CRITERIA FOR LABORATORY ACCREDITATION IN MASS METROLOGY

Prepared by: SADCAS Advisory Committee – CLAP	**Approved by**: SADCAS CEO.	**Approval Date**: 2018-03-19 **Effective Date**: 2018-04-01

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1. PURPOSE AND SCOPE

The purpose of this document is to define the specific environmental, general and technical requirements to be met by accredited laboratories in the field of mass metrology.

This document is applicable to Southern African Development Community Accreditation System (SADCAS) accredited Laboratories. This document does not address the requirements for accreditation of facilities for compliance to national legal metrology legislation.

2. ABBREVIATIONS

d	Readability
CMC	Calibration and Measurement Capability
LMA	Legal Metrology Authority
MC	Measurement Capability
mpe	Maximum permissible error
NPL	National Physical Laboratory, United Kingdom
OECD	Organization for Economic Co-operation and Development
OIML	International Organization of Legal Metrology
RH	Relative Humidity

3. DEFINITIONS

3.1 Apparent Mass

The value indicated by the balance i.e. the result of a measurement before correction for systematic error (e.g. for buoyancy correction). *Refer to the OECD Guidance on objective tests for determining the ripeness of fruit AGR/CA/FVS (1993)11/REV6*.

3.2 Buoyancy Correction

The correction applied when weights of differing densities are compared with each other during the calibration process, the buoyancy being a result of the upward force when the weight is immersed in a fluid (such as air) during the weighing process.

This is a correction made when comparing the mass of artefacts of different volumes. It is equal to the difference in the volumes of the artefacts multiplied by the density of the medium in which they are compared (usually air). *Refer to OIML International Recommendation R 111-1: 2004 (E) Weights of Classes E1, E2, F1, F2, M1, M2, M3.*

3.3 Calibration Authority

Body responsible for the maintenance of the national measurement standards of a country, and their dissemination to the national quality infrastructure, or a laboratory accredited by SADCAS.

3.4 Conventional Mass

Conventional value of the result of weighing in Air. For a weight taken at a reference temperature (t_{ref}) 20º C, the conventional mass is the mass of a reference weight of a density (ρ_{ref}) of 8000 kg/m^3 which it balances in air of a reference density (ρ_0) of 1.2 kg/m^3. *Refer to OIML International Recommendation R76-1 Non-automatic weighing instruments, Part 1- Metrological and technical requirements – Tests 2006 (E).*

3.5 Discrimination

The smallest change in mass that can be detected by the weighing instrument. For practical purposes discrimination is synonymous with readability. *Refer to AS TG2 IANZ Technical Guide Laboratory balances - Calibration requirements – International Accreditation New Zealand*.

3.6. Readability (d)

The smallest scale division or digital interval of the weighing instrument. For some mechanical weighing instruments the scale marks may be sufficiently far apart for an estimation to be made of the weighing instrument reading when the pointer lies between two scale marks. The estimated readability may therefore be lower than the marked readability. *Refer to AS TG2 IANZ Technical Guide Laboratory balances - Calibration requirements – International Accreditation New Zealand.*

3.7 Resolution

The readability expressed as a portion of the capacity. For example a weighing instrument with a capacity of 3 000g and a readability of 0.1g has a resolution of 1 part in 30 000. *Refer to AS TG2 IANZ Technical Guide Laboratory balances - Calibration requirements – International Accreditation New Zealand.*

3.8. Scale Interval

The value expressed in units of mass:

a) In the case of analogue indication, the difference between the values that correspond to two consecutive scale marks, or
b) In the case of digital indication, the difference between two consecutively indicated values.

3.9 True Mass

The true mass of a body relates to the amount of material it contains. The prefix true is added to the word mass where it is important to make it clear that a particular value of mass being considered is not a conventional mass value and it is important to avoid potential ambiguity. The international prototype kilogram, on which the international mass scale is realized, is defined as a true mass of exactly 1 kilogram. Most high accuracy comparisons are performed on a true mass basis. *Refer to OIML International Recommendation R 111- : 2004 (E) Weights of Classes E1, E2, F1, F2, M1, M2, M3.*

3.10 Mass Reference Standard

Measurement standard designated for the calibration of other measurement standards for mass within an accredited facility.

