INTERNATIONAL RECOMMENDATION

OIML R 111-2

Edition 2004 (E)

Weights of classes E_1, E_2, F_1, F_2, M_1, $M_{1–2}$, M_2, $M_{2–3}$ and M_3

Part 2: Test Report Format

Poids des classes E_1, E_2, F_1, F_2, M_1, $M_{1–2}$, M_2, $M_{2–3}$ et M_3

Partie 2: Format du rapport d'essai

OIML R 111-2 Edition 2004 (E)

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

Contents

Foreword

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States.

The two main categories of OIML publications are:

- **International Recommendations (OIML R)**, which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent;
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Cooperative agreements are established between OIML and certain institutions, such as ISO and IEC, with the objective of avoiding contradictory requirements; consequently, manufacturers and users of measuring instruments, test laboratories, etc. may apply simultaneously OIML publications and those of other institutions.

International Recommendations and International Documents are published in French (F) and English (E) and are subject to periodic revision.

This publication - OIML R 111-2, Edition 2004 (E) - was developed by TC 9/SC 3 *Weights*.

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Explanatory notes

This Annex is mandatory according to 15.1 of R 111-1.

For each test, the "SUMMARY OF TYPE EVALUATION" and the appropriate "CHECKLIST" shall be completed according to this example:

Test conducted	**Pass**	**Fail**
When the weight has passed the test:	**X**	
When the weight has failed the test:		**X**
When the test is not applicable:	/	/

The white spaces in boxes in the headings of the report should always be filled in according to the following example:

	At start	At end	
Temperature:	20.5	20.6	°C
Relative humidity:			%
Dew point:			°C
Barometric pressure:			hPa
Air density:			kg m^{-3}
Time:	11:55	12:08	hh:mm

"Date" in the test reports refers to the date on which the test was performed.

Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3

General information on the type

Application no.: ....

Type designation: ....

Accuracy class:
According to the manufacturer

E_1 ☐ E_2 ☐ F_1 ☐ F_2 ☐

M_1 ☐ M_{1-2} ☐ M_2 ☐ M_{2-3} ☐ M_3 ☐

Weight set submitted: ....

Identification no.: ....

Date of report: ....

Observer: ....

Use this space for additional remarks and information: (weight box, additional equipment)

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Summary of the classification

Application no.: ....

Type designation: ....

Weight set is classified as: ....

	Tests	Report page	Pass	Fail	Class	Remarks
	Checklist					
1	Surface conditions					
2	Magnetism					
3	Density					
4	Calibration					

Passed or failed indicates that the weight(s) or weight set passed or failed the accuracy class requested by the manufacturer.

The *[insert laboratory's name]* has determined that use of these weights or weight set at an elevation where the deviation is in excess of 10 % from normal air density, such as would be observed at elevations above *[use data from the standard here . . .]*, may affect the measurement error.

Remarks:

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CHECKLIST – General requirements for all weight classes

Application no.: ....

Type designation: ....

Weight set is classified as: ....

Use only one checklist for a set of weights. Do not use a separate checklist for each weight when classifying an entire set. It is sufficient to list the differences for individual weights in the "Remarks" column.

R 111-1 ref.	Requirement	Pass	Fail	Remarks
4	**Units and nominal values for weights**			
4.1	**Units**			
	Mass in units of milligram (mg), gram, (g) or kilogram (kg)			
	Density in units of kilogram per cubic metre ($kg\ m^{-3}$)			
4.2	**Nominal values**			
	1×10^n, 2×10^n, or 5×10^n			
4.3.1	Weight sequence is:			
	$(1;1;2;5) \times 10^n$			
	$(1;1;1;2;5) \times 10^n$			
	$(1;2;2;5) \times 10^n$ or			
	$(1;1;2;2;5) \times 10^n$			
4.3.2	Weight set consists of *n* weight pieces each having nominal value *x*			
	n = ...			
	x = ...			
5	**Maximum permissible errors on verification**			
5.1.1	Table 1 MPEs for weights			
5.2	Expanded uncertainty: $U(k = 2) \leq 1/3$ MPE in Table 1			
5.3.1	Conventional mass shall not differ from nominal value by more than mpe – expanded uncertainty			
6	**Shape**			
6.1	General			
6.1.1	Simple geometrical shape			
	No sharp edges or corners			
	No pronounced hollows			
6.1.2	Weights of a set are the same shape			
6.2	Weights ≤ 1 g			
6.2.1	Weights < 1 g:			
	Flat polygonal sheets or wires			
	Shape indicative of the nominal value			

