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CONTENTS

1. Classification of Groups and sub-groups

1.1 Name of the product/Device under Calibration

Table-1

Sr. No.	Parameter	Relevant Standard	Permanent Facility	Onsite Calibration	Mobile Facility
1.	Non-automatic Weighing Balances	EURAMET cg - 18/v.3 or OIML-R-76-1 and OIML-R76-2	Yes*	Yes	No
2.	Electronic Balances		Yes*	Yes	No
3.	Comparators		Yes*	Yes	No
4.	High Capacity Weighing Machines (above 50 kg)	OIML R 47	Yes*	Yes	No

Note 1: Permanent facility for their internal use only and not meant for external customer.

Note 2: This technical requirement is based on the above-mentioned guideline. Lab may follow any relevant standard; however, care shall be taken to follow the requirements in totality.

1.2 Classification basedon Minimum Readability

Table-2

Sr. No.	Type of Balance	Minimum Readability (d)	No. of Digits after Decimal Place (g)	Accuracy Class
1.	Ultra-micro balance	d = 0.1µg=0.0000001g	7	I
2.	Micro balance	d = 0.1µg=0.000001g	6	I

Sr. No.	Type of Balance	Minimum Readability (d)	No. of Digits after Decimal Place (g)	Accuracy Class
3.	Semi-micro balance	d = 0.01 mg=0.00001g	5	I
4.	Analytical balance	d = 0.1mg=0.0001g	4	I
5.	Precision balance	d = 50 mg to 1 mg = 0.05g to 0.001g	2 to 3	II
6.	Medium balance	d = 1 g to 2 g	0	III
7.	Ordinary balance	d >5 g	0	IV

1.3 Classification based on scale interval

Table-3

Accuracy Class		Verification of Scale Interval, e	Number of Verification Scale Intervals, n = Max/e		Minimum Capacity, Min (Lower limit)
			Minimum	Maximum	
Special	I	0.001 g ≤ e*	50 000**	-	100 e
High	II	0.001 g ≤ e ≤ 0.05 g 0.1 g ≤ e	100 5000	100 000 100 000	20 e 50 e
Medium	III	0.1 g ≤ e ≤ 2 g 5 g ≤ e	100 500	10 000 10 000	20 e 20 e
Ordinary	IIII	5 g ≤ e	100	1000	10 e

*It is not normally feasible to test and verify an instrument e< 1mg, due to uncertainty of the test loads.

** Refer section exception in 3.4.4 of OIML R 76-1.

2. Reference

2.1 Selection of Weights &Restriction

a) Selection of weights for calibration of weighing machines depending on capacity and scale division (resolution):

Lowest class of weights required for different types of weighing machine

Table - 4

Capacity	Resolution							
	100g	10g	1g	100mg	10mg	1mg	0.1mg	0.01mg or less

Up to 200g				M1	M1	F2	F1	E2
200g to 1kg			M1	M1	F2	F1/E2	E2	E2
1kg to 30kg	M2	M2	M1	F2	E2	E2	E2	
30kg to 100kg	M2	M1	F2	F1	E2			
Above 100kg	M2	M1/F2	F1	E2				

b) The standard weights or standard masses used for the verification of an instrument shall not have an error greater than 1/3 of the maximum permissible error of the instrument for the applied load.

2.2 Example for Selection of Weights for Balance Calibration:

Table - 5

Capacity of the balance	Calibration weight required	Readability	Required accuracy of weight (Readability/3)	Error as per E2 Class	Error as per F1 class	Selectable class as per class requirement
1000g	1kg	0.01g=10mg	10/3=3mg	1.6mg	5mg	1.6mg

From the above table it is clear that we need to select 1kg of E2 class for calibration of the above balance.

Note 1: Based on the historical data validity of reference weights may be extended upto 5 years for E1.

