ORGANISATION INTERNATIONALE

DE MÉTROLOGIE LÉGALE

INTERNATIONAL RECOMMENDATION

Weights of classes E_1, E_2, F_1, F_2, M_1, M_2, M_3

Poids des classes E_1, E_2, F_1, F_2, M_1, M_2, M_3

OIML R 111
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FOREWORD

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TERMINOLOGY

Note: The terminology relative to uncertainties in measurement is defined in Annex B (B.1).

T.1 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.

T.2 Accuracy class of weights

A class of weights which meets certain metrological requirements intended to keep the errors within specified limits.

T.3 Set of weights

A series of weights, usually presented in a case so arranged to make possible any weighing of all loads between the mass of the weight with the smallest nominal value and the sum of the masses of all weights of the series with a progression in which the mass of the smallest nominal value weight constitutes the smallest step of the series.

T.4 Conventional mass

Conventional value of the result of weighing in air, in accordance to International Recommendation OIML R 33.

For a weight taken at 20 °C, the conventional mass is the mass of a reference weight of a density of 8 000 $kg \cdot m^{-3}$ which it balances in air of a density of 1.2 $kg \cdot m^{-3}$.

CHAPTER I - **GENERAL**

1 Scope

1.1 This Recommendation contains the principal physical characteristics and metrological requirements for weights which are used:

- for the verification of weighing instruments;
- for the verification of weights of a lower class of accuracy;
- with weighing instruments.

The nominal values of mass of the weights covered by this Recommendation range from 1 milligram (mg) to 50 kilograms (kg).

1.2 This Recommendation applies to weights in classes of accuracy as follows: E_1, E_2, F_1, F_2, M_1, M_2 and M_3.

1.2.1 Weights used for the verification of weighing instruments

The classes of accuracy of the weights used for the verification of weighing instruments shall be specified in the appropriate International Recommendations relating to these instruments.

1.2.2 Weights used for the verification of weights of a lower class of accuracy

E_1 - Weights intended to ensure traceability (see OIML R 33, paragraph A.3) between national mass standards (with values derived from the International Prototype of the kilogram) and weights of class E_2 and lower.
Class E_1 weights or sets of weights shall always be accompanied by a calibration certificate (see 12.2).

E_2 - Weights intended to be used for the initial verification of weights of class F_1.
Class E_2 weights or sets of weights shall always be accompanied by a calibration certificate; they may be used as class E_1 weights if they comply with the requirements for surface roughness and magnetic susceptibility of class E_1 weights and if their calibration certificate gives the appropriate data (specified in 12.2).

F_1 - Weights intended to be used for the initial verification of weights of class F_2.

F_2 - Weights intended to be used for the initial verification of weights of class M_1 and possibly M_2.

M_1 - Weights intended to be used for the initial verification of weights of class M_2.

M_2 - Weights intended to be used for the initial verification of weights of class M_3.

1.2.3 Minimum accuracy class of weights used with weighing instruments

The accuracy classes of weights used with weighing instruments shall be chosen in accordance with the requirements of OIML R 76 "Nonautomatic weighing instruments".

F_1, E_2 - Weights intended to be used with weighing instruments of accuracy class I.

F_2 - Weights intended to be used for important commercial transactions (e.g. gold and precious stones) on weighing instruments of accuracy class II.

M_1 - Weights intended to be used with weighing instruments of accuracy class II.

M_2 - Weights intended to be used in normal commercial transactions and on weighing instruments of accuracy class III.

M_3 - Weights intended to be used on weighing instruments of accuracy classes III and IIII.

2 Principles of the Recommendation

2.1 The weights covered by this Recommendation shall meet the applicable requirements of OIML R 33, *Conventional value of the result of weighing in air*.(1)

2.2 The nominal values of the mass of the weights shall be equal to 1×10^n kg, or 2×10^n kg, or 5×10^n kg, where "n" represents a positive or negative integer or zero.

2.3 The sequence of a set of weights shall be composed of one of the following:
$(1;1;2;5) \times 10^n$ kg
$(1;1;1;2;5) \times 10^n$ kg
$(1;2;2;5) \times 10^n$ kg
$(1;1;2;2;5) \times 10^n$ kg, where "n" represents a positive or negative whole number or zero.

CHAPTER II - **METROLOGICAL REQUIREMENTS**

3 Maximum permissible errors on verification

3.1 The maximum errors permissible on initial and subsequent verification for each individual weight are given in Table 1. These maximum permissible errors relate to the conventional mass. The maximum errors permissible in service are left to the discretion of each State.

3.2 For each weight, the expanded uncertainty U for $k = 2$ (see Annex B) of the conventional mass shall be less than or equal to one-third of the maximum permissible error given in Table 1, except for class E_1 weights (no specific requirement relating to U for class E_1 weights; however, U shall be significantly less than the maximum permissible error).

(1) NOTE: The reference conditions applicable to the adjustment of standard weights are as follows:
- standard reference density: 8 000 $kg \cdot m^{-3}$
- ambient air density: 1.2 $kg \cdot m^{-3}$
- equilibrium in air at 20 °C, without correction for air buoyancy.

3.3 For each weight, the conventional mass, m_c (determined with an expanded uncertainty according to 3.2) shall not differ by more than the difference: maximum permissible error δm minus expanded uncertainty, from the nominal value of the weight, m_o:

$$m_o - (\delta m - U) \leq m_c \leq m_o + (\delta m - U)$$

For class E_1 and E_2 weights, which are always accompanied by certificates giving the appropriate data (specified in 12.2), the deviation from the nominal value, $|m_c - m_o|$, shall be taken into account by the user.