6.2.2	1 g weights:			
	Flat polygonal sheets or wires			
	If not marked, shape indicative of the nominal value as given in Table 2			
6.2.3	A sequence of weights of a different shape shall not be inserted between two sequences of weights that have the same shape			
6.3	Weights 1 g to 50 kg:			
6.3.1	1 g weight: shape of multiples of 1 g weights or submultiples of 1 g weights			
6.3.2	Dimensions conform to Annex A			
6.3.2.1	May have cylindrical or slightly conical body, height of which is between 3/4 and 5/4 of its mean diameter			
6.3.2.2	May have lifting knob of height between 0.5 × and 1 × the mean diameter of the body			
6.3.3	Weights of 5 kg to 50 kg:			
	May have shape suitable for their method of handling			
	Instead of a lifting knob, may have a rigid handling device (e.g. axle, handle, hook or eye)			
6.4	Weights greater than or equal to 50 kg:			
6.4.1	Shape provides for safe storage and handling			
6.4.2	May have rigid handling device (e.g. axle, handle, hook, eye)			
8	**Material**			
8.1	Corrosion resistant			
	Material quality ensures change in mass of weights negligible in relation to MPE under normal use			
10	**Density**			
10.1	Density of the material such that a deviation of 10 % from the specified air density (1.2 kg m^{-3}) does not produce an error exceeding ¼ MPE, see Table 5			
11	**Surface conditions**			
11.1	Surface qualities such that any alteration of the mass of the weights is negligible with respect to the maximum permissible error			
11.1.1	Surface of the weights (including the base and corners) smooth and edges rounded			
13	**Marking**			
13.1	General			
13.1.2	Marking of duplicate or triplicate weights according to requirements			

CHECKLIST – E_1 and E_2 weights

R 111-1 ref.	Requirement	Pass	Fail	Remarks
7	**Construction**			
7.1.1	Class E_1 and E_2 weights from 1 mg to 50 kg: Solid single piece with no cavity			
7.1.2.1	Class E_2 weights greater than 50 kg: Adjusting cavity conforms to requirements			
7.1.2.2	Class E_2 weights greater than 50 kg: Empty volume conforms to requirement			
8	**Material**			
8.2.1	For weights of 1 g or more hardness shall be equal to or better than austenitic stainless steel[1]			
9	**Magnetism**			
9.1	Meets polarization requirements in Table 3			
9.2	Meets susceptibility requirements in Table 4			
10	**Density**			
10.2.2	Weights are to be used at an altitude > 330 m: Density and associated uncertainty are documented			
11	**Surface conditions**			
11.1.2	Surface not porous			
	Surface presents a glossy appearance when visually examined			
12	**Adjustment**			
12.1	Surface requirements met after adjustment process			
13	**Marking**			
13.1	Nominal value - Table 7			
13.2	E_1 and E_2 weights			
	Class indicated on cover of case as E_1 or E_2			
	Class E_2 weights may bear an off-center point on the top surface to distinguish them from class E_1 weights			
	Surface quality and stability of the weight not affected by markings or by marking process			
13.6	User markings according to Table 7			
14	**Presentation**			
14.1.1	Lid of case containing the weights is marked with class in the form E_1 or E_2			
14.1.2	Weights of the same set are of same accuracy class			
14.2.1	Protected against deterioration or damage due to shock or vibration			
	Case made of wood, plastic or any suitable material having individual cavities			
14.2.2	Means of handling such that it does not scratch or change weight surface			

[1] Based on information from the manufacturer or measured on a test specimen of the same alloy that the weights are made of. Austenitic stainless steel normally has a hardness in the range 160 – 200 HV. Reference: R.B. Ross, Metallic materials specification handbook (1972).

R 111-1 ref.	Requirement	Pass	Fail	Remarks
15	**Submission to metrological control**			
15.2.2.1	For E_1 weights, certificate states:			
	- conventional mass, m_c			
	- expanded uncertainty, U			
	- coverage factor, k			
	- density or volume			
	- a statement on whether the density has been measured or estimated			
15.2.2.2	For E_2 weights, certificate states:			
	- conventional mass, m_c			
	- expanded uncertainty, U			
	- coverage factor, k			
	or the information required for E_1 weights calibration certificates			
16	**Control marking**			
16.2.1	Control marks may be affixed to the case			
16.2.2	Certificate given by metrological authorities			

CHECKLIST – F_1 and F_2 weights

R 111 Ref.	Requirement	Pass	Fail	Remarks
7	**Construction**			
7.2	Weights of one or more pieces manufactured from the same material			
7.2.1	Class F_1 and F_2 weights from 1 g to 50 kg			
7.2.1.1	Adjusting cavity conforms to requirements			
7.2.1.2	Empty volume conforms to requirement			
7.2.2	Class F_1 and F_2 weights greater than 50 kg			
	Box sufficiently rigid and airtight			
	Mass/volume ratio meets density requirement in Table 5			
7.2.2.1	Adjusting cavity conforms to requirements			
7.2.2.2	Empty volume conforms to requirement			
8	**Material**			
8.3	Surface of weights ≥ 1 g may have metallic coating			
8.3.1	Hardness of weights ≥ 1 g at least equal to that of drawn brass[1]			
	Brittleness of weights ≥ 1 g at least equal to that of drawn brass[2]			
8.3.2	Hardness and brittleness of whole body or external surfaces of weights ≥ 50 kg at least equal to that of stainless steel			
9	**Magnetism**			
9.1	Meets polarization requirements in Table 3			
9.2	Meets susceptibility requirements in Table 4			
10	**Density**			
10.2.2	F_1 weights to be used at an altitude > 800 m: Density and associated uncertainty are documented			
11	**Surface conditions**			
11.1.2	Surface not porous			
	Surface presents a glossy appearance when visually examined			
12	**Adjustment**			
12.2	Adjusted by method which does not alter surface			
	Weight with adjusting cavities adjusted with material from which they are made or stainless steel, brass, tin, molybdenum or tungsten			
13	**Marking**			
13.3	All class F weights ≥ 1 g: Indication of nominal value by burnishing or engraving as in 13.1 (not followed by the name or symbol of the unit)			