Note 2: Lab cannot calibrate balances using lower class of accuracy weights than required.**Accuracy**

2.3 Maximum permissible errors for reference standard (weights) (± δm in mg)

Table-

Nominal Value	Maximum Permissible Error for weights (±δm in mg)								
	E_1	E_2	F_1	F_2	M_1	M_{1-2}	M_2	M_{2-3}	M_3
5000 kg			25000	80000	250000	500000	800000	1600000	2500000
2000 kg			10000	30000	100000	200000	300000	600000	1000000
1000 kg		1600	5000	16000	50000	100000	160000	300000	500000
500 kg		800	2500	8000	25000	50000	80000	160000	250000
200 kg		300	1000	3000	10000	20000	30000	60000	100000
100 kg		160	500	1600	5000	10000	16000	30000	50000
50 kg	25	80	250	800	2500	5000	8000	16000	25000
20 kg	10	30	100	300	1000		3000		10000
10 kg	5.0	16	50	160	500		1600		5000
5 kg	2.5	8.0	25	80	250		800		2500
2 kg	1.0	3.0	10	30	100		300		1000
1 kg	0.5	1.6	5.0	16	50		160		500
500 g	0.25	0.8	2.5	8.0	25		80		250
200 g	0.10	0.3	1.0	3.0	10		30		100
100 g	0.05	0.16	0.5	1.6	5.0		16		50
50 g	0.03	0.10	0.3	1.0	3.0		10		30
20 g	0.025	0.08	0.25	0.8	2.5		8.0		25
10 g	0.020	0.06	0.20	0.6	2.0		6.0		20
5 g	0.016	0.05	0.16	0.5	1.6		5.0		16

2 g	0.012	0.04	0.12	0.4	1.2		4.0		12
1 g	0.010	0.03	0.10	0.3	1.0		3.0		10
500 mg	0.008	0.025	0.08	0.25	0.8		2.5		
200 mg	0.006	0.020	0.06	0.20	0.6		2.0		
100 mg	0.005	0.016	0.05	0.16	0.5		1.6		
50 mg	0.004	0.012	0.04	0.12	0.4				
20 mg	0.003	0.010	0.03	0.10	0.3				
10 mg	0.003	0.008	0.025	0.08	0.25				
5 mg	0.003	0.006	0.020	0.06	0.20				
2 mg	0.003	0.006	0.020	0.06	0.20				
1 mg	0.003	0.006	0.020	0.06	0.20				

2.4 Use of Reference standard (Weights) for Lab & Site;

Table - 7

Sr. No.	Class	Permanent Facility	Onsite Calibration	Mobile Facility
1.	E1	Yes*	Yes	Yes
2.	E2	Yes*	Yes	Yes
3.	F1	Yes*	Yes	Yes
4.	F2	Yes*	Yes	Yes
5.	M1	Yes*	Yes	Yes
6.	M2	Yes*	Yes	Yes

3. Environmental Conditions: (At Lab & Site)

3.1 Temperature: If no particular working temperature is stated in the descriptive markings of an instrument, this instrument shall maintain its metrological properties within the following temperature limits: -10°C +40°C.

An instrument for which particular limits of working temperature are stated in the descriptive markings shall comply with the metrological requirements within those limits. The limits may be chosen according to the application of the instrument.

The ranges within those limits shall be at least equal to:

5°C for instruments of class I,

15°C for instruments of class II,

30°C for instruments of classes III and IV

3.2 Humidity: Humidity shall be maintained in between 40%RH to 60%RH

3.3 Vibration: The Calibration area shall be free from vibrations generated by central air-conditioning plants, vehicular traffic and other sources to ensure consistent and uniform operational conditions.

3.4 Illumination: The recommended level of illumination is 250-500 lux on theworking table.

3.5 Acoustic Noise: Noise level shall be maintained less than 60 dBA, it affects adversely the required accuracy of measurement.

3.6 Effect of Gravity 'g' on Calibration of Balance

a) The weighing values are different when the weighing height changes.

b) The further a weight is from the centre of earth, the smaller the gravitational force acting on it. It decreases with the square of the distance. Example: The weight display changes when the weighing is performed at 10 m higher (moving from the first floor to fourth floor of a building). To determine the weight of a body, the balance measures the weight force i.e., the force of attraction (Gravitation force) between the earth & the weighing sample. The force depends essentially on the latitude of the location & its height above sea level (distance from the centre of earth).

c) The nearer a location is to the equator, the greater the centrifugal acceleration due to the rotation of the earth. The centrifugal acceleration counteracts the force of attraction (Gravitation Force).

d) The poles are the greatest distance from the equator & closest to the earth centre. The force acting on a mass is therefore greatest at the poles.

