, Kenya Bureau of Standards, P.O. Box 54974 - 00200, Nairobi, Kenya.
7	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
8	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
9	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

10	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
11	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
12	NMISA (South Africa)	Zanele Nzimande Patrick Masina	znzimande@nmisa.org pmasina@nmisa.org Tel. +27 12 841 2944	Private Bag X34 Lynnwood Ridge Pretoria 0040

3. Form of Comparison

The comparison is made according to round robin scheme. All artifacts including the caliper 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 Caliper, only 11 countries participated (shown in blue in figure 1).

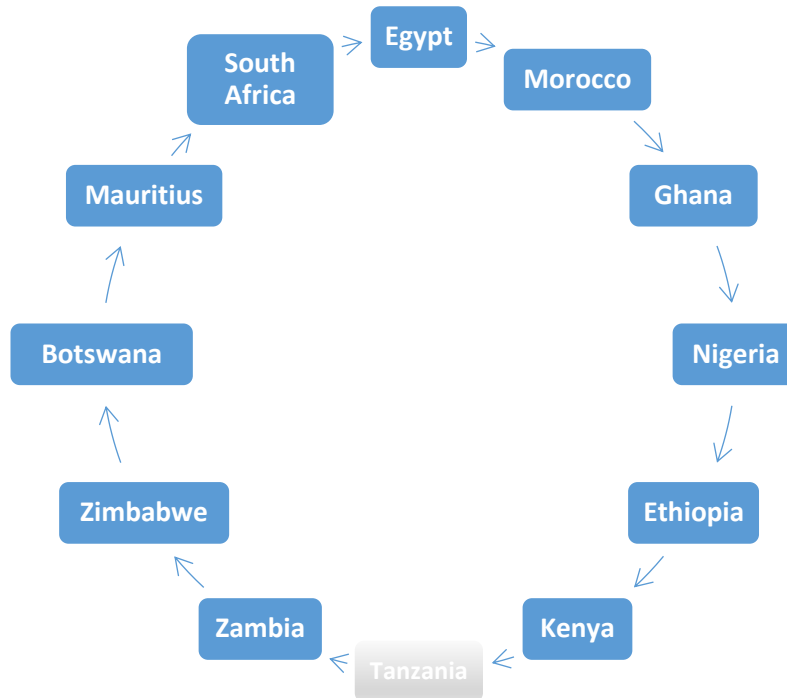


Figure 1: The transportation sequence and measurements of the artifacts.

Final report: Calibration of Caliper**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 in 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	

Final report: Calibration of Caliper**5. Description of the artifact:**

NIS artifact is an external caliper as shown in figure 2 that ranges from 0-300 mm.



Figure 2: photograph of a caliper (similar one).

6. Calibration method used by each participant

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

Table 3 methods used for calibration of caliper by each participant

Nr.	Participant	Method used for calibration of caliper
1	NIS (Egypt) (Pilot)	Reference Gauge Blocks Set
2	LPEE/LNM(Morocco)	grade K Mitutoyo 122-gauge blocks set
3	GSA (Ghana)	Koba gauge block with serial number 88141
4	NMI/SON (Nigeria)	Gauge Blocks combination
5	NMIE (Ethiopia)	Not mentioned
6	KEBS (Kenya)	Gauge blocks grade 0
7	ZMA (Zambia)	Gauge blocks set
8	SIRDC- NMI (Zimbabwe)	Gauge blocks set s. no. 0905759
9	BOBS (Botswana)	TRIMOS s. no. 1207
10	MSB (Mauritius)	Grade K Gauge blocks set
11	NMISA (South Africa)	Gauge blocks set

7. Calibration results

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

Table 4. Calibration results by each participant.

Nr.	Institute, Country	Nominal	U, mm	Nominal	U, mm	Nominal	U, mm	Nominal	U, mm
		0.00		3.30		10.00		20.00	
1	NIS (Egypt) (Pilot)	0.00	0.010	3.30	0.010	10.00	0.010	20.00	0.010
2	LPEE/LNM(Morocco)	0.00	0.0164	3.30	0.0164	10.00	0.0164	20.00	0.0165
3	GSA (Ghana)	N.P	N.P	3.30	0.00288	10.00	0.00288	20.00	0.00288
4	NMI/SON (Nigeria)	0.00	0.01155	3.31	0.02033	10.00	0.01156	20.00	0.011159
5	NMIE (Ethiopia)	0.00	0.01159	3.30	0.01159	9.99	0.01159	19.99	0.01159
6	KEBS (Kenya)	0.00	0.012	3.30	0.012	10.00	0.012	20.00	0.012
7	ZMA (Zambia)	0.00	0.025	3.30	0.025	10.00	0.025	20.00	0.025
8	SIRDC- NMI (Zimbabwe)	0.00	0.03	3.30	0.03	10.00	0.03	20.00	0.03
9	BOBS (Botswana)	0.00	0.019	3.30	0.019	10.00	0.019	20.00	0.019
10	MSB (Mauritius)	0.00	0.02	3.32	0.02	10.02	0.02	20.02	0.02
11	NMISA (South Africa)	0.00	0.023	N.P	N.P	10.00	0.023	20.00	0.023
1	NIS (Egypt) (After)	0.00	0.010	3.30	0.010	10.01	0.010	20.00	0.010
Nr.	Institute, Country	Nominal	U, mm	Nominal	U, mm	Nominal	U, mm	Nominal	U, mm
		40.00		50.00		100.00		150.00	
1	NIS (Egypt) (Pilot)	40.00	0.010	50.00	0.010	100.01	0.010	150.00	0.010
2	LPEE/LNM(Morocco)	40.00	0.0166	50.00	0.0166	100.00	0.0168	150.00	0.017
3	GSA (Ghana)	40.00	0.00288	50.00	0.00288	100.00	0.00288	150.00	0.00288
4	NMI/SON (Nigeria)	40.01	0.02044	50.00	0.01183	100.01	0.02422	150.01	0.02176
5	NMIE (Ethiopia)	39.99	0.01159	50.00	0.01159	99.99	0.01159	150.00	0.01159
6	KEBS (Kenya)	40.00	0.012	50.00	0.012	100.00	0.012	150.00	0.012
7	ZMA (Zambia)	40.00	0.025	50.00	0.025	100.00	0.025	150.00	0.025
8	SIRDC- NMI (Zimbabwe)	40.00	0.03	50.00	0.03	100.00	0.03	150.00	0.03
9	BOBS (Botswana)	40.00	0.019	50.00	0.019	100.00	0.019	150.00	0.019
10	MSB (Mauritius)	40.04	0.02	50.04	0.02	100.04	0.02	150.04	0.02
11	NMISA (South Africa)	40.00	0.023	50.00	0.023	100.00	0.023	150.00	0.023
1	NIS (Egypt) (After)	40.00	0.010	50.00	0.010	100.00	0.010	150.00	0.010