[1] Based on information from the manufacturer or measured on a test specimen of the same alloy that the weights are made of.

[2] Normally not tested. Based on information from the manufacturer. The brittleness of brass is normally in the range 28 – 100 (Impact [J]).

R 111 Ref.	Requirement	Pass	Fail	Remarks
13.3.1	F_1 weights: not to bear any class reference			
13.3.2	F_2 weights ≥ 1 g: bear a reference to their class in the form "F" together with indication of nominal value			
13.6	User markings according to Table 7			
14	**Presentation**			
14.1.1	Lids of cases containing weights marked to indicate their class in the form "F_1" or "F_2"			
14.1.2	Weights of same set are of same accuracy class			
14.2.1	Protected against deterioration or damage due to shock or vibration			
	Cases made of wood, plastic or any suitable material that has individual cavities			
14.2.2	Means of handling such that it does not scratch or change weight surface			
16	**Control marking**			
16.3.1	Class F_1 weights: If the weights are subject to metrological controls, the marks shall be on the case			
16.3.2	Class F_2 weights: If cylindrical 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			

CHECKLIST – M_1, M_{1-2}, M_2, M_{2-3} and M_3 weights

R 111 Ref.	Requirement	Pass	Fail	Remarks
6	**Shape**			
6.3.4	Weights of 5 kg to 50 kg may be rectangular parallelepipeds with rounded edges and rigid handle, as shown in Figures A.2 and A.3			
6.4.3	Class M weights > 50 kg equipped with roller tracks or grooves of limited area if they are intended to run on a flat floor or rails			
7	**Construction**			
7.3.1	Class M_1, M_2 and M_3 weights 1 g to 50 kg			
7.3.1.1	1 g to 10 g: solid with no adjusting cavity			
	20 g to 50 g: have optional adjusting cavities			
	100 g to 50 kg: shall have adjusting cavity (except for class M_1 and M_2 20 g to 200 g weights made of stainless steel where it is optional)			
	Cavity design reduces buildup of debris			
	Cavity volume ≤ ¼ of total volume of the weight			
7.3.1.2	Approximately half total volume of adjusting cavity empty after initial adjustment			
7.3.2	Cylindrical weights from 100 g to 50 kg:			
	Have adjusting cavity meeting requirements			
	Cavity can be closed and sealed by appropriate means			
7.3.3	5 kg to 50 kg rectangular parallelepiped weights: shall have an adjusting cavity properly located			
7.3.3.1	Cavity on pipe handle weights can be closed with appropriate means			
7.3.3.2	Cavities on upright and opening to the side or top face of weight can be sealed by appropriate means			
7.3.4	Class M_1, M_2 and M_3 weights > 50 kg and all class M_{1-2} and M_{2-3} weights			
7.3.4	Shall not have surface cavities that may cause rapid accumulation of dust or debris			
7.3.4.1	Have adjusting cavity meeting requirements			
7.3.4.2	At least one third of the total volume of the adjusting cavity empty after initial adjustment			
8	**Material**			
8.4	M_1, M_2 and M_3 weights ≤ 50 kg			
	Weights ≥ 1 g may be treated with a suitable coating to improve corrosion resistance or hardness			
8.4.1	Weights < 1 g made of material sufficiently resistant to corrosion and oxidation			
8.4.2	Cylindrical class M_1 weights below 5 kg and class M_2 and M_3 weights below 100 g shall be made of brass or a material whose hardness and resistance to corrosion is similar or better than that of brass			