Table 1
Maximum permissible errors

Nominal value	± δm in mg						
	Class E_1	Class E_2	Class F_1	Class F_2	Class M_1	Class M_2	Class M_3
50 kg	25	75	250	750	2 500	7 500	25 000
20 kg	10	30	100	300	1 000	3 000	10 000
10 kg	5	15	50	150	500	1 500	5 000
5 kg	2.5	7.5	25	75	250	750	2 500
2 kg	1.0	3.0	10	30	100	300	1 000
1 kg	0.5	1.5	5	15	50	150	500
500 g	0.25	0.75	2.5	7.5	25	75	250
200 g	0.1	0.30	1.0	3.0	10	30	100
100 g	0.05	0.15	0.5	1.5	5	15	50
50 g	0.030	0.10	0.30	1.0	3.0	10	30
20 g	0.025	0.080	0.25	0.8	2.5	8	25
10 g	0.020	0.060	0.20	0.6	2	6	20
5 g	0.015	0.050	0.15	0.5	1.5	5	15
2 g	0.012	0.040	0.12	0.4	1.2	4	12
1 g	0.01	0.030	0.10	0.3	1.0	3	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	0.015	0.05	0.15	0.5	1.5	
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	0.002	0.008	0.025	0.08	0.25		
5 mg	0.002	0.006	0.020	0.06	0.20		
2 mg	0.002	0.006	0.020	0.06	0.20		
1 mg	0.002	0.006	0.020	0.06	0.2		

4 Shape

4.1 General

4.1.1 Weights shall have a simple geometrical shape to facilitate their manufacture; they shall have no sharp edges so as to prevent their deterioration; and, there shall be no pronounced hollows so as to avoid deposits (i.e. dust) on their surface.

4.1.2 Weights of a given set shall have the same shape, except for weights of one gram or less.

4.2 Weights less than or equal to one gram

4.2.1 Weights less than one gram shall be flat polygonal sheets or wires, with appropriate shapes which permit easy handling. The shapes shall be indicative of the nominal value of the weights.

Weights of one gram may be flat polygonal sheets or wires.

4.2.2 The shape of weights not marked with their nominal value shall conform with the following table:

Table 2
Shape of weights of 1 g or less

Nominal values (mg)	Polygonal sheets	Wires		
5 - 50 - 500	pentagon	pentagon	} or {	5 segments
2 - 20 - 200	square	square		2 segments
1 - 10 - 100 - 1 000	triangle	triangle		1 segment

4.2.3 A set of weights may be comprised of more than one sequence of shapes, differing from one sequence to the other. In a series of sequences, however, a sequence of weights of a different shape shall not be inserted between two sequences of weights that have the same shape.

4.3 Weights of one gram and larger

4.3.1 A one-gram weight may have either the shape of multiples of one-gram weights or the shape of sub-multiples of one-gram weights.

4.3.2 The weights of nominal values from 1 g to 50 kg may have the external dimensions shown in Annex A.

Those weights may also have a cylindrical or slightly tapered conical body. The height of the body shall be approximately equal to the mean diameter; the height shall be between 3/4 and 5/4 of that diameter.

Those weights may also be provided with a lifting knob which has a height between the mean diameter and half-diameter of the body.

4.3.3 In addition to the above shapes (4.3.2), weights of 5 kg to 50 kg may have a different shape suitable for their method of handling, instead of a lifting knob. They may have rigid handling devices embodied with the weights, such as axles, handles, or the like.

4.3.4 Class M_1, M_2, and M_3 weights with nominal values from 5 kg to 50 kg may also have the shape of rectangular parallelepipeds with rounded edges and a rigid handle, as shown in Annex A.

4.3.5 The typical examples of dimensions and dimensional tolerances for weights of classes M_1, M_2, and M_3 are shown in Annex A.

5 CONSTRUCTION

5.1 Class E_1 and E_2 weights

Class E_1 and E_2 weights shall be solid and shall have no cavity open to the atmosphere. They shall have an integral construction i.e. consist of a single piece of material.

5.2 Class F_1 and F_2 weights

Class F_1 and F_2 weights from 1 g to 50 kg may be one or more pieces from the same material. Class F_1 and F_2 weights may contain an adjusting cavity; however, the volume of this cavity shall not exceed one-fifth of the total volume of the weight, and the cavity shall be closed either by means of the lifting knob or by any other suitable device.

5.3 Class M_1 weights

5.3.1 Class M_1 weights from 100 g to 50 kg shall have an adjusting cavity. For class M_1 weights from 1 g to 50 g, the adjusting cavity is optional but it is recommended that weights from 1g to 10 g be manufactured without an adjusting cavity.

5.3.2 Class M_1 weights from 5 kg to 50 kg with a rectangular parallelepiped shape may have an adjusting cavity constructed as described in point 5.4.2, or by similar means.

The adjusting cavity shall be sealed by either a threaded plug (with a screwdriver slot) or a disc (with a central handling hole) made of brass or of another appropriate metal; its volume shall not be greater than one-fifth of the total volume of the weight.

After initial adjustment, approximately two-thirds of the total volume of the adjusting cavity of new weights shall be empty.

The plug or disc shall be sealed by a lead plug (or similar material) driven into an internal circular groove or into the threads of the tube.

5.3.3 Class M_1 weights of 100 g to 10 kg of the cylindrical type shall have adjusting cavities constructed as described in point 5.4.3, or by similar means.

The volume of the adjusting cavity shall not be greater than one-fifth of the total volume of the weight. The adjusting cavity shall be sealed by a lead plug driven into an internal circular groove provided in the widened portion of the diameter.

After initial adjustment, approximately two-thirds of the total volume of the adjusting cavity of new weights shall be empty.

The plug or disc shall be sealed by a lead plug (or similar material) driven into an internal circular groove.

5.4 Class M_2 and M_3 weights

5.4.1 Class M_2 and M_3 weights from 100 g to 50 kg shall have an adjusting cavity.

For class M_2 weights of 20 g and 50 g, the adjusting cavity is optional.

Class M_2 weights of 10 g and less shall be solid without any adjusting cavity.

5.4.2 Class M_2 and M_3 weights from 5 kg to 50 kg with a rectangular parallelepiped shape shall have an adjusting cavity either formed by the inside of the tubular handle, or, if the handle is solid, it shall have an adjusting cavity which is cast within one of the uprights of the weight, that opens on the side or the top face of the upright.

After initial adjustment, approximately two-thirds of the total volume of the adjusting cavity of new weights shall be empty.

5.4.2.1 If the adjusting cavity is in the pipe handle, the cavity shall be closed by either a threaded plug (with a screwdriver slot) or a disc (with a central handling hole); the plug or disc shall be made of brass or of another appropriate metallic material and shall be sealed by a lead plug (or similar material) driven into an internal circular groove or into the threads of the tube.