Example: In the case of 200 g weight that shows exactly 200.00000 g on the first floor, the following weight result on the fourth floor (10m height).

$$200\text{g} \times r^2 / (r + \Delta)^2$$

Where, r is the radius of earth at that point of measurement, Δ is change in height

200 $6370000^2 / 6370010^2 = 199.99937$g

e) **The formula to determine the mass needed to obtain the required force is as follows:**

$$m = \left(\frac{9.80665}{g}\right) x \left(1 + \frac{\alpha}{\rho}\right) x\ f$$

Where:

m = mass of the weight (true mass)

g = gravity at fixed location, m/s^2.

It is very important the gravity value for the location where the weight is to be used to be established. Not using the correct gravity for the location will result in significant errors.

α = air density - Mass per unit volume of air (kg/m^{3})

ρ = material density - A quantitative expression of the amount of mass contained per unit volume. The standard unit is the kilogram per meter cubed (kg/m^3)

f = required force

Calculation Example

1 newton = 101.971621 grams-force

mass = (9.80665/g)(1 + (α / ρ)f

g = local gravity in m/s^2

α = air density = 0.0012 g/cm^3

ρ = density of weight material = 7.9 g/cm^3

f = force

9.79957 m/s^2 local gravity

mass =(9.80665/9.79957)(1+(0.0012/7.9)*101.971621 = 102.0607941 grams

Note: This example calculation was performed using a standard value for air density and material density. To minimize uncertainty, the actual value for the air density at the place of use and the density of the material should be used.

3.7. Mains Power supply: An instrument operated form a mains power supply shall comply with the metrological requirements if the power supply varies**:**

a) In voltage from – 15% to + 10% of the value marked on the instrument,

b) In frequency from – 2% to +2% of the value marked on the instrument, if AC is used.

4. Metrological Traceability Requirement

To achieve traceability, laboratories shall follow EAS ‘Policy on Calibration and Traceability of Measurements’.

5. Calibration Method

5.1 Suggested standards:

a) OIML R76-1 Metrological and technical requirements – Non-automatic weighing instruments.

b) OIML R76-2 Non-automatic weighing instruments – Test report format.

c) EURAMET cg – 18 V.03 guidelines on the calibration of Non-automatic weighing instruments.

d) OIML-R-111-1 Weights of classes E1, E2, F1, F2, M1, M1-2, M2, M2-3 and M3 metrological and Technical requirements.

e) OIML R 47- Standard weights for testing of high capacity weighing machine.

f) OIML D28 Conventional value of the result of weighing in air.

g) UKAS Guide Lab - 14: Calibration of weighing balance.

Note: Latest version of the relevant standard(s) should be followed

6. Calibration Procedure

6.1 Preconditions, preparations: Calibration should not be performed unless:

a) the instrument can be readily identified,

b) all functions of the instrument are free from effects of contamination or damage, and functions essential for the calibration operate as intended,

c) presentation of weight values is unambiguous and indications, where given, are easily readable,

d) the normal conditions of use (air currents, vibrations, stability of the weighing site etc.) are suitable for the instrument to be calibrated,

e) the instrument is energized prior to calibration for an appropriate period, e.g. as long as the warm-up time specified for the instrument, or as set by the user,

f) the instrument is levelled, if applicable,

g) the instrument has been exercised by loading approximately up to the largest test load at least once, repeated loading is advised. Instruments that are intended to be regularly adjusted before use should be adjusted before the calibration, unless otherwise agreed with the client. Adjustment should be performed with the means that are normally applied by the client, and following the manufacturer's instructions where available. Adjustment could be done by means of external or built-in test loads. The most suitable operating procedure for high resolution balances (with relative resolution better 1×10^{-5} of full scale) is to perform the adjustment of the balance immediately before the calibration and also immediately before use. Instruments fitted with an automatic zero-setting device or a zero-tracking device should be calibrated with the device operative or not, as set by the client. For onsite calibration the user of the instrument should be asked to ensure that the normal conditions of use prevail during the calibration. In this way disturbing effects such as air currents, vibrations, or inclination of the measuring platform will, so far as is possible, be inherent in the measured values and will therefore be included in the determined uncertainty of measurement.

6.2 Performance Check of the balance

6.2.1 Repeatability Test: This test is carried out at max load capacity and half load capacity of the balance under calibration. At least 10 readings for balance up to 10 kg and 5 readings for balance above 10 kg shall be taken and the standard deviation gives the repeatability values. Maximum of the two should be considered for uncertainty calculation.