R 111 Ref.	Requirement	Pass	Fail	Remarks
	Other cylindrical class M_1, M_2 and M_3 weights of 50 kg or less shall be made of grey cast iron or of another material whose brittleness and resistance to corrosion is similar or better than that of grey cast iron			
8.4.3	Rectangular parallelepiped weights 5 kg to 50 kg: Made from material with corrosion resistance and brittleness equal to or better than grey cast iron.			
8.4.4	Handles of rectangular weights made of seamless steel tube or cast iron integral with the weight			
8.5	M_1, M_2 and M_3 weights > 50 kg All M_{1-2} and M_{2-3} weights			
8.5.1	Surface may have a coating to improve corrosion resistance and capable of withstanding shocks and outdoor weather conditions			
8.5.2	Material has corrosion resistance at least equal to grey cast iron			
8.5.3	Material of such hardness and strength that it withstands loads and shocks that will occur under normal conditions of use			
8.5.4	Handles of rectangular weights made of seamless steel tube or cast iron integral with the weight			
9	**Magnetism**			
9.1	Meets polarization requirements in Table 3			
11	**Surface conditions**			
11.1.3	M_1, M_2 and M_3 cylindrical weights 1 g to 50 kg: Surface smooth and not porous when visually examined			
	M_1, M_2 and M_3 cast weights 100 g to 50 kg, M_{1-2} and M_{2-3} weights > 50 kg: Surface finish similar to grey cast iron carefully cast in a sand mould			
12	**Adjustment**			
12.3.1	Thin sheet and wire weights 1 mg to 1 g: Adjusted by cutting abrasion or grinding			
12.3.2	Cylindrical weights without cavities: Adjusted by grinding			
12.3.3	Weights with adjusting cavity adjusted by adding dense metallic material. If no more material can be removed, may be adjusted by grinding			
13	**Marking**			
13.4.1	Rectangular weights 5 kg to 5 000 kg: Nominal value of weight, followed by the "kg" symbol in hollow or relief on body of weight			
13.4.2	Cylindrical weights 1 g to 5 000 kg: Nominal value of weight, followed by the "g" or "kg" symbol in hollow or relief on knob			
	Cylindrical weights 500 g to 5 000 kg: Indication may be reproduced on the cylindrical surface of the weight's body			
13.4.3	M_1 weights: "M_1" or "M" marked in hollow or relief, with the indication of the nominal value			
	Rectangular M_1 weights may bear manufacturer's mark in hollow or relief on center part of weight			

R 111 Ref.	Requirement	Pass	Fail	Remarks
13.4.4	M_2 rectangular weights: May bear "M_2" in hollow or relief, with the indication of the nominal value			
13.4.5	M_3 rectangular weights: "M_3" or "X" in hollow or relief, with the indication of the nominal value			
13.4.6	M_2 and M_3 weights (except wire weights) may bear manufacturer's mark in hollow or in relief: • On the center part of rectangular weights; • on the upper face of the knob of cylindrical weights; or • on the upper face of the cylinder for class M_3 cylindrical weights fitted with a handle			
13.4.7	Class M_3 weights ≥ 50 kg: Nominal value in numerals followed by the unit's symbol			
13.5	M_{1-2} and M_{2-3} weights: • Shall bear "M_{1-2}" or "M_{2-3}" in hollow or relief with the nominal value, followed by "kg"; • May bear manufacturer's mark in hollow or relief on upper face, of similar size to that for M_1, M_2 and M_3 weights			
13.6	User markings according to Table 7			
14	**Presentation**			
14.1.1	M_1 weights: Lid of case containing weights marked "M_1"			
14.1.2	Weights of same set shall be same accuracy class			
14.3.1	Cylindrical M_1 weights ≤ 500 g contained in case with individual cavities			
14.3.2	Thin sheet and wire M_1 weights:			
	Contained in cases which have individual cavities			
	Class reference "M_1" on the cover of the case			
16	**Control marking**			
16.4.1	Class M_1, M_2 and M_3 weights: If subject to metrological controls, appropriate control marks shall be affixed to the seal of the adjusting cavity. For weights with no adjusting cavity, the marks shall be affixed to their base			
16.4.2	Thin plate and wire class M_1 weights: If subject to metrological controls, appropriate control marks shall be affixed to the case			

SURFACE CONDITIONS
(11, B.5)

Application no.: ....

Type designation: ....

Date: ....

Refer to Table 6 in R 111-1 for maximum values of surface roughness.

Weight	**R_a µm**	**R_z µm**	**Method[1] (CS/SI)**	**Pass**	**Fail**	**Weight**	**R_a µm**	**R_z µm**	**Method[1] (CS/SI)**	**Pass**	**Fail**
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			
	≤	≤					≤	≤			

[1] Enter either "CS" for Comparison Specimen or "SI" for Stylus Instrument according to method used

Passed ☐ Failed ☐ the accuracy class that was specified by the manufacturer

Remarks:

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MAGNETIZATION
(9, B.6.1, B.6.2, B.6.4)

Application no.: ....

Type designation: ....

Date: ....

Starting time: [   ]   Ending time: [   ]

Refer to Table 3 in R 111-1 for maximum polarization, $\mu_0 M$ / μT

Weight (nominal)	**$\mu_0 M$ / μT**		**Uncertainty (k = ______)**	**Method Used[1] S/H/F**	**Pass**	**Fail**
	(Top)	**(Bottom)**				
			±			
			±			
			±			
			±			
			±			
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			±			
			±			
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			±			
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[1] Enter either "S" for Susceptometer, "H" for Hall sensor or "F" for Fluxgate probe according to method used

Passed [ ]   Failed [ ]   the accuracy class that was specified by the manufacturer

Remarks:

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SUSCEPTIBILITY
(9, B.6.1, B.6.3, B.6.4, B.6.5, B.6.6)

Application no.: ....