5.4.2.2 If the adjusting cavity is cast within the upright, the cavity shall be closed by a platelet made of soft steel or of another appropriate material, sealed by a lead plug (or similar material) driven into a housing having a conical section.

5.4.3 Class M_2 and M_3 cylindrical weights from 100 g to 10 kg shall have an adjusting cavity drilled into the axis of the weight, opening on the upper face of the knob and including a widening of the diameter at the entrance.

After initial adjustment, approximately two-thirds of the total volume of the adjusting cavity of new weights shall be empty.

The cavity shall be closed by either a threaded plug (with a screwdriver slot) or a disc (with a central handling hole), made of brass or of another appropriate metal.

The cap or disc shall be sealed by a lead plug driven into an internal circular groove provided in the widened portion of the diameter.

6 Material

6.1 General

The weights shall be corrosion resistant. The quality of the material shall be such that the change in the mass of the weights shall be negligible in relation to the maximum errors permitted in their accuracy class under normal conditions of use and the purpose for which they are being used.

6.2 Class E_1 and E_2 weights

The metal or alloy used for weights of classes E_1 and E_2 shall be practically non-magnetic (magnetic susceptibility not to exceed $\kappa = 0.01$ for class E_1 and $\kappa = 0.03$ for class E_2 weights).

The hardness of this material and its resistance to wear shall be similar to or better than that of austenitic stainless steel.

6.3 Class F_1 and F_2 weights

The hardness and brittleness of the materials used for weights of classes F_1 and F_2 shall be at least equal to that of drawn brass.

The metal or alloy used for weights of class F_1 and F_2 shall be practically non-magnetic (magnetic susceptibility not to exceed $\kappa = 0.05$).

6.4 Class M_1 weights

6.4.1 The material used for rectangular weights of class M_1 from 5 kg to 50 kg shall have a resistance to corrosion that is at least equal to that of gray cast iron; its brittleness shall not exceed that of gray cast iron.

6.4.2 Class M_1 cylindrical weights of 10 kg and below shall be made of brass or of another material whose quality is similar or better than that of brass.

6.4.3 Class M_1 weights of 1 g and less shall be made of material that is sufficiently resistant to corrosion and oxidization. The surface shall not be coated, except for weights of 1 g with a cylindrical shape in which case a surface treatment is allowed.

6.5 Class M_2 and M_3 weights

6.5.1 The body of class M_2 and M_3 rectangular weights from 5 kg to 50 kg shall be made of gray cast iron or another material whose quality is similar or better than gray cast iron.

6.5.2 Class M_2 and M_3 cylindrical weights of 10 kg and below shall be made of a material which has a hardness and corrosion resistance at least equal to that of cast brass and a brittleness not exceeding that of gray cast iron. However, gray cast iron shall not be used for weights with a nominal value less than 100 g.

6.6 Class M_1, M_2, and M_3 weights

Class M_1, M_2, and M_3 weights shall practically not be magnetic.

The handles of class M_1, M_2, and M_3 rectangular weights shall be made of seamless steel tube or shall be cast iron, integral with the body of the weight.

7 Density

7.1 General

The density of the material used for weights shall be such that a deviation of 10 % from the specified air density (1.2 $kg \cdot m^{-3}$) does not produce an error exceeding one quarter of the maximum permissible error. These limits are given in the following table.

Table 3
Minimum and maximum limits for density (ρ_{min}, ρ_{max})

Nominal value	ρ_{min}...ρ_{max} (10^3 kg·m^{-3})					
	Class E_1	Class E_2	Class F_1	Class F_2	Class M_1	Class M_2
≥100 g	7.934 .... 8.067	7.81....8.21	7.39 .... 8.73	6.4 .... 10.7	≥4.4	≥2.3
50 g	7.92 .... 8.08	7.74 .... 8.28	7.27 .... 8.89	6.0 .... 12.0	≥4.0	
20 g	7.84 .... 8.17	7.50 .... 8.57	6.6 .... 10.1	4.8 .... 24.0	≥2.6	
10 g	7.74 .... 8.28	7.27 .... 8.89	6.0 .... 12.0	≥4.0	≥2.0	
5 g	7.62 .... 8.42	6.9 ..... 9.6	5.3 .... 16.0	≥3.0		
2 g	7.27 .... 8.89	6.0 .... 12.0	≥4.0	≥2.0		
1 g	6.9 ..... 9.6	5.3 .... 16.0	≥3.0			
500 mg	6.3 .... 10.9	≥4.4	≥2.2			
200 mg	5.3 .... 16.0	≥3.0				
100 mg	≥4.4	≥2.3				
50 mg	≥3.4					
20 mg	≥2.3					

8 Surface conditions

8.1 Under normal conditions of use, the surface qualities shall be such that any alteration of the mass of the weights is negligible with respect to the maximum permissible error.

8.2.1 The surface of the weights (including the base and corners) shall be smooth and the edges shall be rounded. The surface of class E_1, E_2, F_1, and F_2 weights shall not appear to be porous and shall present a glossy appearance when visually examined.

8.2.2 The surface of class M_1, M_2, and M_3 cylindrical weights from 1 g to 10 kg shall be smooth, and shall not appear to be porous when visually examined. The finish of class M_1, M_2, and M_3 rectangular weights of 5 kg, 10 kg, 20 kg, 50 kg shall be similar to that of gray cast iron carefully cast in a fine sand mould. This may be obtained by appropriate painting.

8.2.3 In case of doubt about the surface quality of a weight, the following maximum values of surface roughness, average peak to valley height R_z (ISO), shall be observed to determine the surface quality of that weight:

Table 4
Maximum values of surface roughness

Class:	E_1	E_2	F_1	F_2
R_z (µm):	0,5	1	2	5

9 Adjustment

9.1 Class E_1 and E_2 weights

Weights shall be adjusted by abrasion, grinding or any appropriate method. The surface requirements shall be met at the end of the process.