3.11 Weight

A material measure of mass, regulated in regard to its physical and metrological characteristics: shape, dimensions, material, surface quality, nominal value, and maximum permissible error. *Refer to OIML International Recommendation R76-1 Non-automatic weighing instruments, Part 1-Metrological and technical requirements – Tests 2006 (E).*

4. ENVIRONMENTAL REQUIREMENTS

4.1 **T**he temperature and humidity in any laboratory where weights are calibrated must be maintained between the limits as specified in Table 1. *Refer to OIML International Recommendation R 111-1: 2004 (E) Weights of Classes E1, E2, F1, F2, M1, M2, M3*.

Table 1 – Temperature and Humidity Limits

Class of Weight	Temperature Range (ºC)		ΔT during calibration		Relative Humidity Range (rh) (%)		Δrh during calibration
	Min	Max	ºC / Hr	ºC / 12 Hr	Min	Max	(% / 4 Hr)
E1	18	27	± 0,3	± 0,5	40	60	± 5
E2	18	27	± 0,7	± 1,0	40	60	± 10
F1	18	27	± 1,5	± 2,0	40	60	± 15
F2	18	27	± 2,0	± 3,5	40	60	± 15
M1	⨯	⨯	± 3,0	± 5,0	⨯	⨯	⨯
M2	⨯	⨯	⨯	⨯	⨯	⨯	⨯
M3	⨯	⨯	⨯	⨯	⨯	⨯	⨯

[9]

Note: ⨯ means No specific requirement

After weights are cleaned with solvents they must be stabilized for the times given in Table 2. *Refer to OIML International Recommendation R 111- : 2004 (E) Weights of Classes E1, E2, F1, F2, M1, M2, M3.*

Table 2 – Stabilization Times

Weight class	E1	E2	F1	F2 to M3
After cleaning with alcohol	7–10 days	3–6 days	1–2 days	I hour
After cleaning with distilled water	4–6 days	2–3 days	1 day	I hour

4.2 Where applicable the laboratory shall maintain appropriate records to demonstrate and confirm the humidity, temperature, temperature gradients and ambient pressure within the laboratory.

4.3 Weighing instruments must be calibrated at ambient temperatures.

4.4 Lighting within the laboratory shall be adequate to facilitate the correct performance of the calibration work undertaken. Cognizance shall be taken of the minimum levels of lighting as specified in national environmental regulations. *Refer to ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories.*

4.5 Drafts in the laboratory caused by doors, fans and/or air conditioners should be such that they do not have an adverse effect on the measurement results, where necessary local isolation in the form of draft shield should be utilized.

4.6 Thermometers and/or temperature, relative humidity, and barometric pressure recorders or indicators used for the measurement and recording of the ambient temperature, humidity and/or barometric pressure in the laboratory, and onsite shall be calibrated.

5. GENERAL REQUIREMENTS

5.1 Laboratories shall have a policy and procedure/s that address how weights, both their own standards, and weights belonging to customers are to be handled, cleaned and refurbished. *Refer to NPL Good Practice Guide Cleaning, handling and storage of weights.*

5.2 All cotton and chamois leather gloves, forceps, tweezers and cloths or other equipment used for the handling of weights shall be kept clean. *Refer to NPL Good Practice Guide Cleaning, handling and storage of weights.*

5.3 Raw data shall not be recorded in pencil, or erasable ink.

5.4 Precision mass standards are normally maintained in storage casings or cupboards, where they may be protected from dust and atmospheric pollution by glass covers. However, when transported for calibration or used outside the laboratory, weights should be contained in specially-built boxes. *Refer to NPL Good Practice Guide Cleaning, handling and storage of weights.*

5.5 The schedule of accreditation shall list the types of weighing instruments that the laboratory is competent to calibrate under the parameter 'weighing instruments'. This list may include the following:

- Digital self-indicating;
- Mechanical self-indicating;
- Semi-self-indicating;
- Non-self-indicating;
- Equal arm balances;
- Automatic scales;
- Hopper scales;
- Conveyor scales;
- Comparators;
- Gram gauges;
- Fruit penetrometers;
- In-motion weighers;
- Crane scales; and
- Weighbridges

Due to the complexity of the calibration of certain types of scale for example equal arm balances, crane scales and weighbridges, these types may be listed separately on the schedule of accreditation with dedicated MC's.

6. TECHNICAL REQUIREMENTS

6.1 Weights used for the Calibration of Weighing Instruments

6.1.1 The weights used to perform the calibration of weighing instruments shall be calibrated to an appropriate level of uncertainty.

6.1.2 Make up weight may not be used for the calibration of weighing instruments having a capacity of 500 kg or less.

6.1.3 For weighing instruments having a capacity of larger than 1 000 kg, the mass of the standard weights used shall be at least 500 kg and the make-up weight may not exceed 50% of the capacity of the weighing instrument.