6.2.2 Linearity Test or Departure of Indication from the Nominal Value: The departure of indication from nominal value or the linearity of the scale is measured at sufficiently equally spaced points over the ranges of the balance to ensure safe interpolation, if needed between these points. Usually minimum 10 such readings are taken including no load and the maximum capacity load.

6.2.3 Eccentricity Test

6.2.3.1

Eccentric loading

a) The indication for different positions of a load shall meet the maximum permissible errors.

b) Unless otherwise specified hereafter, a load corresponds to $^{1}/_{3}$ of the sum of the maximum capacity and the corresponding maximum additive tare effect shall be applied.

c) On an instrument with a load receptor having 'n' points of support, with n>4, the fraction $^{1}/_{(n-1)}$ of the sum of the maximum capacity and the maximum additive tare effect shall be applied to each point of support.

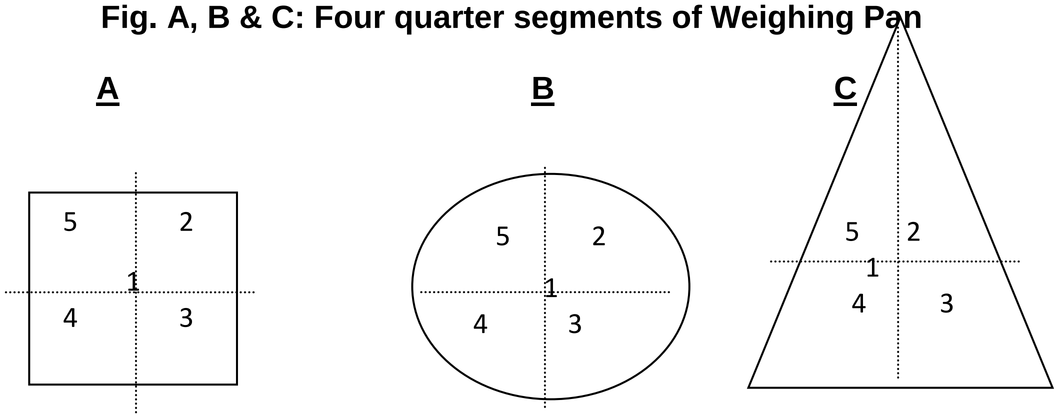
d) On an instrument with a load receptor subject to minimal off-centre loading (e.g. tank, hopper...) a test load corresponding to $^{1}/_{10}$ of the sum of the maximum capacity and the maximum additive tare effect shall be applied to each point of support.

e) On an instrument used for weighing rolling loads (e.g. vehicle scale, rail suspension instrument) a rolling test load corresponding to the usual rolling load, the heaviest and the most concentrated on which may be weighed, but not exceeding 0.8 times the sum of the maximum capacity and additive tare effect shall be applied at different points on the load receptor.

f) Large weights should be used in preference to several small weights. Smaller weights shall be placed on the top of larger weights, but unnecessary stacking should be avoided within the segment to be tested. The load shall be applied centrally in the segment if a single weight is used, but applied uniformly over the segment, if several small weights are used.

g) Maximum deviation observed is recorded as eccentricity error.

Fig. A, B & C: Four quarter segments of Weighing Pan



7. Recommended Calibration Interval

For the reference weights used in calibration of balance/ comparator at permanent lab or at site facility.

Reference Weights	Recommended Interval (Permanent)	Recommended Interval *(For on-Site)
Weights of E1 class	3 years	2 years
Weights of class E2 to F2	2 years	1 years
Weights of class M1 to M2	1 years	1 years

Note: *Recommendation is based on present international practice. However, laboratory may refer ISO 10012 and ILAC G24 for deciding the periodicity of calibration other than above recommendations.*

8. Measurement Uncertainty

8.1 Uncertainty Components in Balance Calibration

The components of measurement uncertainty to be considered but are not limited to the following:

a) Repeatability.

b) Linearity or departure of indication

c) Resolution

d) Reference standard weights

e) Drift in mass or instability of the mass of weights used

f) Eccentricity (whenever the test is carried out)

8.1.1 Uncertainty due to Repeatability: At least six repeated readings shall be taken with a weight near to the maximum capacity of the balance or the range to be calibrated. Estimated standard deviation will be the repeatability contribution.