Type designation: ....

Date: ....

Starting time: [ ] Ending time: [ ]

Refer to Table 4 in R 111-1 for maximum susceptibility

Weight (nominal)	χ		Uncertainty (k = ______)	Method Used[1] A/S/F/Sp	Pass	Fail
	χ (Top)	χ (Bottom)				
			±			
			±			
			±			
			±			
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			±			

[1] Enter either "A" for Attracting method, "S" for Susceptometer, "F" for Fluxgate probe or "Sp" for material specification, according to method used, as shown in Table B.3(b) in R 111-1

Passed [ ] Failed [ ] the accuracy class that was specified by the manufacturer

Remarks:

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DENSITY DETERMINATION – Method A
(10, B.7.1, B.7.2, B.7.4)

Application no.:	....	Environmental conditions		
Type designation:	....	Air temperature		°C
Date:	....	Liquid temperature		°C

Starting time:		Ending time:	

Refer to Table 5 in R 111-1 for maximum and minimum limits for density

Test method A1 (two different reference weights weighed in air) (R111-1 B.7.4.2)

Calculation according to equation *(B.7.4-2)* in R 111-1.

$$\rho_t = \frac{\rho_l (C_a m_{ra} + \Delta m_{wa}) - \rho_a (C_{al} m_{rl} + \Delta m_{wl})}{C_a m_{ra} + \Delta m_{wa} - C_{al} m_{rl} - \Delta m_{wl}}$$

with: $C_a = 1 - \frac{\rho_a}{\rho_{ra}}$, $C_{al} = 1 - \frac{\rho_{al}}{\rho_{rl}}$, $\Delta m_{wa} = (I_{ta} - I_{ra}) C_s$, $\Delta m_{wl} = (I_{tl} - I_{rl}) C_s$, and $C_s = 1 - \frac{\rho_{as}}{\rho_s}$

Calculation according to equation *(B.7.4-16)* in R 111-1.

In most cases, the buoyancy correction factors C_a, C_{al} and C_s do not differ significantly from each other and may be set to unity, thereby simplifying equation *(B.7.4-2)* as follows:

$$\rho_t = \frac{\rho_l (m_{ra} + \Delta m_{wa}) - \rho_a (m_{rl} + \Delta m_{wl})}{m_{ra} + \Delta m_{wa} - m_{rl} - \Delta m_{wl}}$$

Method A2 (reference weights weighed in air and in the liquid) (R111-1 B.7.4.3)

Calculation according to equation *(B.7.4-22)* or *(B.7.4-31)* in R 111-1.

When the same reference standard is used for air and liquid measurement, $m_{ra} = m_{rl} = m_r$ and $\rho_{ra} = \rho_{rl} = \rho_r$, then use equation *(B.7.4-22)*:

$$\rho_t = \frac{\rho_l (C_a m_r + \Delta m_{wa}) - \rho_a (C_l m_r + \Delta m_{wl})}{m_r \frac{\rho_l - \rho_a}{\rho_r} + \Delta m_{wa} - \Delta m_{wl}}$$

When different reference standards are used for air and liquid measurement, $m_{ra} \neq m_{rl}$ and $\rho_{ra} \neq \rho_{rl}$, then use equation *(B.7.4-31)*:

$$\rho_t = \frac{\rho_l (C_a m_{ra} + \Delta m_{wa}) - \rho_a (C_l m_{rl} + \Delta m_{wl})}{C_a m_{ra} + \Delta m_{wa} - C_l m_{rl} - \Delta m_{wl}}$$

Density determination – Method A (continued)

Weight	Observed				Calculated			Estimated uncertainty	Pass	Fail
	ρ_a kg m^{-3}	ρ_l kg m^{-3}	I_{ta}	I_{tl}	Δm_{wa}	Δm_{wl}	ρ_t kg m^{-3}			
10 kg										
5 kg										
2 kg										
2 kg										
1 kg										
500 g										
200 g										
200 g										
100 g										
50 g										
20 g										
20 g										
10 g										
5 g										

Passed ☐ Failed ☐ the accuracy class that was specified by the manufacturer

Remarks:

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DENSITY VERIFICATION – Method B
(10, B.7.1, B.7.2, B.7.5)

Application no.:	....		Environmental conditions	
Type designation:	....	Air temperature		°C
Date:	....	Liquid temperature		°C

Starting time: [ ] Ending time: [ ]

Refer to Table 5 in R 111-1 for maximum and minimum limits for density

Calculation according to equation *(B.7.5-1)* (mandatory for Class E_1).

$$\rho_t = \frac{\rho_l m_t}{m_t - I_{tl}\left(1 - \frac{\rho_a}{\rho_{ref}}\right)}$$