6.1.4 For weighing instruments having a capacity of larger than 10 000 kg, the mass of the standard weights used shall be at least 5 000 kg and the make-up weight may not exceed 80% of the capacity of the weighing instrument.

6.1.5 All make-up weight must be of a stable material.

6.1.6 In certain instances it may not be possible to use weights having an uncertainty equal or smaller than the readability of the weighing instrument due to local and international limitations on the uncertainty of weight calibration. For example the maximum uncertainty for a 5 gram Class E1 weight is ± 5 µg ($^{1}/_{3}$ of 16µg); whilst micro balances with a capacity of 5 gram and readability of 0.1 µg are available. *Refer to OIML International Recommendation R76-1 Non-automatic weighing instruments, Part 1- Metrological and technical requirements – Tests 2006 (E).*

6.2 Calibration of Weighing Instruments - Minimum Requirements

The following are the minimum tests which must be carried out when calibrating a weighing instrument unless the user or client has requested or agreed to a partial calibration, in which case both the weighing instrument and the calibration certificate/report must be marked accordingly. Laboratories may also carry out any number of additional measurements using various test loads, or applicable tests recommended in *OIML International Recommendation R76-1 Non-automatic weighing instruments, Part 1- Metrological and technical requirements – Tests 2006 (E).*

6.2.1 Repeatability (or Precision) Measurement

a) Take at least five readings using (where practical) a single standard weight (or other suitable artefact) as close as practical to half the capacity of the weighing instrument.

b) Where the capacity of the weighing instrument exceeds 30 kg, the number of readings may be reduced to a minimum of three.

c) Report at least the nominal load applied and the standard deviation of the repeated weighings.

6.2.2 Eccentric (or Corner) Measurement

a) Place standard weights (or a suitable artefact) of between one quarter and one third of the weighing instrument’s capacity alternately in the centre and in the various eccentric positions on the load receptor to determine the deviation (if any) caused by the off-centre loading.

   Report at least the nominal load applied and the maximum deviation from the centre, caused by the off-centre loading.

b) Where a manufacturer of a weighing instrument specifies a particular load for this test, that load may be used.

c) The eccentric test is not carried out in the case of a weighing instrument with a suspended load receptor.

d) Where the load receptor is supported on more than four points, a load as close as practicable to the capacity of the instrument divided by the number of supporting points minus one, is used.

e) Where a load receptor has a single point of support, the load must be placed in any position on the load receptor, at a distance of approximately two thirds of the distance from the centre to the edge of the load receptor. In the case of a square or rectangular load receptor, the receptor is divided into quarters and the load placed in the centre of the quarter.

f) Where a load receptor has four or more supporting points, the surface area is divided by the number of supporting points and the load is placed in the centre of (or evenly spread over) each segment in turn.

g) Where a load receptor is in the form of rails or tracks (e.g. rail vehicle scales or overhead track scales) the load must be applied at the beginning, in the middle and at the end of the rail or track.

6.2.3 Accuracy and Linearity

Test the accuracy and linearity using at least five different test loads (excluding zero), approximately evenly spread over the weighing range of the instrument. Additional measurements, such as treating each range as a separate instrument, must be carried out in the case of:

a) Multi-range or multi–interval weighing instruments;

b) Weighing instruments with multi–revolution indicators;

c) Weighing instruments with optically projected indication together with built–in unit weights to increase the capacity;

In the case of non-self-indicating weighing instruments, the accuracy of any travelling or sliding poises and proportional counterpoise weights must be tested. Record also the actual load applied to reach equilibrium of the beam or steelyard.

Report both the actual values of the loads applied and the resultant indication. Where the total of the actual errors or inaccuracies of the standard weights used is less than one quarter of the value of the smallest graduation or readability of the weighing instrument, the nominal values of the loads may be stated instead of the actual values.

Hysterisis is checked by taking readings of increasing and decreasing load. Significant difference may indicate mechanical problems within the balance. This test is identical to that described in more detail for a single pan electronic balance. *Refer to OIML International Recommendation R 111- : 2004 (E) Weights of Classes E1, E2, F1, F2, M1, M2, M3.*

6.3 Weighing Instruments – Measurement Uncertainty

Measurement uncertainty shall be evaluated in accordance to references *SADCAS TR 12 Estimation of the uncertainty of measurement by calibration laboratories and specification of* *calibration and measurement capability on schedules of accreditation* and *SADCAS TR 15 Contributions to uncertainty of measurement in mass metrology*

6.4 Calibration of Weights - Requirements

6.4.1 Weighing in the laboratory must take place on a weighing bench of adequate construction, which will facilitate the stable and correct operation of the weighing instrument. The weighing bench design shall take cognizance of vibration, stability, magnetic susceptibility, static charging, and support.