Nr.	Institute, Country	Nominal	U, mm	Nominal	U, mm	Nominal	U, mm
		200.00		300.00		50 (internal)	
1	NIS (Egypt) (Pilot)	200.00	0.010	300.00	0.010	49.99	0.010
2	LPEE/LNM(Morocco)	200.00	0.0172	300.00	0.0176	N.P	N.P
3	GSA (Ghana)	200.00	0.00288	300.00	0.00288	N.P	N.P
4	NMI/SON (Nigeria)	200.01	0.0228	300.01	0.10121	N.P	N.P
5	NMIE (Ethiopia)	200.00	0.01159	300.00	0.01159	N.P	N.P
6	KEBS (Kenya)	200.00	0.012	300.00	0.012	50.00	0.012
7	ZMA (Zambia)	200.00	0.025	300.00	0.025	50.00	0.025
8	SIRDC- NMI (Zimbabwe)	200.00	0.03	300.00	0.03	50.00	0.03
9	BOBS (Botswana)	200.00	0.019	300.00	0.019	N.P	N.P
10	MSB (Mauritius)	200.04	0.02	300.04	0.02	50.00	0.04
11	NMISA (South Africa)	200.00	0.023	300.00	0.023	50.00	0.023
1	NIS (Egypt) (After)	200.00	0.010	299.99	0.010	50.00	0.010

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Nr.	Institute, Country	Nominal	U, mm	Nominal	U, mm
		100 (internal)		100 (depth)	
1	NIS (Egypt) (Pilot)	99.99	0.010	100.01	0.010
2	LPEE/LNM(Morocco)	N.P	N.P	N.P	N.P
3	GSA (Ghana)	N.P	N.P	N.P	N.P
4	NMI/SON (Nigeria)	N.P	N.P	100.04	0.09083
5	NMIE (Ethiopia)	N.P	N.P	N.P	N.P
6	KEBS (Kenya)	100.00	0.012	100.03	0.012
7	ZMA (Zambia)	100.00	0.025	100.00	0.025
8	SIRDC- NMI (Zimbabwe)	100.00	0.03	100.02	0.03
9	BOBS (Botswana)	N.P	N.P	N.P	N.P
10	MSB (Mauritius)	99.93	0.04	100.00	0.02
11	NMISA (South Africa)	100.00	0.023	100.00	0.023
1	NIS (Egypt) (After)	100	0.010	100.01	0.010

N.P.: not participated

8. Traceability

Reference for the calibration of the caliper 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) (Pilot)	To SI units of length through NIS primary length standard (He Ne 633 laser)
2	LPEE/LNM(Morocco)	To SI units of length through Mitutoyo Japan Accredited JCSS
3	GSA (Ghana)	Traceable to the SI (International System of Units) through Zentrum fur Messen and Kalibrieren and ANALYTIK GmbH (D-K-15186-01-00)
4	NMI/SON (Nigeria)	Not mentioned
5	NMIE (Ethiopia)	Not mentioned
6	KEBS (Kenya)	To SI units of length through NMISA standards
7	ZMA (Zambia)	To SI units of length through NMISA standards
8	SIRDC- NMI (Zimbabwe)	To SI units of length through NMISA standards
9	BOBS (Botswana)	To SI units of length through NMISA standards
10	MSB (Mauritius)	To SI units of length through NMISA standards
11	NMISA (South Africa)	To SI units of length through NMISA standards

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

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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:

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

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
0	0.00	0.00	0.01	Fulfilled
3.3	0.01	0.00	0.01	Fulfilled
10	0.00	0.00	0.01	Fulfilled
20	0.00	0.00	0.01	Fulfilled
40	0.00	0.00	0.01	Fulfilled
50	0.01	0.00	0.01	Fulfilled
100	0.00	0.00	0.01	Fulfilled
150	0.01	0.00	0.02	Fulfilled
200	0.01	0.00	0.01	Fulfilled
300	0.00	0.00	0.01	Fulfilled
50 (internal)	0.00	0.00	0.01	Fulfilled
100 (internal)	0.00	0.00	0.01	Fulfilled
100 (depth)	0.01	0.00	0.01	Fulfilled

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Table 7. correction of combined uncertainties for each participant

Nr.	Institute, Country	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$
		0.00	, mm	3.30	, mm	10.00	, mm	20.00	, mm
1	NIS (Egypt) (Pilot)	0.00	0.005	3.30	0.005	10.00	0.006	20.00	0.005
2	LPEE/LNM(Morocco)	0.00	0.0082	3.30	0.0082	10.00	0.00869329	20.00	0.0083
3	GSA (Ghana)	N.P	N.P	3.30	0.0014	10.00	0.00322598	20.00	0.0014
4	NMI/SON (Nigeria)	0.00	0.006	3.31	0.010	10.00	0.006	20.00	0.006
5	NMIE (Ethiopia)	0.00	0.006	3.30	0.006	9.99	0.006	19.99	0.006
6	KEBS (Kenya)	0.00	0.006	3.30	0.006	10.00	0.007	20.00	0.006
7	ZMA (Zambia)	0.00	0.0125	3.30	0.0125	10.00	0.012829	20.00	0.0125
8	SIRDC- NMI (Zimbabwe)	0.00	0.015	3.30	0.015	10.00	0.015	20.00	0.015
9	BOBS (Botswana)	0.00	0.010	3.30	0.010	10.00	0.010	20.00	0.010
10	MSB (Mauritius)	0.00	0.010	3.32	0.010	10.02	0.010	20.02	0.010
11	NMISA (South Africa)	0.00	0.012	N.P	N.P	10.00	0.012	20.00	0.012
Nr.	Institute, Country	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$
		40.00	, mm	50.00	, mm	100.00	, mm	150.00	, mm
1	NIS (Egypt) (Pilot)	40.00	0.005	50.00	0.005	100.01	0.006	150.00	0.005
2	LPEE/LNM(Morocco)	40.00	0.0083	50.00	0.0083	100.00	0.0089	150.00	0.0085
3	GSA (Ghana)	40.00	0.00144	50.00	0.0014	100.00	0.0032	150.00	0.00144
4	NMI/SON (Nigeria)	40.01	0.010	50.00	0.006	100.01	0.012	150.01	0.011
5	NMIE (Ethiopia)	39.99	0.006	50.00	0.006	99.99	0.006	150.00	0.006
6	KEBS (Kenya)	40.00	0.006	50.00	0.006	100.00	0.007	150.00	0.006
7	ZMA (Zambia)	40.00	0.0125	50.00	0.0125	100.00	0.0128	150.00	0.0125
8	SIRDC- NMI (Zimbabwe)	40.00	0.015	50.00	0.015	100.00	0.030	150.00	0.015
9	BOBS (Botswana)	40.00	0.010	50.00	0.010	100.00	0.019	150.00	0.010
10	MSB (Mauritius)	40.04	0.010	50.04	0.010	100.04	0.010	150.04	0.010
11	NMISA (South Africa)	40.00	0.012	50.00	0.012	100.00	0.012	150.00	0.012