8.1.2 Uncertainty due to Eccentric Loading: If this contribution is known to be significant, the magnitude must be estimated and if necessary, the contribution must be included in the uncertainty budget. Acceptable solution for the uncertainty due to eccentricity:

$$u_E = [(d_1/d_2) * D] / (2*\sqrt{3})$$

WhereD is the difference between maximum and minimum values from the eccentricity test performed according to OIML R 76-2; d_1 is the estimated distance between the centres of theweights and d_2 is the distance from the center of the load receptor to one of the corners.

Note: *When 10 readings are taken for estimation of repeatability error, the contribution of eccentricity need not be added to the uncertainty.*

8.1.3 Uncertainties associated with the Balance

a. Uncertainty due to the display resolution of a digital balance

For a digital balance with the scale interval, d, the uncertainty due to resolution is:

$$u_d = (d/2/\sqrt{3})$$

b. Uncertainty due to Reference Mass

$$u_s = (Us/k)$$

Where Us is the standard uncertainty of the reference standard weight and k is the coverage factor from its calibration certificate.

c. Uncertainty due to Drift in Mass

Drift in Mass u_D= 10% of $u_s / \sqrt{3}$

d. Uncertainty due to Repeatability

Standard uncertainty due to Repeatability $\mathbf{u_A} = s/\sqrt{\mathbf{n-1}}$

e. Combined Standard Uncertainty of the Weighing Balance

$$u_c = \sqrt{(u_s^2 + u_d^2 + u_D + u_A^2)}$$

Expanded uncertainty $\mathbf{U = k * u_c}$

f. Overall Uncertainty of the Balance: The overall uncertainty of the balance to be reported is the limit of the performance (F) of the balance given by:

F = k * SD (max) + U (Cmax)

Where,

SD (max) = the maximum standard deviation of repeatability at half load and full load = magnitude of the maximum correction for the balance reading

U (Cmax) = the expanded uncertainty associated with C_{max} the correction of the balance.

8.2 Reporting of Results

The calibration certificates issued to the customer shall be in accordance with clause 7.8.1.2 ofISO/IEC/17025:2017. Apart from that it shall also include the following:

a) Thermal stabilization hours (as per 2.9)

b) Class of weight used for calibration depending on the class of accuracy of balance

c) Environmental conditions during calibration

d) Exact location of the balance during calibration

e) Declaration that, the calibration certificate issued for weighing balance used for scientific or industrial purposes only.

8.3 Verification of Comparator

To verify the performance of the comparator same procedure shall be followed to ascertain its performance as per manufacturer specification. Only uncertainty due to standard deviation (from repeatability) is considered during calibration of weights. No other components like eccentricity, error of indication etc. are taken into account for a comparator.

8.4 Evaluation of CMC

8.4.1 CMC value is not the same as expanded uncertainty reported in the calibration Certificate/Report. CMC values exclude the uncertainties which are attributed to the UUT (Unit under test/calibration).

8.4.2 For the purpose of CMC evaluation, the following components should be considered:

a) Type A uncertainty

b) Uncertainty of the reference standard weight.

c) Uncertainty due to drift in reference standard weight (due to wear and tear, transportation or temperature variation)

8.5 Legal Aspects

Calibration of weighing balance done by any accredited laboratories is meant for scientific and industrial purpose only. However, if used for commercial trading, additional recognition/ approval shall be complied as required by Dept. of Legal Metrology, Regulatory Bodies, etc.

9 Sample Scope

An illustrative example: Correct Presentation of Scope

Sr. No.	Parameter* / Device under Calibration	Master equipment used	Range(s) of measurement	Calibration and Measurement Capability **			Remarks/ Method Used
				Claimed by Laboratory	Observed by Assessor	Recommended by Assessor	
1.	**Mass** - Electronic Weighing Balance Readability : 1mg	F2 Class Standard Weights	up to 210 g	1.5 mg	2 mg	2 mg	Calibration of electronic weighing balance of Class II and coarser As per OIML R-76-1

Revision No.	Date approved	Revision History
1	2022-05-10	• The document is revised due to the name Ethiopian National Accreditation Office (ENAO) change to Ethiopian Accreditation Service (EAS) and new logo developed.
1.1	2023-02-07	• Correction done on page 1 that, this document was prepared by Meseret Tessema replaced by Zewdu Ayele (new quality manager). • Former director general was resigned and replaced by Mrs. Meseret Tessema.