9.2 Class F_1 and F_2 weights

Solid weights shall be adjusted by abrasion, grinding or any appropriate method that does not alter the surface. Weights with adjusting cavities shall be adjusted with the same material from which they are made or with tin, molybdenum or tungsten.

9.3 Class M_1, M_2 and M_3 weights

9.3.1 Weights from 100 g to 50 kg shall be adjusted using dense, metallic materials such as lead shot.

9.3.2 Cylindrical weights from 1 g to 50 g without cavities shall be adjusted by removing the material or grinding. If these weights have adjusting cavities, they shall be adjusted using dense, metallic materials such as lead shot.

9.3.3 Thin sheet and wire weights from 1 mg to 1 g shall be adjusted by cutting, abrasion or grinding.

9.3.4 The material used for adjusting shall be any solid material that maintains its mass and constitution; it shall not change (chemically or electrolytically) the mass and constitution of the weight into which it is included.

10 Marking

10.1 General

Except weights of classes E_1 and E_2, weights of one gram and multiples of one gram shall be marked to clearly indicate their nominal value.

The numerals indicating the nominal values of the mass of the weights shall represent:

kilograms - for masses 1 kg and above,
grams - for masses from 1 g to 500 g.

Duplicate or triplicate weights in a set shall be clearly distinguished by one or two asterisks or points on the center of the surface, except for wire weights which shall be distinguished by one or two hooks.

Thin sheet or wire weights from 1 mg to 1 g shall not bear any indication of nominal value or class reference.

10.2 Class E_1 and E_2 weights

Class E_1 and E_2 weights shall not bear any indication of nominal value or class reference; the class shall be indicated on the cover of the case (see 11.1) of the weights. The class shall be indicated as E_1, E_2.

Class E_2 weights may bear an off-center point on the top surface to distinguish them from class E_1 weights.

10.3 Class F_1 and F_2 weights

Weights from 1 kg to 50 kg shall bear, by burnishing or engraving, the indication of their nominal value expressed in accordance with point 10.1 (not followed by the name or symbol of the unit).

10.3.1 Weights of class F_1 shall not bear any class reference.

10.3.2 Weights of class F_2 from 1 g to 50 kg shall bear their reference class under the form "F" together with the indication of their nominal value.

10.4 Class M_1, M_2, and M_3 weights

10.4.1 Rectangular weights from 5 kg to 50 kg shall indicate the nominal value of the weight, followed by the symbol "kg", in hollow or relief, on the upper surface of the body of the weight.

10.4.2 Cylindrical weights from 1 g to 10 kg shall indicate the nominal value of the weight, followed by the symbol "g" or "kg", in hollow or relief, on the upper surface of the knob.
On cylindrical weights from 500 g to 10 kg, the indication may be reproduced on the cylindrical surface of the body of the weight.

10.4.3 Class M_1 weights shall bear the sign M_1 or M, in hollow or relief, together with the indication of the nominal value.

10.4.4 Class M_2 weights shall bear, together with the indication of the nominal value, the sign M_2, in hollow or relief, or no indication of the class.

10.4.5 Class M_3 weights shall bear the sign M_3 or X, in hollow or relief, together with the indication of the nominal value.

10.4.6 Class M_2 and M_3 weights (except the wire weights) may bear the manufacturer's mark; in such case, it shall appear in hollow or in relief on the upper surface of the center portion of the rectangular weights, on the upper face of the knob of cylindrical weights and on the upper face of the cylinder for class M_3 cylindrical weights which are fitted with a handle.

11 Presentation

11.1 General

Except for weights of classes M_2 and M_3, weights shall be presented in accordance with the following requirements.

The lid of the cases which contain the weights shall be marked to indicate their class in the form E_1, E_2, F_1, F_2, M_1.

Weights belonging to the same set shall be of the same accuracy class.

11.2 Class E_1, E_2, F_1, and F_2 weights

Individual weights and sets of weights shall be protected against deterioration or damage due to shock or vibration. They shall be contained in cases made of wood, plastic or any suitable material which has individual cavities.

11.3 Class M_1 weights

11.3.1 Cylindrical weights of class M_1, up to and including 500 g, (individual or in sets) shall be contained in a case with individual cavities.

11.3.2 Thin sheet and wire weights shall be contained in cases which have individual cavities; the class reference shall be inscribed on the cover of the case (M_1).

CHAPTER IV - **METROLOGICAL CONTROLS**

12 Submission to metrological controls

In a country where weights are subject to metrological controls of the State, these controls may, depending on the national legislation of the country, comprise one or more of the following:

12.1 Pattern approval

12.1.1 Each manufacturer or authorized representative may submit a model of the weights intended for manufacture to the Legal Metrology Service in order for the Service to ascertain that it conforms with the statutory requirements.

12.1.2 An approved model shall not be modified without special authorization.

12.2 Calibration or initial verification

Certain categories of new weights may either be calibrated individually or be subjected to initial verification, depending on their intended use and the national legislation of the countries.

Calibrated weights shall be accompanied by a certificate which gives at least the conventional mass of each weight, its expanded uncertainty and the value of the coverage factor *k*.

Class E_1 and class E_2 weights shall always be accompanied by certificates.

The certificate for class E_1 weights shall mention at least the values of conventional mass, the expanded uncertainty and the coverage factor *k* (see 3.2 and Annex B) and the density or volume for each weight.

The certificate for class E_2 weights shall mention at least:
- the values of conventional mass of each weight and the expanded uncertainty and the coverage factor *k*, or
- the information required for class E_1 weights certificates (under the conditions of 1.2.2, E_2, 2nd paragraph).

12.3 Recalibration or periodic verification

The categories of weights which are subject to calibration or initial verification should also be subject to either recalibration or periodic verification, making it possible to verify that they maintain their metrological properties. Any weights found defective at the time of the periodic verification shall be discarded or readjusted.

13 Control marking

13.1 General

Control marks are not required on weights when a calibration certificate is issued.

13.2 Class E_1 and E_2 weights

Control marks may be affixed on the case.
Concerning E_1 and E_2 weights, a certificate shall be given by the metrological authorities (e.g. accredited calibration services or laboratories) for each weight or set of weights.

13.3 Class F_1 weights

If the weights are subject to metrological controls, the marks of these controls shall be affixed on the case containing the weights.