Nr.	Institute, Country	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$
		200.00	, mm	300.00	, mm	50 (internal)	, mm
1	NIS (Egypt) (Pilot)	200.00	0.005	300.00	0.006	49.99	0.006
2	LPEE/LNM(Morocco)	200.00	0.0086	300.00	0.00926	N.P	N.P
3	GSA (Ghana)	200.00	0.0014	300.00	0.00323	N.P	N.P
4	NMI/SON (Nigeria)	200.01	0.011	300.01	0.051	N.P	N.P
5	NMIE (Ethiopia)	200.00	0.006	300.00	0.006	N.P	N.P
6	KEBS (Kenya)	200.00	0.006	300.00	0.007	50.00	0.007
7	ZMA (Zambia)	200.00	0.0125	300.00	0.01283	50.00	0.013
8	SIRDC- NMI (Zimbabwe)	200.00	0.015	300.00	0.015	50.00	0.015
9	BOBS (Botswana)	200.00	0.010	300.00	0.010	N.P	N.P
10	MSB (Mauritius)	200.04	0.010	300.04	0.010	N.P	N.P
11	NMISA (South Africa)	200.00	0.012	300.00	0.012	50.00	0.012
Nr.	Institute, Country	Nominal	$U_a(X_i)$	Nominal	$U_a(X_i)$		
		100 (internal)	, mm	100 (depth)	, mm		
1	NIS (Egypt) (Pilot)	99.99	0.006	100.01	0.005		
2	LPEE/LNM(Morocco)	N.P	N.P	N.P	N.P		

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3	GSA (Ghana)	N.P	N.P	N.P	N.P
4	NMI/SON (Nigeria)	N.P	N.P	100.04	0.09
5	NMIE (Ethiopia)	N.P	N.P	N.P	N.P
6	KEBS (Kenya)	100.00	0.007	100.03	0.006
7	ZMA (Zambia)	100.00	0.013	100.00	0.013
8	SIRDC- NMI (Zimbabwe)	100.00	0.003	100.02	0.015
9	BOBS (Botswana)	N.P	N.P	N.P	N.P
10	MSB (Mauritius)	N.P	N.P	N.P	N.P
11	NMISA (South Africa)	100.00	0.012	100.00	0.012

N.P.: not participated

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:

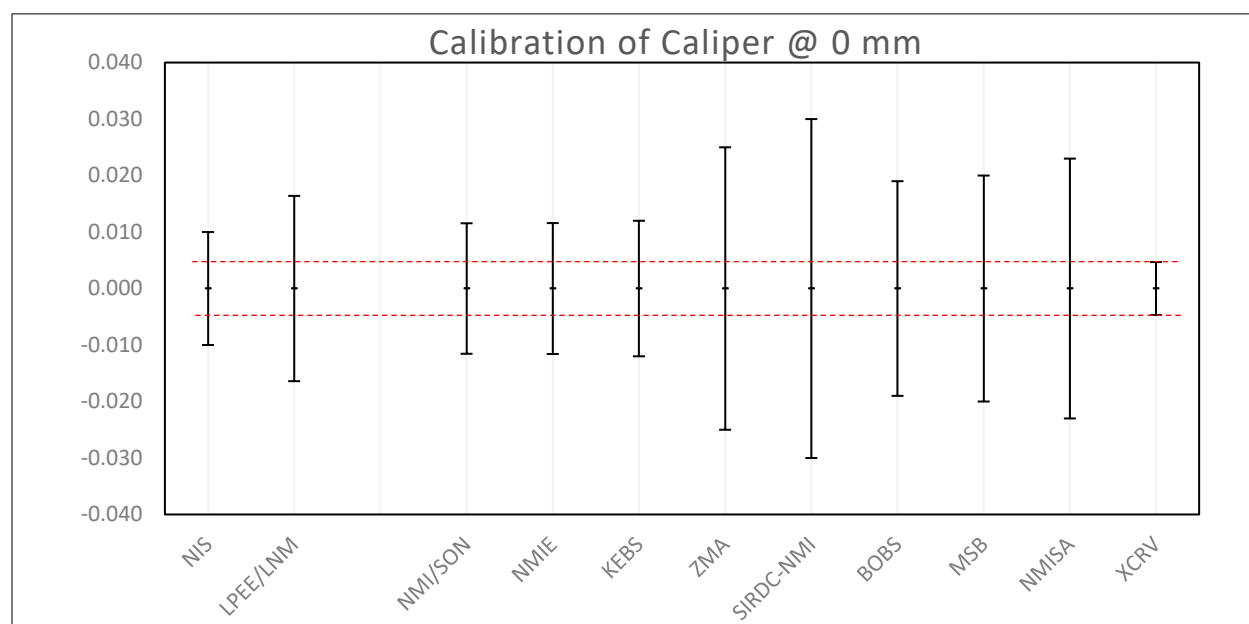
$$u(x_{CRV}) = \frac{\sqrt{\sum_{i=1}^N \frac{u^2(x_i)}{u_a^4(x_i)}}}{\sum_{i=1}^N u_a^{-2}(x_i)}$$

Calculation of the CRV and its uncertainty are given in table 6 and figure 2. The calculation is made after removing the inconsistent data according to section 9.3

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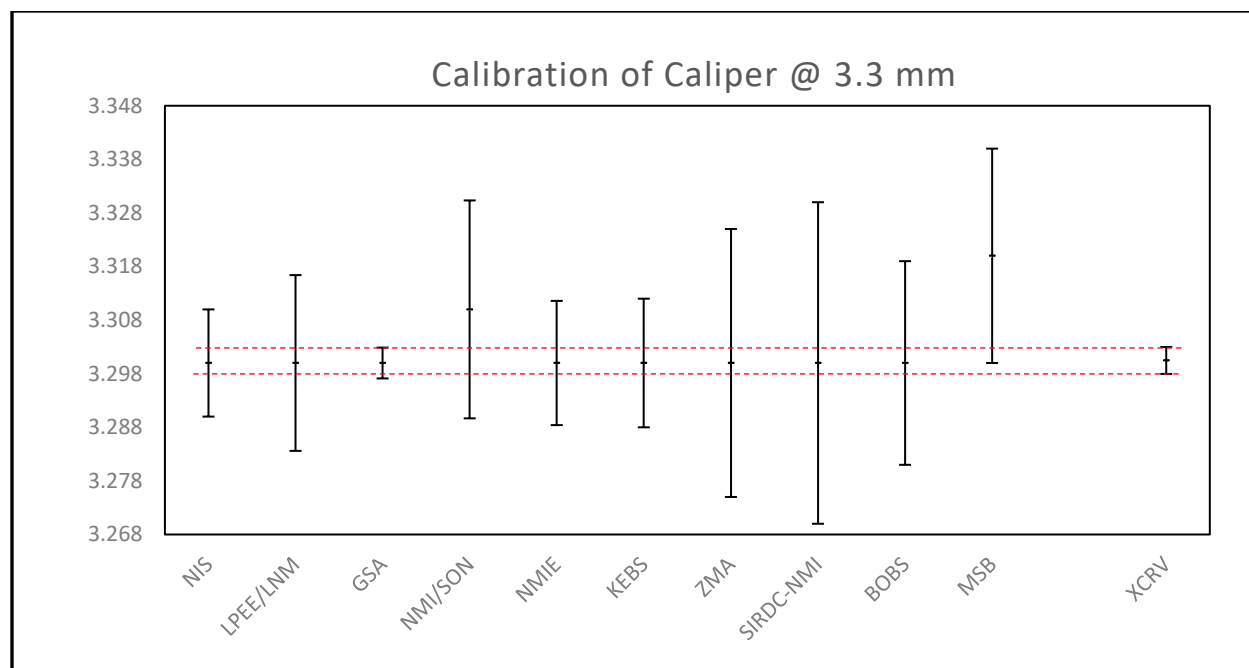
Table 8. Comparison CRV and its uncertainty