6.4.2 Laboratory procedures shall address stabilization times for the calibration of weights.

6.4.3 Where an uncertainty of less than or equal to ± 0,000 02% ($\pm 2.10^{-7}$ ●M) is quoted, the density of the weights must either be known (from a prior determination) or determined and a buoyancy correction must be applied. *(Typical OIML Class E1)*. [M is the nominal mass].

6.4.4 Where an uncertainty of between ± 0,000 50 % ($\pm 5.10^{-6}$ ● M) and ± 0,000 02% ($\pm 2.10^{-7}$ ●M) is quoted, the density of the weights may be measured or assumed and a buoyancy correction applied.

Refer to **Appendix C** for a table of expected material densities and uncertainties. *(Typical OIML Classes E2 to F2).*

6.4.5 No buoyancy correction need to be applied when weights are calibrated against standards of similar material, (i.e. Stainless Steel versus Stainless Steel), and uncertainties of between ± 0,000 2% (2.10^{-6}●M) and ± 0,005 % (5.10^{-5}●M) are claimed. *(Typical OIML Classes M1 to M2).*

6.4.6 No buoyancy correction need to be applied when uncertainties of 0,005% (5.10^{-5}●M) and larger are claimed. *(Typical OIML Class M3).*

6.4.7 When cast iron weights are calibrated, laboratories may not quote uncertainties of less than 0,001 6 % (± 1,6●10^{-5}.M).

6.4.8 The calibration laboratory shall, where applicable, indicate on the calibration certificate the prevailing measurement conditions such as air density, weight density, temperature, and indicate whether these values are assumed or have been measured.

6.4.9 A SADCAS accredited mass laboratory may calibrate inspection standard mass pieces for use by national Legal Metrology Authorities (LMA). The metrological characteristics of these mass pieces should conform to the maximum permissible tolerance requirements as specified in the national legal metrology legislation.

In order to claim metrological compliance the sum of the error and the uncertainty of measurement may not exceed the tolerances as specified in the national legal metrology legislation. National legal metrology legislation may include both physical (material of manufacture, shape, adjustment, surface finish, nominal values, identification, calibration mark) and metrological (maximum tolerance) specification.

Any statement of compliance on the calibration certificate shall indicate which clauses or sub-clauses of the relevant national legal metrology legislation have been complied with.

6.4.10. Laboratories wishing to certify weights according to the OIML accuracy classes [8] shall ensure that the measurement uncertainty does not exceed one third of the tolerance specification. OIML class compliance cannot be claimed unless both physical and metrological requirements have been satisfied. Where a statement of compliance is made to an accuracy class and the physical requirements have not been evaluated, this shall be clearly indicated on the calibration certificate.

6.4.11 When reporting the results the laboratory may not report on the calibration certificate more significant digits than it is able to measure on the weighing instrument, or more significant digits than have been specified on the certificate of calibration of their standard mass piece used during the calibration.

6.4.12 No laboratory shall be accredited to perform on site calibration of weights of denomination 50 kg and above unless they also have the capability to perform the calibration in their own laboratory, and their measurement capability is based on the equipment which they have in their own laboratory. This equipment shall include, but is not limited to, standard mass pieces (weights), balances and/or mass comparators, **except** where the laboratory has entered into a written agreement with a customer, confirming that the laboratory has been granted access to the necessary equipment. This agreement could be in the form of a letter granting the necessary authorization. In such cases the equipment shall be treated as equipment outside the direct control of the laboratory, in accordance with ISO/IEC 17025:2017 clauses 5.5.1 & 5.5.9.

6.4.13 Laboratories accredited to perform the calibration of weights the nominal mass of which exceeds 100 kg shall have access to suitable ancillary equipment as may be necessary to load and move these weights onto and from the weighing instrument. Such ancillary equipment may include slings, crawl beam, block and tackle, and a fork lift, as appropriate.

6.4.14 Laboratories who wish to be accredited for the calibration of weights the nominal mass of which exceed 500 kg, and where circumstances prevent the removal of these weights from their place of use, shall provide evidence of the calibration of the weighing instruments used to perform the calibration of the weight. Such calibration may be limited to a particular site.