13.4 Class F_2, M_1, M_2, and M_3 weights

13.4.1 If rectangular M_1 and cylindrical M_1 or F_2 weights are subject to metrological controls, the appropriate control marks shall be affixed to the seal of the adjusting cavity; for weights without an adjusting cavity, the control marks shall be affixed to their base.

If thin plate and wire class M_1 weights are subject to metrological controls, the legal control marks shall be affixed to the case.

13.4.2 The legal control marks for class M_2 and M_3 weights shall be affixed to the lead plug sealing the adjusting cavity; for class M_2 and M_3 weights without an adjusting cavity, the control marks shall be affixed to their base.

ANNEX A

SHAPES AND DIMENSIONS

A.1 TABLE OF DIMENSIONS (in millimetres)

WEIGHTS

Nominal value	Φ	Φ'	Φ"	H	E	R	r	o
1 g	6	5.5	3	DEPENDING ON MATERIAL	1	0.9	0.5	1
2 g	6	5.5	3		1	0.9	0.5	1
5 g	8	7	4.5		1.4	1.25	0.5	1
10 g	10	9	6		1.6	1.5	0.5	1
20 g	13	11.5	7.5		2	1.8	0.5	1.5
50 g	18	16	10		3	2.5	1	2
20 g	13	11.5	7.5		2	1.8	0.5	1.5
50 g	18	16	10		3	2.5	1	2
100 g	22	20	13		4	3.5	1	2
200 g	28	25	16		4.5	4	1.5	3.2
500 g	38	34	22		6	5.5	1.5	3.2
1 kg	48	43	27		8	7	2	5
2 kg	60	54	36		10	9	2	5
5 kg	80	72	46		13	12	2	10
10 kg	100	90	58		17	15	3	10

without adjusting cavity

ADJUSTING CAVITIES

Variant 1

	a	b	c	d	e	f	g	h	t	l	m	n	δ	ϵ
		18	5.5	2.5	6.5	1.5	1	9	M4×0.5	5	1	5	5	1
according to the standard		25	7.5	3.5	9	2	1	10	M6×0.5	5	1.5	7	7	1.5
		30	7.5	3.5	9	2	1	10	M6×0.5	5	1.5	7	7	1.5
		40	10.5	4.5	12	2.5	1.5	15	M8×1	8	2	10	10	2
		50	10.5	4.5	12	2.5	1.5	15	M8×1	8	2	10	10	2
		65	18.5	7	20	4	2.5	20	M14×1.5	13	3	18	18	3
		80	18.5	7	20	4	2.5	20	M14×1.5	13	3	18	18	3
		120	24.5	8	26.5	4	2.5	35	M20×1.5	18	4	24	24	3
		160	24.5	8	26.5	4	2.5	35	M20×1.5	18	4	24	24	3

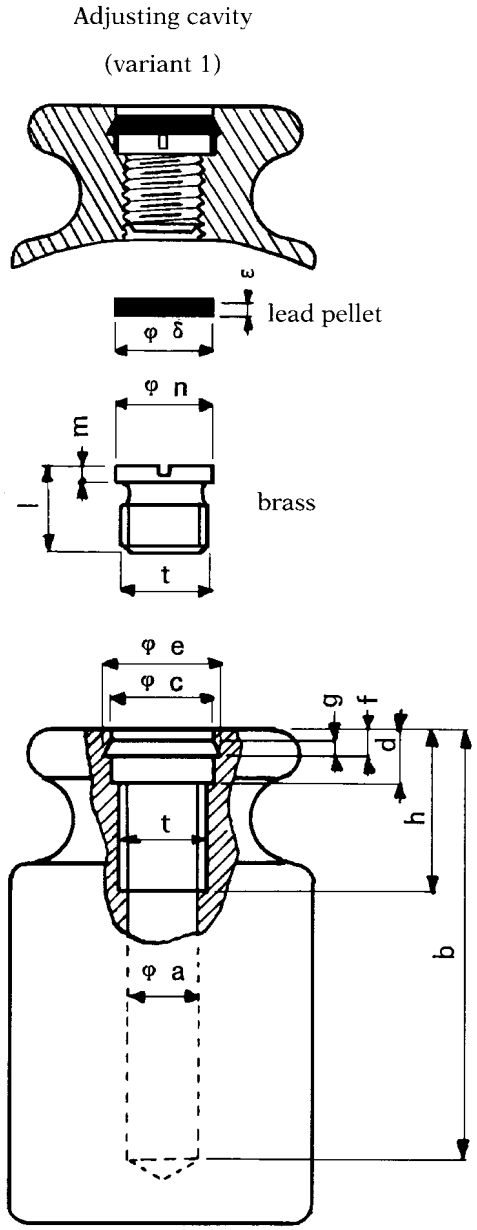
Variant 2

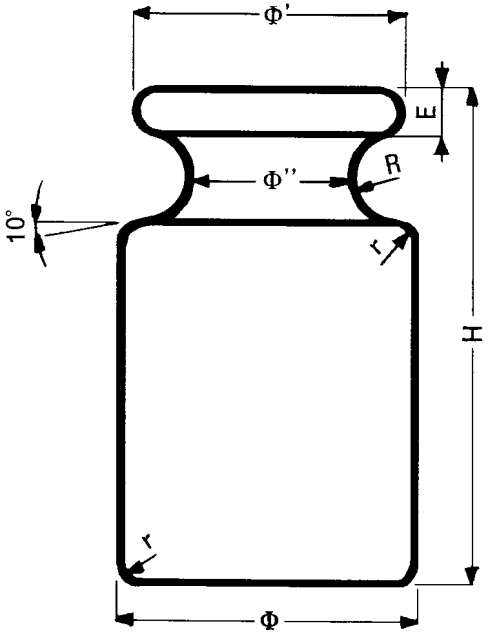
a	b	c	d	e	f	g	m	n
3	18	5.5	2.5	6.5	1.5	1	1	5
4.5	25	7.5	3.5	9	2	1	1.5	7
4.5	30	7.5	3.5	9	2	1	1.5	7
7	40	10.5	4.5	12	2.5	1.5	2	10
7	50	10.5	4.5	12	2.5	1.5	2	10
12	65	18.5	7	20	4	2.5	3	18
12	80	18.5	7	20	4	2.5	3	18
18	120	24.5	8	26.5	4	2.5	4	24
18	160	24.5	8	26.5	4	2.5	4	24