Nominal Length, (mm)	CRV value (length) (mm)	Expanded Uncertainty (@ $k=2$), (mm)
0	0.000000	0.00469
3.3	3.300466	0.00251
10	9.999781	0.00308
20	19.999853	0.00245
40	39.999681	0.00251
50	50.000604	0.00246
100	100.000603	0.00318
150	150.000755	0.00250
200	200.000745	0.00250
300	300.001685	0.00319
50 (internal)	49.995716	0.00684
100 (internal)	99.998385	0.00249
100 (depth)	100.008371	0.00828

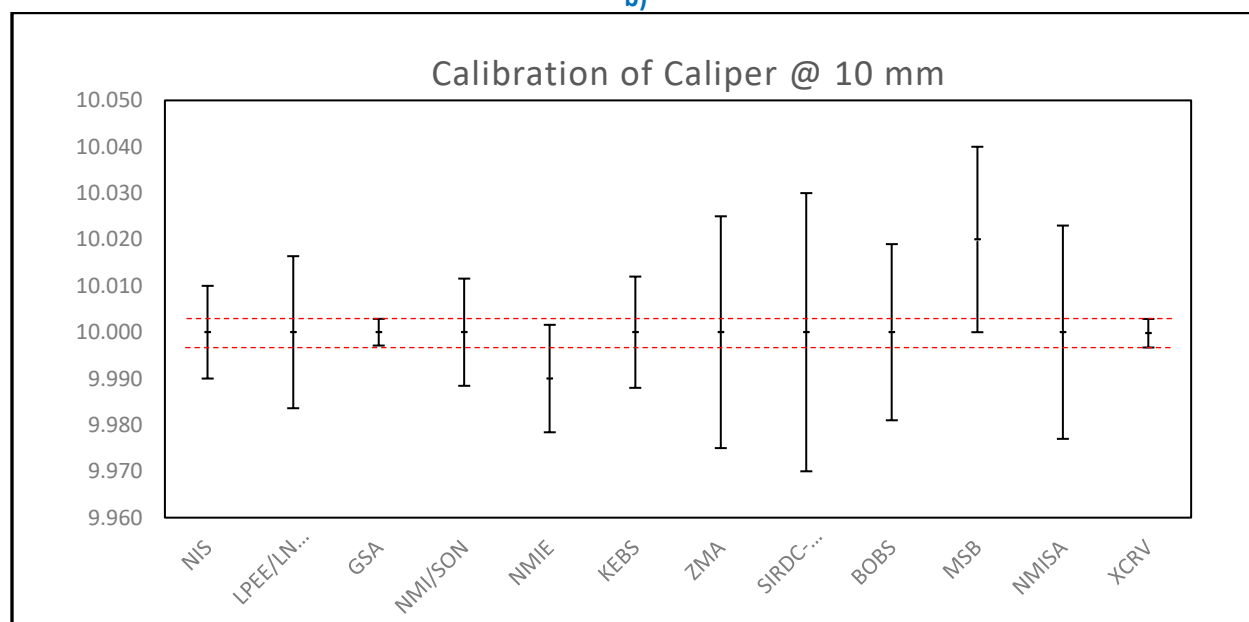


a)

Final report: Calibration of Caliper

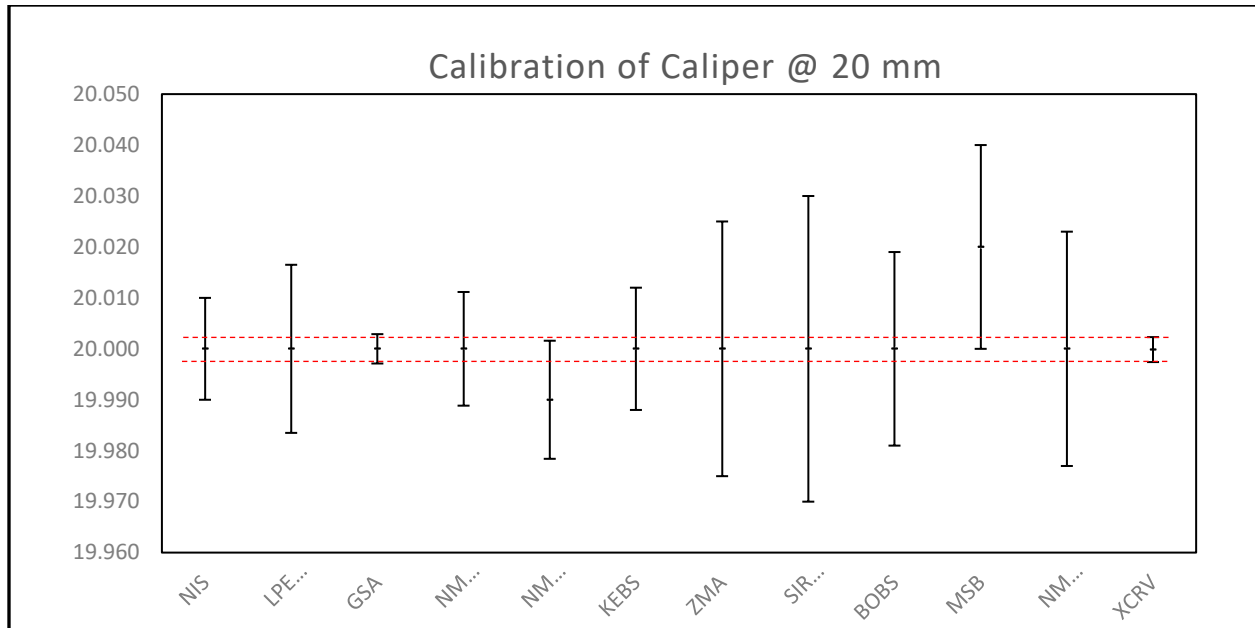


b)