Weight	**Observed**				**Calculated** ρ_t **kg m**$^{-3}$	**Estimated uncertainty**	**Pass**	**Fail**
	I_{tl}	m_t	ρ_l **kg m**$^{-3}$	ρ_a **kg m**$^{-3}$				

Passed [ ] Failed [ ] the accuracy class that was specified by the manufacturer

Remarks:

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LIMIT DENSITY VALUES
Density determination – Method B

Weight	Class E_1		Class E_2		Class F_1	
	Lowest acceptable $I_{tl(min)}$	Highest acceptable $I_{tl(max)}$	Lowest acceptable $I_{tl(min)}$	Highest acceptable $I_{tl(max)}$	Lowest acceptable $I_{tl(min)}$	Highest acceptable $I_{tl(max)}$
50 kg	43.738	43.801	43.638	43.910	43.277	44.274
20 kg	17.495	17.520	17.455	17.564	17.311	17.709
10 kg	8.7476	8.7602	8.7277	8.7819	8.6555	8.8547
5 kg	4.3738	4.3801	4.3638	4.3910	4.3277	4.4274
2 kg	1.7495	1.7520	1.7455	1.7564	1.7311	1.7709
1 kg	0.87476	0.87602	0.87277	0.87819	0.86555	0.88547
500 g	437.41	437.98	436.42	439.07	432.81	442.71
200 g	174.98	175.17	174.59	175.61	173.15	177.07
100 g	87.50	87.58	87.30	87.80	86.58	88.53
50 g	43.741	43.797	43.596	43.948	43.184	44.365
20 g	17.472	17.545	17.358	17.660	17.000	18.017
10 g	8.720	8.788	8.638	8.872	8.352	9.166
5 g	4.3506	4.4041	4.283	4.478	4.069	4.688
2 g	1.7280	1.7742	1.671	1.833	1.51	2.00
1 g	0.8568	0.8954	0.814	0.937	0.67	1.00

Shaded areas: Method B2 not recommended

DENSITY DETERMINATION – Method C
(10, B.7.1, B.7.2, B.7.6)

Application no.:	....	Environmental conditions		
Type designation:	....	Air temperature		°C
Date:	....	Liquid temperature		°C

Starting time: [ ] Ending time: [ ]

Refer to Table 5 in R 111-1 for maximum and minimum limits for density.

Calculation according to equation *(B.7.6-1)* or *(B.7.6-2)*.

Use Tables B.6 to determine ρ_l

Weight	Observed				Calculated	Estimated uncertainty	Pass	Fail
	m_t	I_{dl}	ρ_a kg m^{-3}	ρ_l kg m^{-3}	ρ_t kg m^{-3}			

Passed [ ] Failed [ ] the accuracy class that was specified by the manufacturer

Remarks:

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DENSITY DETERMINATION – Method D
(10, B.7.1, B.7.2, B.7.7)

Application no.: ....

Type designation: ....

Date: ....

Environmental conditions

Air temperature		°C
Liquid temperature		°C

Starting time: [ ] Ending time: [ ]

Refer to Table 5 in R 111-1 for maximum and minimum limits for density.

Calculation according to equation *(B.7.7-1)*.

Weight	**Observed**					**Calculated**	**Estimated uncertainty**	**Pass**	**Fail**
	m_t	ρ_l kg m^{-3}	I_{l+t}	I_l	ρ_a kg m^{-3}	ρ_t kg m^{-3}			

Passed [ ] Failed [ ] the accuracy class that was specified by the manufacturer

Remarks:

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DENSITY DETERMINATION – Method E
(10, B.7.1, B.7.2, B.7.8)

Application no.: ....
Type designation:: ....
Date: ....

Refer to Table 5 in R 111-1 for maximum and minimum limits for density.
Calculation according to equations *(B.7.8-1)* to *(B.7.8-5)*.
See Figure B.8 for dimension variables for cylindrical weight.

Weight	Measured values											Calculated					Calculated ρ_a kg m^{-3}	Estimated uncertainty	Pass	Fail
	H	R_1	R_2	R_3	D_1	D_2	D_3	l_1	l_2	l_3	m_0	V_A	V_B	V_C	V_D	V_{weight}				

Passed ☐ Failed ☐ the accuracy class that was specified by the manufacturer

Remarks:

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DENSITY DETERMINATION – Method F
(10, B.7.1, B.7.2, B.7.9)

Application no.: ....

Type designation: ....

Date: ....

Starting time: ☐ Ending time: ☐

Refer to Table 5 in R 111-1 for maximum and minimum limits for density.

Method used: F1 (R 111-1 B.7.9.2) ☐ F2 (R 111-1 B.7.9.3) ☐

Weight	Alloy	ρ_t kg m^{-3}	Estimated uncertainty	Pass	Fail

Passed ☐ Failed ☐ the accuracy class that was specified by the manufacturer

Remarks:

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COMPARISON OF THE TEST WEIGHT USING ONE REFERENCE WEIGHT AND CYCLE ABBA (C.4.1)

Application no.: ....