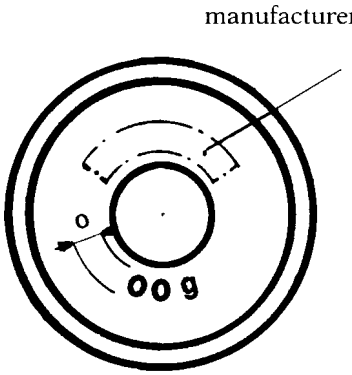
(threads according to ISO/R 261)

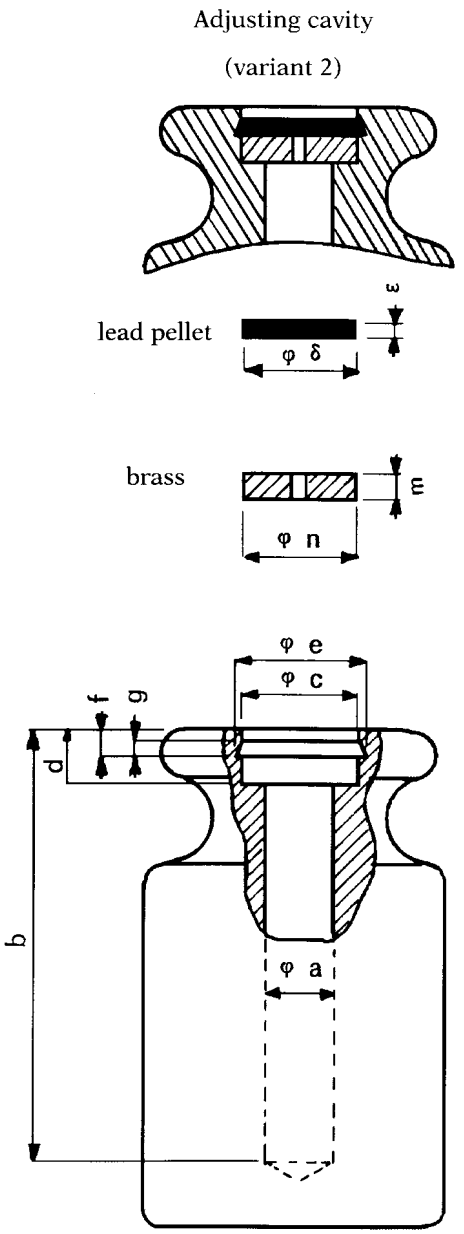
The depth b of the adjusting cavities is given only as an indication.

A.2 CYLINDRICAL WEIGHTS









A.3 RECTANGULAR BAR WEIGHTS (TYPE 1)

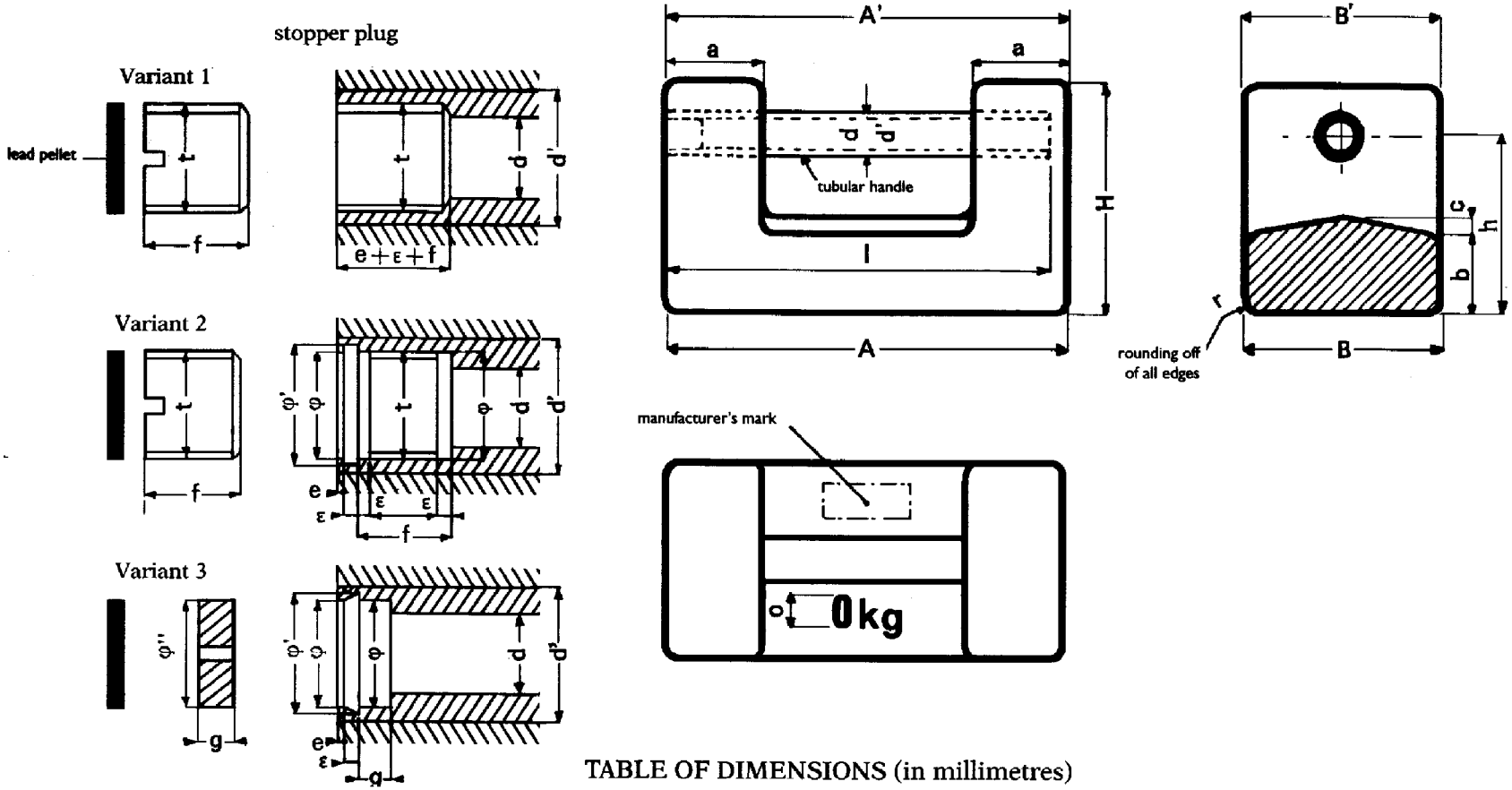


TABLE OF DIMENSIONS (in millimetres)