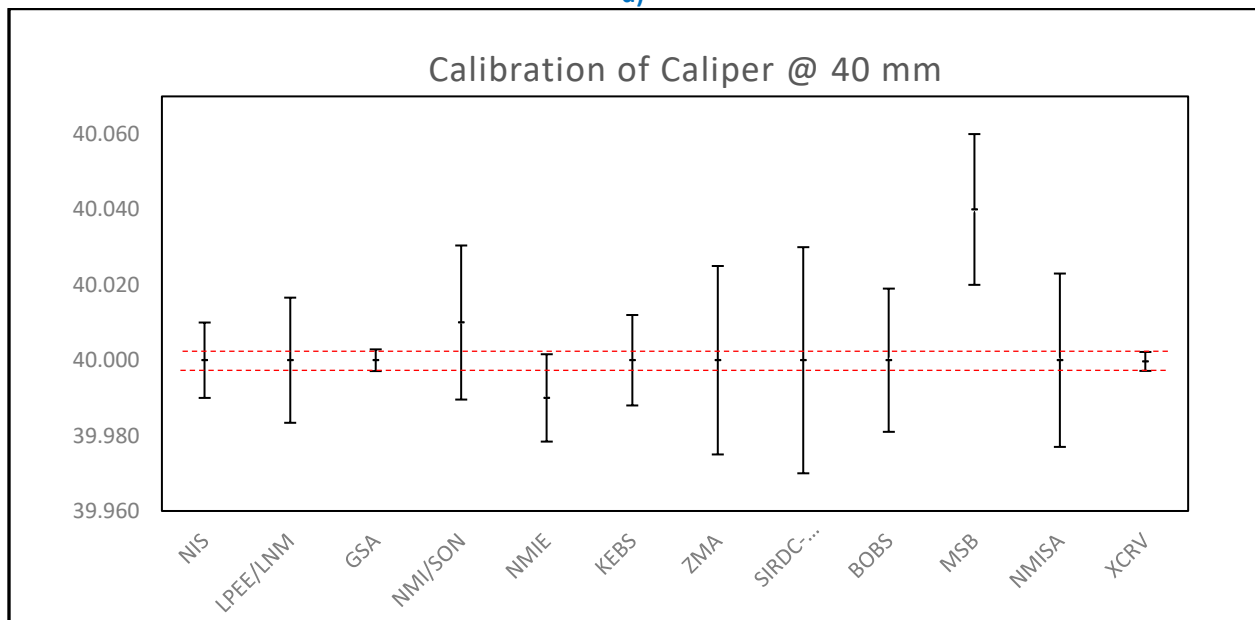


c)

Final report: Calibration of Caliper

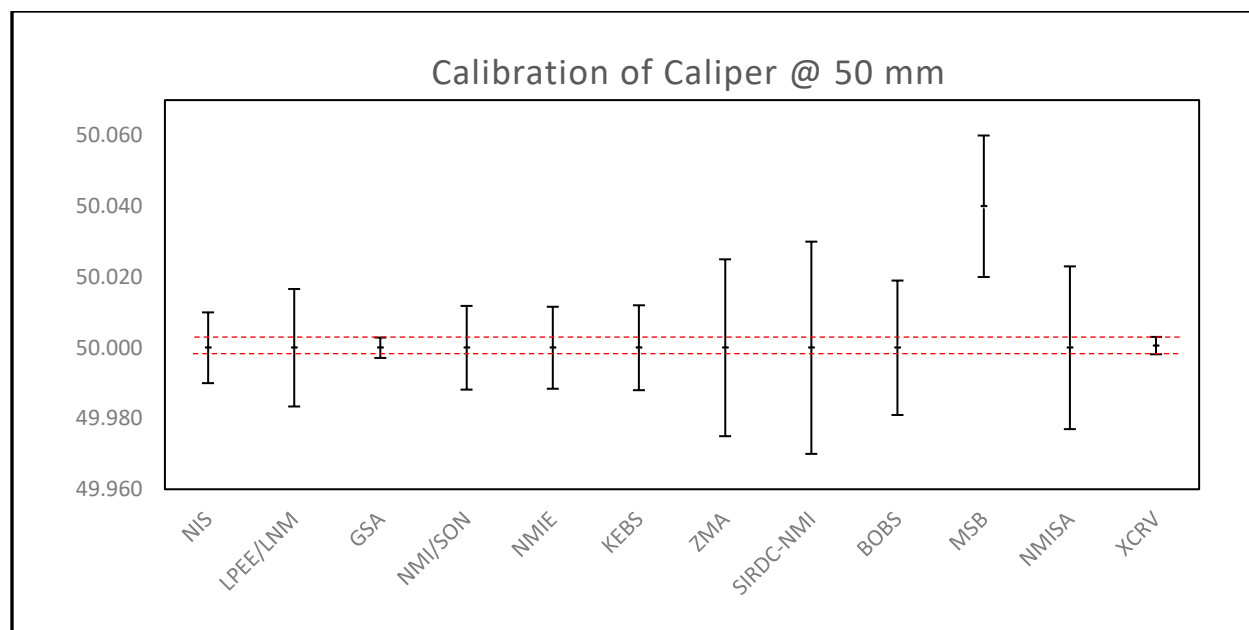


d)

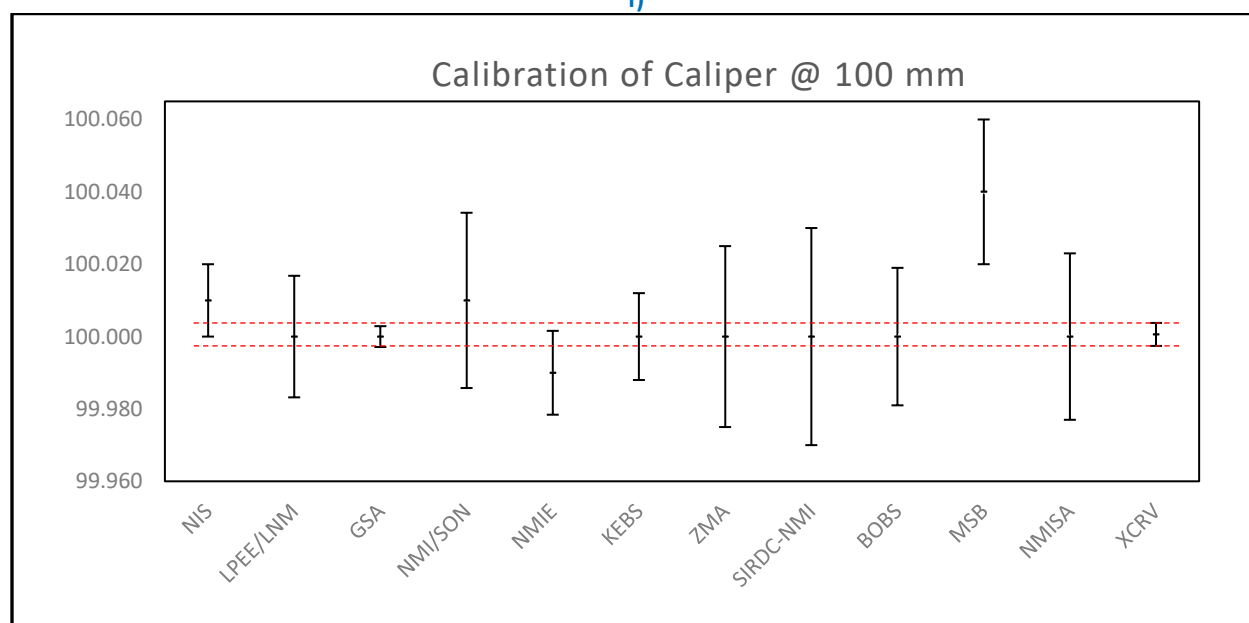


e)