6.5 Calibration of Weights – Measurement Uncertainty

Measurement uncertainty shall be evaluated in accordance to references *SADCAS TR 12 Estimation of the uncertainty of measurement by calibration laboratories and specification of calibration and measurement capability on schedules of accreditation* and *SADCAS TR 15 Contributions to uncertainty of measurement in mass metrology.*

6.6 Calibration of Force (Newton) or Non-metric Weights

6.6.1 The laboratory may calibrate weights in non-metric or weights marked in a nominal force in Newton's, the results and the associated uncertainty shall be reported in metric units of mass (kg, gram, mg, etc.) together with the conversion factor, and gravity (standard or local) used optionally along with the calculated equivalent value in the non-metric unit. The certificate shall include a statement indicating the source (reference) of the conversion factor used.

7. REFERENCES

- SADCAS TR 12 : Estimation of the uncertainty of measurement by calibration laboratories and specification of calibration and measurement capability on schedules of accreditation.
- SADCAS TR 15 : Contributions to uncertainty of measurement in mass metrology.
- ISO/IEC 17025:2017 : General requirements for the competence of testing and calibration laboratories.
- NPL Good Practice Guide : Cleaning, handling and storage of weights.
- AS TG2 IANZ Technical Guide : Laboratory balances - Calibration requirements – International Accreditation New Zealand.
- Mettler-Toledo : Fundamentals of mass determination.
- OIML International Recommendation R76-1 : Non-automatic weighing instruments, Part 1- Metrological and technical requirements – Tests 2006 (E).
- OIML International Recommendation R 111-1 : 2004 (E) : Weights of Classes E1, E2, F1, F2, M1, M2, M3.
- NPL Guide 71 Good Practice Guide Nº 71 : The Measurement of mass and weight.
- OECD Guidance : On objective tests for determining the ripeness of fruit AGR/CA/FVS (1993)11/REV6.
- PTB-MA-24e : Determination of mass Part 1 - Dissemination of the unit of mass – balances, weights and Test rooms. (ISBN 3-89429-756-5) 1996.

APPENDIX A: SAMPLE OF SCHEDULE OF ACCREDITATION

ANNEXURE

MASS METROLOGY

Laboratory Accreditation Number: ………………… (ISO/IEC 17025:2017)

Permanent Address of Laboratory: Postal Address: **Tel** : +………………………. **Fax** : +………………………. **Email** : …………………………………………	**Technical Signatory** : Mr………………………………………………… **Nominated Representative** : Mr………………………………………………… **Issue No** : ………. **Date of Issue** : ………………………………………… **Expiry Date** : …………………………………………..

ITEM	MEASURED QUANTITY OR TYPE OF GAUGE OR INSTRUMENT	RANGE OF MEASURED QUANTITY	MEASUREMENT CAPABILITIES EXPRESSED AS AN UNCERTAINTY (±)	OIML R111 Weight Class
1	Mass pieces (Weights)	1 mg to 10 g 10 g to 200 g 200 g to 20 kg 20 kg to 500 kg	0,005 mg 0,0001% 0,002 % 0,003 %	F1 F1 M2 M2
2	Weighing Instruments (Type – specify)	0 g to 6 g 6 g to 200 g 200 g to 2 kg 2 kg to 5000 kg	0,0005 % + 3 µg 0,0015 % + 0,1 mg 0,003 % 0,01 %	
3	On-site calibration of weighing instruments			

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The CMC, expressed as an expanded uncertainty of measurement, is stated as the standard uncertainty of measurement multiplied by a coverage factor *k* = 2, corresponding to a confidence level of approximately 95%

APPENDIX B: METAL DENSITIES AS PUBLISHED IN REF [8], TABLE B 7

Alloy/Material	Assumed Density	Uncertainty (k=2)
Platinum	21 400 kg/m^3	± 150 kg/m^3
Nickel silver	8 600 kg/m^3	± 170 kg/m^3
Brass	8 400 kg/m^3	± 170 kg/m^3
Stainless Steel	7 950 kg/m^3	± 140 kg/m^3
Carbon Steel	7 700 kg/m^3	± 200 kg/m^3
Iron	7 800 kg/m^3	± 200 kg/m^3
Cast Iron (white)	7 700 kg/m^3	± 400 kg/m^3
Cast Iron (grey)	7 100 kg/m^3	± 600 kg/m^3
Aluminium	2 700 kg/m^3	± 130 kg/m^3

APPENDIX C - AMENDMENT RECORD

Revision Status	Change			Approved by	Effective Date
	Page	Clause/ Sub-clause	Description of Change		
Issue 1	-	-	-	SADCAS CEO	2018-04-01