Nominal value	A	A'	B	B'	H	a	b	c	h	d / d'	l	r	o	t	f	e	ε	φ	φ'	φ''	g
5 kg	150	152	75	77	84	36	30	6	66	12/20	145	5	12	M16×1.5	14	1	2	16.5	18	16	5
10 kg	190	193	95	97	109	46	38	8	84	12/20	185	6	16	M16×1.5	14	1	2	16.5	18	16	5
20 kg	230	234	115	117	139	61	52	12	109	24/32	220	8	20	M27×1.5	21	2	3	27.5	30	27	8
50 kg	310	314	155	157	192	83	74	16	152	24/32	300	10	25	M27×1.5	21	2	3	27.5	30	27	8

Dimensions A and A' as well as B and B' can be reversed.

(threads according to ISO/R 261)

A.4 RECTANGULAR BAR WEIGHTS (TYPE 2)

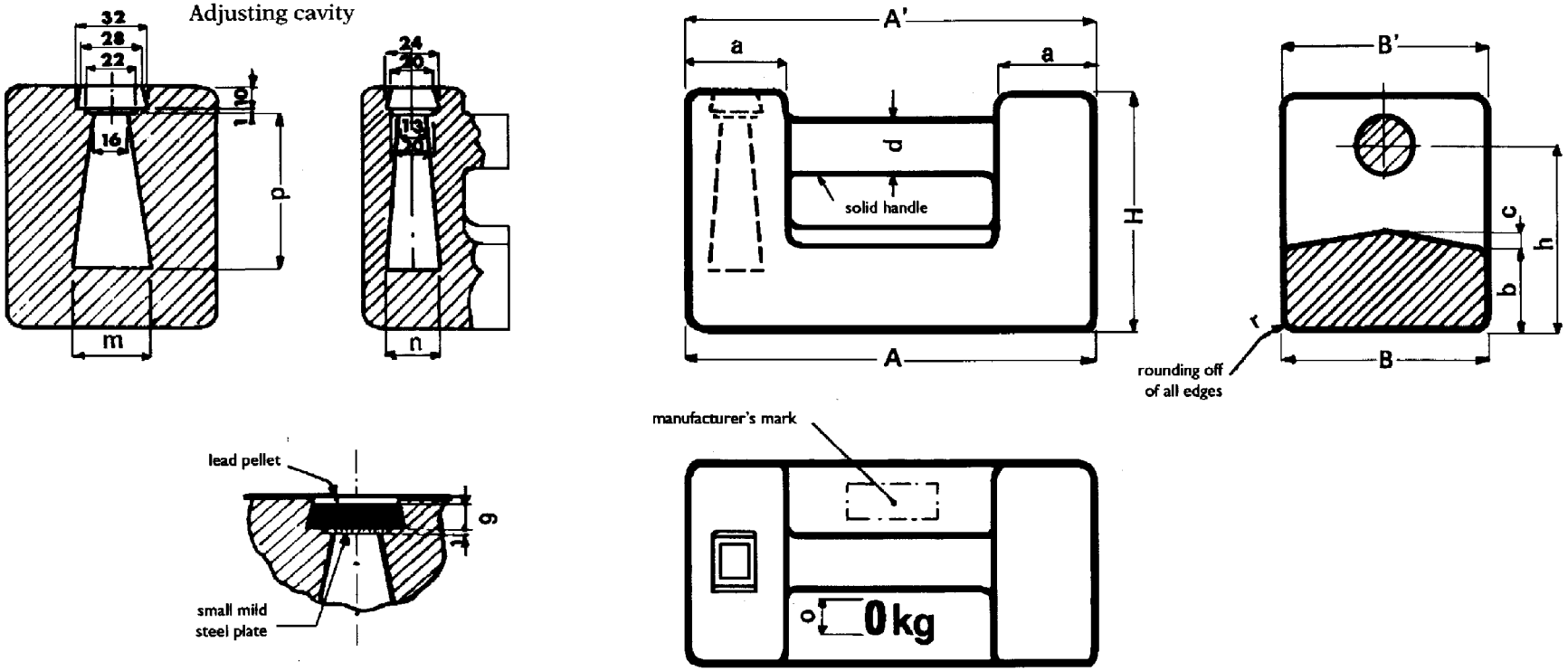


TABLE OF DIMENSIONS (in millimetres)

Nominal value	A	A'	B	B'	H	a	b	c	h	d	r	o	m	n	p
5 kg	150	152	75	77	84	36	30	6	66	19	5	12	16	13	55
10 kg	190	193	95	97	109	46	38	8	84	25	6	16	35	25	70
20 kg	230	234	115	117	139	61	52	12	109	29	8	20	50	30	95
50 kg	310	314	155	157	192	83	74	16	152	40	10	25	70	40	148

Dimensions A and A' as well as B and B' can be reversed.

The internal dimensions m, n, p of the adjusting cavities are given only as an indication.

ANNEX B
UNCERTAINTIES FOR WEIGHTS

Preliminary note

The provisions and calculations of this Annex B are not mandatory, and shall be considered as a guide. Only the four general statements hereafter are mandatory:

1 The value of the expanded uncertainty *U* shall include all uncertainty components arising from standards used, from weighing processes, and from air buoyancy.

2 A statement of the uncertainty shall be supported in the records by a complete list of the components considered, specifying for each component the method used to obtain its numerical value.