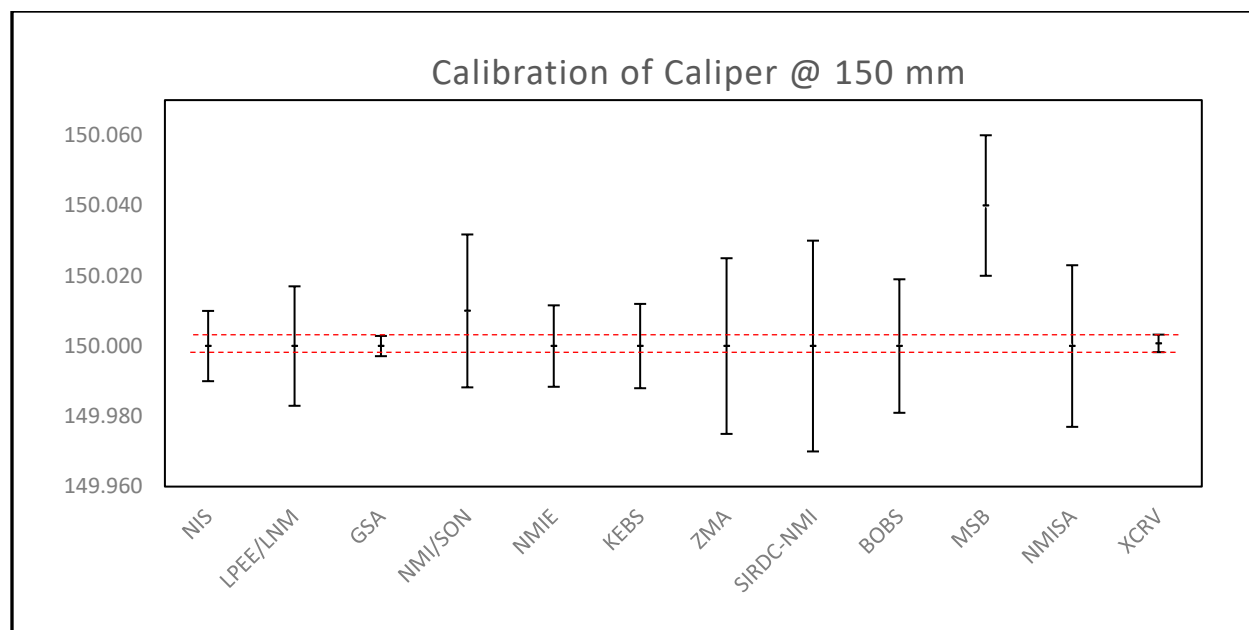
Final report: Calibration of Caliper



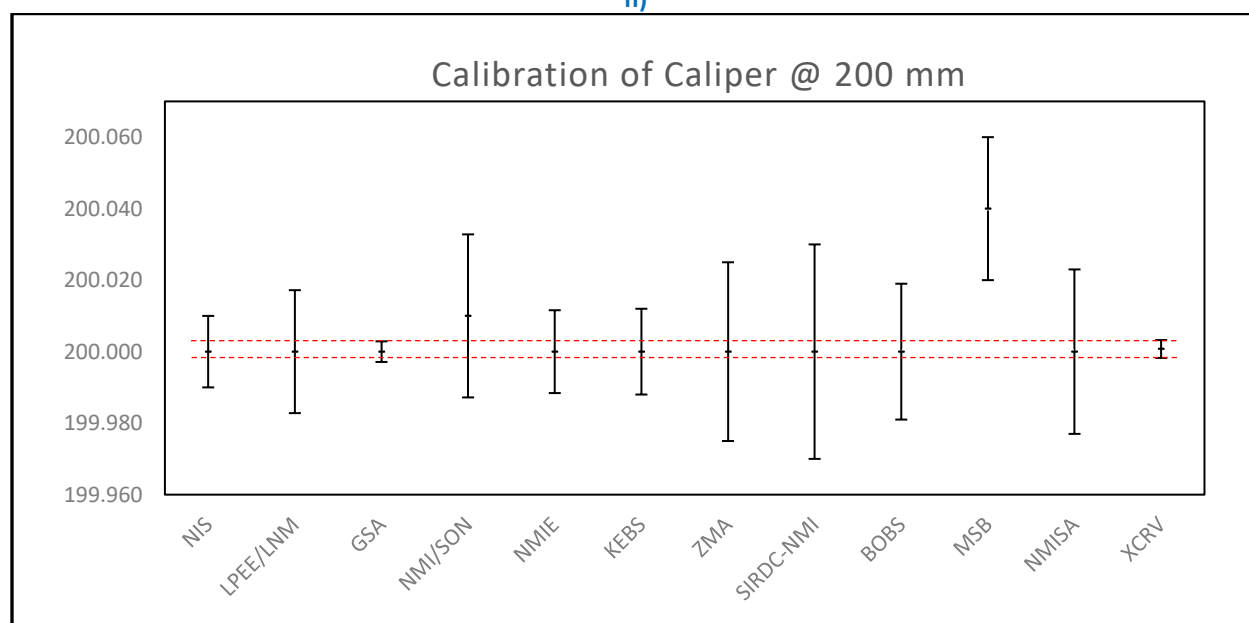
f)



g)

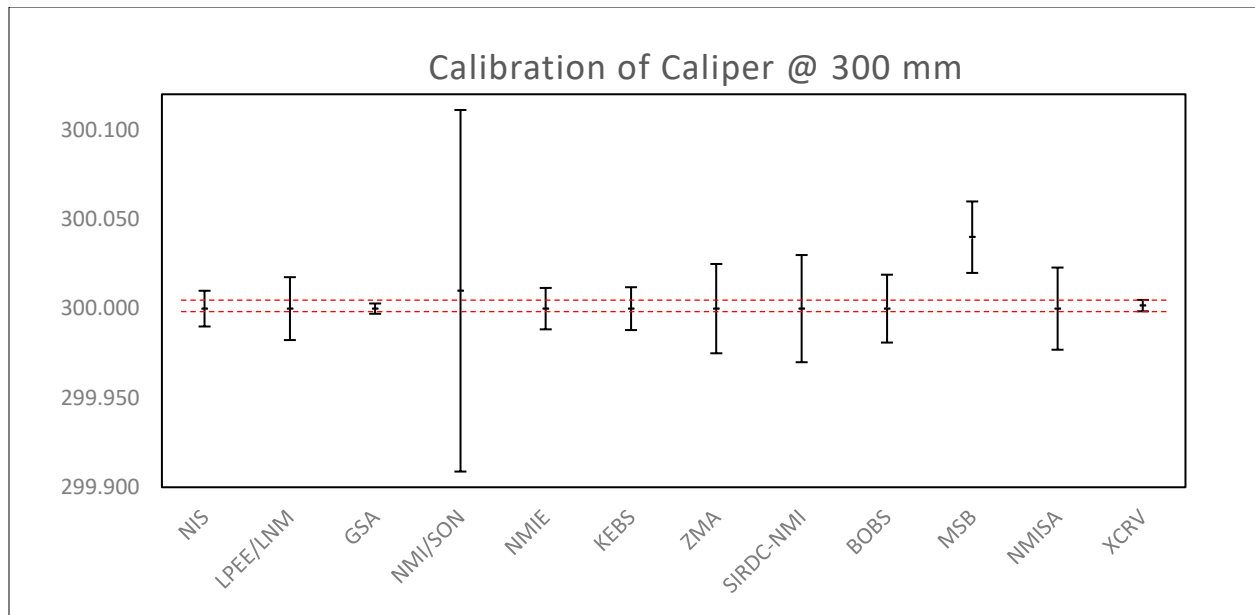
Final report: Calibration of Caliper

h)

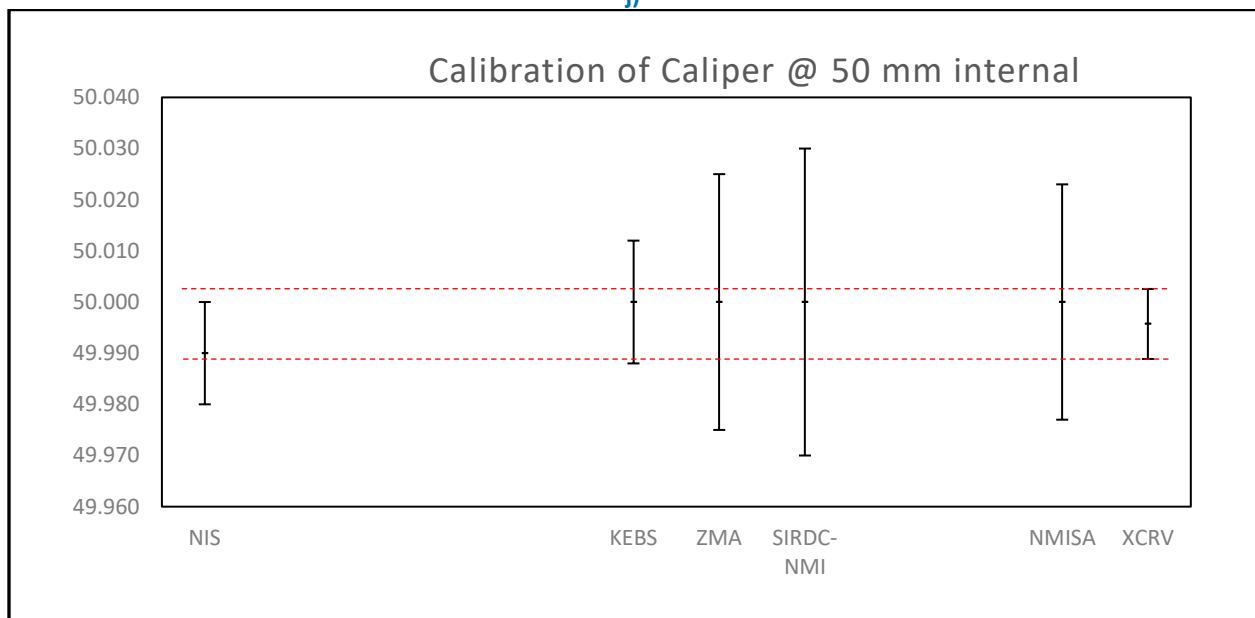


i)