3 For uncertainty components which are evaluated by statistical methods, the relation between the quoted uncertainty and the standard deviation (σ value of the mean) shall be stated (the Student factor t may be used).

4 The method of combining the various uncertainty components mentioned in point 1 shall be specified and shall be based on an appropriate International Recommendation or recognized International Standard.

B.1 Terminology

Note: The terminology used in this Recommendation conforms to the *Guide to the expression of uncertainty in measurement* published by ISO on behalf of BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML (First edition 1993).

B.1.1 Uncertainty of measurement

Parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note: The uncertainty of measurement comprises, in general, several components which may be grouped into two categories according to the method used to estimate their numerical value:

A - components evaluated by statistical methods to a series of repeated determinations;

B - components evaluated by other means.

B.1.2 Standard uncertainty

Uncertainty of the result of a measurement expressed as an estimated standard deviation.

B.1.3 Combined standard uncertainty (u_c)

Standard uncertainty of a measurement result when that result is obtained from the values of a number of quantities; it is equal to the positive square root of the appropriate sum of the variances and covariances of these quantities. The variance of a quantity is the square of its standard deviation.

B.1.4 Expanded uncertainty

The expanded uncertainty U is obtained by multiplying the combined standard uncertainty by the coverage factor k.

$$U = k \cdot u_c$$

B.1.5 Coverage factor k - Level of confidence

In most cases, it is appropriate to use the factor $k = 2$.

For the Normal distribution, the factor $k = 2$ signifies that the limits of the expanded uncertainty apply when the confidence level is approximately 95 %.

B.2 Uncertainties for weights

$$u_c^2 = u_A^2 + u_B^2$$

with u_A, u_B: standard uncertainties of category A and B, respectively.

B.2.1 Uncertainties in the weighing process (category A)

B.2.1.1 F_2 and lower classes of weights

The standard uncertainty, u_w, which is based on the assumption of a rectangular statistical distribution of measurement values, is given by:

$$u_w = \frac{a_w}{\sqrt{3}}$$

where a_w is an estimate of a maximum variation, equal to either:
- half the observed variation width, or
- the scale interval d of the balance used, whichever is greater.

B.2.1.2 Class E_1, E_2 and F_1 weights

$$\bar{x} = \frac{1}{n} \sum_{k=1}^{n} x_k \qquad (1)$$

with $\bar{x}$: average of the results of n mass determinations x_k

$$s^2 = \frac{1}{n-1} \sum_{k=1}^{n} (x_k - \bar{x})^2 \qquad (2)$$

with s: standard deviation of $\bar{x}$

$$u_A = \left| \frac{s}{\sqrt{n}} \right| \qquad (3)$$

If the number n of data is smaller than 10, u_A shall be multiplied by the factor t_r, given in the table below:

n	t_r
2	7.0
3	2.3
4	1.7
5	1.4
6	1.3
7	1.3
8	1.2
9	1.2

The factors t_r apply for $k = 2$ and are derived from Student and Normal distributions (WECC Document 19 - 1990, Annex B, Table 1).

If identical series of measurements are taken at different days or under different circumstances, and if these series differ by significantly more than the uncertainties of single series, a standard uncertainty u'_A should be calculated by replacing in equation (1) and (2) x_k by the means of the series and n by the number of series. If u''_A is the standard uncertainty of a single series, u_A is obtained by:

$$u_A^2 = u'^2_A + u''^2_A \qquad (4)$$

B.2.2 Other uncertainties (category B)

The category B uncertainty u_B, usually is composed of the uncertainties u_N (reference weight), u_b (air buoyancy), and u_s (sensitivity of the balance):

$$u_B^2 = u_N^2 + u_b^2 + u_s^2 \qquad (5)$$

B.2.2.1 Uncertainty in the standard (category B)

The standard uncertainty u_N associated with the mass of the reference weight should be calculated from its calibration certificate by dividing the quoted expanded uncertainty, U, by the quoted coverage factor k:

$$u_N = \frac{U}{k}$$

In cases where the quoted expanded uncertainty associated with the reference weight is lacking, an uncertainty should be assumed according to the accuracy class of the reference weight, as specified in 3.2.

B.2.2.2 Combinations of reference weights

If combinations of reference weights are used, covariances have to be taken into account. However, in most cases, the covariances are unknown, because, usually, they are not given in certificates. In this case, because weights of the same set usually have large covariances, the combined standard uncertainty u_N should be calculated as the sum:

$$u_N = \sum u_{Ni}$$

of the standard uncertainties u_{Ni} of the individual reference weights. Then, u_N is an upper estimate for the combined standard uncertainty (assumed correlation coefficient: 1).

B.2.2.3 Air buoyancy

A buoyancy correction is not necessary and u_b can be considered as negligibly small under the following condition:

$$| C | \leq \frac{1}{3} \frac{U}{m_o} \tag{6}$$

with:

$$C = \frac{(\rho_r - \rho_t)(\rho_a - \rho_o)}{\rho_r \rho_t} \tag{7}$$

ρ_a: air density
ρ_o: 1.2 kg·m^{-3}
ρ_r: density of the reference weight
ρ_t: density of test weight
m_o: nominal value of the weight

In all other cases, a buoyancy correction shall be applied by multiplying m_c (reference weight) with the factor (1+C). When the air density ρ_a during the weighing of the test weight is equal to the air density during the weighing of the reference weight (m_r), u_b is then calculated from standard uncertainties (taking account of the coverage factor k (B.1.4, B.1.5) of air density $u_{\rho a}$, material density of the reference weight $u_{\rho r}$, and of the test weight $u_{\rho t}$ as follows:

$$u_b^2 = \left[m_r \frac{\rho_r - \rho_t}{\rho_r \rho_t} u_{\rho a} \right]^2 + (m_r (\rho_a - \rho_o))^2 \left[\frac{u_{\rho r}^2}{\rho_r^4} + \frac{u_{\rho t}^2}{\rho_t^4} \right] \tag{8}$$

B.2.2.4 Sensitivity of the balance

The standard uncertainty associated with the sensitivity of the balance u_s shall be estimated from a calibration procedure taking into account the indication difference or deflection difference observed between the reference weight and the test weight.