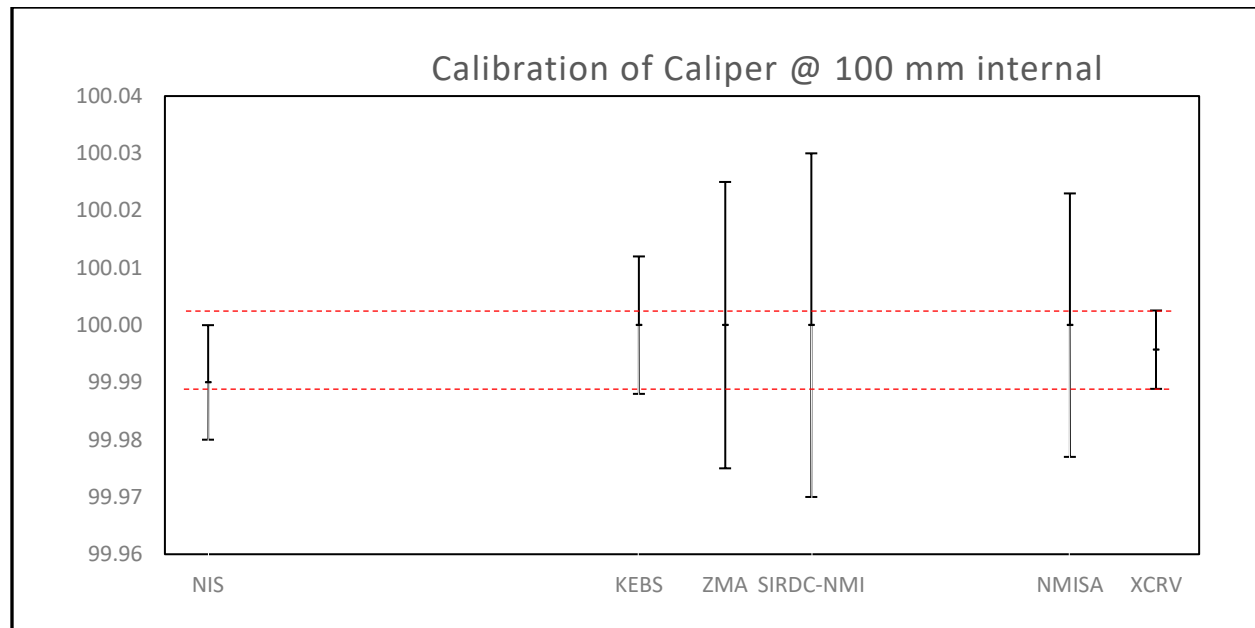
Final report: Calibration of Caliper



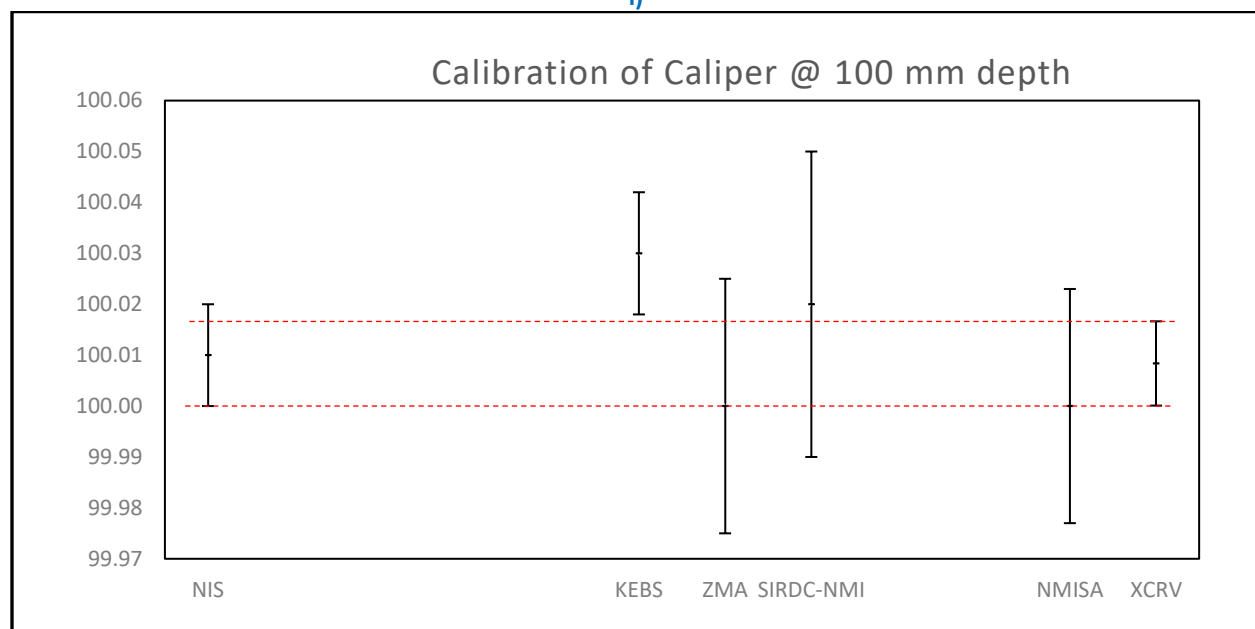
j)



k)

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l)



m)

Figure 3. The results of the participants in comparison with the CRV and it's uncertainty (expanded), a, b, c, d, e, f, g, h, i, j, k, l & m.

Note : the dashed red lines are the uncertainty limits for each CRV

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

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comparisons results Chi-square value χ_{obs}^2 is calculated according to the following equation:

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

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

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

Where v is the degrees of freedom which is the number of participant 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_{obs}^2 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 , therefore, the degrees of freedom $v = N - 1$. From the Chi-Square table at 95 % confidence level, we obtain $\chi_{0.05}^2$ as tabulated according to number of participants in each point.

Table 9: Consistency check (satisfied)

Nominal length, (mm)	χ_{obs}^2	$\chi_{0.05}^2$	v	Consistency $\chi_{obs}^2 \leq \chi_{0.05}^2$?
0	0.00	16.92	9	Satisfied
3.3	4.829	16.92	9	Satisfied
10	6.066	18.31	10	Satisfied
20	6.963	18.31	10	Satisfied
40	19.874	18.31	10	Not Satisfied
50	15.758	18.31	10	Satisfied
100	19.675	18.31	10	Not Satisfied
150	16.479	18.31	10	Satisfied
200	16.414	18.31	10	Satisfied
300	14.179	18.31	10	Satisfied
50 (internal)	1.715	9.49	4	Satisfied
100 (internal)	2.515	9.49	4	Satisfied
100 (depth)	10.492	9.49	4	Not Satisfied

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- The results from the following participants are removed before calculating the CRV and its uncertainty for the data to be consistent
 - Participants MSB (Mauritius) @ 40 mm & 100 mm.
 - Participants KEBS (Kenya) @ 100 mm depth.

After removing these results from the CRV calculation, the consistency check is.

Table 10: Consistency check (satisfied)

Nominal Length, (mm)	χ^2_{obs}	$\chi^2_{0.05}$	ν	Consistency $\chi^2_{obs} \leq \chi^2_{0.05}$?
40	3.871	16.92	9	Satisfied
100	5.955	16.92	9	Satisfied
100 depth	1.686	7.81	3	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;

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

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:

$|E_n| \leq 1 \rightarrow$ **Satisfactory performance**

$|E_n| > 1 \rightarrow$ Unsatisfactory performance

Final report: Calibration of Caliper**Table 11. Evaluation of performance for the participants using E_n**

Nominal Length, (mm)	$ E_n $										
	NIS (Egypt) (Pilot)	LPEE/LNM (Morocco)	GSA (Ghana)	NMI/SON (Nigeria)	NMIE (Ethiopia)	KEBS (Kenya)	ZMA (Zambia)	SIRDC- NMI (Zimbabwe)	BOBS (Botswana)	MSB (Mauritius)	NMISA (South Africa)
0	0.00	0.00	N.E.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.3	0.05	0.03	0.12	0.47	0.04	0.04	0.02	0.02	0.02	0.97	N.E.
10	0.02	0.01	0.05	0.02	0.82	0.02	0.01	0.01	0.01	1.00	0.01
20	0.01	0.01	0.04	0.01	0.83	0.01	0.01	0.00	0.01	1.00	0.01
40	0.03	0.02	0.08	0.50	0.82	0.03	0.01	0.01	0.02	2.00	0.01
50	0.06	0.04	0.16	0.05	0.05	0.05	0.02	0.02	0.03	1.96	0.03
100	0.90	0.04	0.14	0.38	0.88	0.05	0.02	0.02	0.03	1.95	0.03
150	0.07	0.04	0.20	0.42	0.06	0.06	0.03	0.03	0.04	1.95	0.03
200	0.07	0.04	0.20	0.40	0.06	0.06	0.03	0.02	0.04	1.95	0.03
300	0.16	0.09	0.39	0.08	0.14	0.14	0.07	0.06	0.09	1.89	0.07
50 (internal)	0.47	N.E.	N.E.	N.E.	N.E.	0.31	0.17	0.14	N.E.	N.E.	0.18
100 (internal)	0.81	N.E.	N.E.	N.E.	N.E.	0.13	0.06	0.65	N.E.	N.E.	0.07
100 (depth)	0.13	N.E.	N.E.	N.E.	N.E.	1.48	0.32	0.37	N.E.	N.E.	0.34

N.E.: not evaluated

10. Conclusion:

- The results from 11 African countries, namely Egypt, Morocco, Ghana, Nigeria, Ethiopia, Kenya, Zambia, Zimbabwe, Botswana, Mauritius and South Africa have participated in an AFRIMET supplementary comparison on the calibration of caliper. The comparison reference value has obtained from the results using the weighted mean method after performing consistency check of the results using the Chai-square method. The Normalized error number E_n is used to evaluate the performance of all participants. All results are found satisfactory except:
 - KEBS (Kenya) @ point of 100 mm (depth).
 - MSB (Mauritius) @ points 40, 50, 100, 150, 200 and 300 mm are found unsatisfactory ($E_n > 1$).
- The countries of Morocco, Ghana, Nigeria, Ethiopia, Botswana and Mauritius do not report their measurements for points 50 mm internal, 100 mm internal and 100 mm depth, so they are not evaluated at these points.
- The country of Ghana does not report its measurements for points 0 mm, so it is not evaluated at this point.
- The country of South Africa does not report its measurements for points 3.3 mm, so it is not evaluated at this point.

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.