Type designation: ....

Date: ....

	At start	At end	
Air temperature:			°C
Relative humidity:			%
Air density:			kg m^{-3}
Time:			hh:mm

Applicable (yes/no): [ ]

Period: [ ] seconds

Conventional mass of the reference weight (m_{cr}): [ ]

Density of the reference mass (ρ_r): [ ] kg m^{-3}

	I_{r1}	I_{t1}	I_{t2}	I_{r2}	ΔI_i	ρ_{ai}	C_i	Δm_{ci}
units / i						kg m^{-3}		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
n =							min(Δm_{ci}) =	
							max(Δm_{ci}) =	
							$\overline{\Delta m_c}$ =	
							m_{ct} =	

COMPARISON OF THE TEST WEIGHT USING ONE REFERENCE WEIGHT AND CYCLE ABA (C.4.1)

Application no.: ....

Type designation: ....

Date: ....

	At start	At end	
Air temperature:			°C
Relative humidity:			%
Air density:			kg m^{-3}
Time:			hh:mm

Applicable (yes/no):

Value of the reference mass (m_{cr}):

Density of the reference mass (ρ_r): kg m^{-3}

	I_{r1}	I_{t1}	I_{r2}	ΔI_i	ρ_{ai}	C_i	Δm_{ci}
units / i					kg m^{-3}		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
n =						min(Δm_{ci}) =	
						max(Δm_{ci}) =	
						$\overline{\Delta m_c}$ =	
						m_{ct} =	

COMPARISON OF THE TEST WEIGHT USING ONE REFERENCE WEIGHT AND CYCLE AB$_1$…B$_n$A (C.4.2)

Application no.: ....

Type designation: ....

Date: ....

	At start	At end	
Air temperature:			°C
Relative humidity:			%
Air density:			kg m^{-3}
Time:			hh:mm

Applicable (yes/no): [ ]

Value of the reference mass (m_{cr}): [ ]

Density of the reference mass (ρ_r): [ ] kg m^{-3}

	I_{r1}	$I_{t(1)}$	$I_{t(2)}$	$I_{t(3)}$	$I_{t(4)}$	$I_{t(5)}$	I_{r2}	ρ_{ai}	C_i
units / i								kg m^{-3}	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

n = [ ]

Note: $J \leq 5$

COMPARISON OF THE TEST WEIGHT USING ONE REFERENCE WEIGHT AND CYCLE $AB_1 \ldots B_nA$ (C.4.2), continued

	$\Delta I_{(1)}$	$\Delta I_{(2)}$	$\Delta I_{(3)}$	$\Delta I_{(4)}$	$\Delta I_{(5)}$	$\Delta m_{c(1)}$	$\Delta m_{c(2)}$	$\Delta m_{c(3)}$	$\Delta m_{c(4)}$	$\Delta m_{c(5)}$
units / i										
1										
2										
5										
6										
7										
8										
9										
10										
$\min(\Delta m_{c(j)})$ =										
$\max(\Delta m_{c(j)})$ =										
$\overline{\Delta m_{c(j)}}$ =										
m_{ct} =										

Remarks:

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STANDARD UNCERTAINTY OF THE WEIGHING PROCESS, u_w, TYPE A
(C.6.1)

Quantity	Value	Unit
$s(\Delta m_{ci})$		mg
n		–

Equation *(C.6.1-1)*:

$u_w\left(\overline{\Delta m_c}\right) = \frac{s(\Delta m_{ci})}{\sqrt{n}} =$		

For classes F_2, M_1, M_2 and M_3 (C.6.1.1)

Quantity	Value	Unit
$\max(\Delta m_{ci})$		mg
$\min(\Delta m_{ci})$		mg

Equation *(C.6.1-2)*:

$s(\Delta m_c) = \frac{\max(\Delta m_{ci}) - \min(\Delta m_{ci})}{2 \times \sqrt{3}} =$		mg

For classes E_1, E_2 and F_1 (C.6.1.2)

Quantity	Value	Unit
n		–
Δm_{c1}		mg
Δm_{c2}		mg
Δm_{c3}		mg
Δm_{c4}		mg
Δm_{c5}		mg

Note: Use these empty rows for additional Δm_{ci}

Equation *(C.6.1-3)*:

$s^2(\Delta m_c) = \frac{1}{n-1}\sum_{i=1}^{n}\left(\Delta m_{ci} - \overline{\Delta m_c}\right)^2$		mg^2

STANDARD UNCERTAINTY OF THE WEIGHING PROCESS, u_w, TYPE A (C.6.1), continued

For J series of measurements (C.6.1.4)

Note: Use these empty rows for additional s_j

Quantity	Value	Unit
J		–
s_1		mg
s_2		mg
s_3		mg
s_4		mg
s_5		mg

Equation *(C.6.1-4)*:

$s^2(\Delta m_c) = \frac{1}{J}\sum_{j=1}^{J} s_j^2(\Delta m_{ci}) =$		mg^2

UNCERTAINTY OF THE REFERENCE WEIGHT, $u(m_{cr})$, TYPE B (C.6.2)

☐ Standard uncertainty of the known reference weight

Quantity	Value	Unit
U		–
k		–
$u_{inst}(m_{cr})$		mg

Equation *(C.6.2-1)*:		
$u(m_{cr}) = \sqrt{\left(\frac{U}{k}\right)^2 + u_{inst}^2(m_{cr})} =$		mg

☐ Standard uncertainty of the unknown reference weight, for F_1, F_2, M_1, M_2, M_3 weights (C.6.2.1)

Quantity	Value	Unit
δm		mg
$u_{inst}(m_{cr})$		mg

Equation *(C.6.2-2)*:		
$u(m_{cr}) = \sqrt{\frac{\delta m^2}{3} + u_{inst}^2(m_{cr})} =$		mg

☐ If a combination of reference weights is used (C.6.2.2)

Quantity	Value	Unit
$u(m_{cr\,1})$		
$u(m_{cr\,2})$		
$u(m_{cr\,3})$		
$u(m_{cr\,4})$		
$u(m_{cr\,5})$		

Note: Use these empty rows for additional $u(m_{cr\,i})$

Equation *(C.6.2-3)*:		
$u(m_{cr}) = \Sigma_i\, u(m_{cr\,i}) =$		

STANDARD UNCERTAINTY OF THE AIR BUOYANCY CORRECTIONS, u_b, TYPE B (C.6.3)

$$u_b^2 = \left[m_{cr} \frac{(\rho_r - \rho_t)}{\rho_r \rho_t} u(\rho_a) \right]^2 + \left[m_{cr} (\rho_a - \rho_0) \right]^2 \frac{u^2(\rho_t)}{\rho_t^4} + m_{cr}^2 (\rho_a - \rho_0) \left[(\rho_a - \rho_0) - 2(\rho_{al} - \rho_0) \right] \frac{u^2(\rho_r)}{\rho_r^4} \qquad (C.6.3\text{-}1)$$

	Quantity	Value	Unit
	m_{cr}		
	ρ_r		
	ρ_t		
	ρ_a		
	ρ_{a1}		
	ρ_0		
	$u(\rho_a)$		
	$u(\rho_t)$		
	$u(\rho_r)$		
First term (A):	$\left[m_{cr} \frac{(\rho_r - \rho_t)}{\rho_r \rho_t} u(\rho_a) \right]^2$		
Second term (B):	$\left[m_{cr} (\rho_a - \rho_0) \right]^2 \frac{u^2(\rho_t)}{\rho_t^4}$		
Third term (C):	$m_{cr}^2 (\rho_a - \rho_0) \left[(\rho_a - \rho_0) - 2(\rho_{al} - \rho_0) \right] \frac{u^2(\rho_r)}{\rho_r^4}$		
Equation *(C.6.3-1)*:	$u_b^2 = A + B + C =$		

STANDARD UNCERTAINTY OF THE AIR BUOYANCY CORRECTION, u_b, Type B (C.6.3), continued

☐ The uncertainty due to air buoyancy is negligible (usually the case for classes M_1, M_2 and M_3) (C.6.3.2)

Air density (C.6.3.4):

Air density not measured, average value for site used. Estimated uncertainty as follows:

☐ $u(\rho_a) = \frac{0.12}{\sqrt{3}} = 0.069\ 282\ 032$ kg m^{-3} *(C.6.3-2)*

☐ Data supporting lower value of uncertainty provided $u(\rho_a)$= ☐ kg m^{-3}

Variance of air density (C.6.3.6):

At relative humidity of hr = 0.5 (50 %), a temperature of 20 °C and a pressure of 101 325 Pa, the following numerical values apply approximately:

u_F = [uncertainty of the formula used] (for CIPM formula: $u_F = 10^{-4}\ \rho_a$)

$$\frac{\partial \rho_a}{\partial p} = 10^{-5}\ \text{Pa}^{-1}\ \rho_a$$

$$\frac{\partial \rho_a}{\partial t} = -3.4 \times 10^{-3}\ \text{K}^{-1}\ \rho_a$$

$$\frac{\partial \rho_a}{\partial hr} = -10^{-2}\ \rho_a$$

where hr = relative humidity, as a fraction.

Values used:

Quantity	Value	Unit
u_F		
$\frac{\partial \rho_a}{\partial p}$		
u_p		
$\frac{\partial \rho_a}{\partial t}$		
u_t		
$\frac{\partial \rho_a}{\partial hr}$		
u_{hr}		

Equation *(C.6.3-3)*:

$u^2(\rho_a) = u_F^2 + \left(\frac{\partial \rho_a}{\partial p} u_p\right)^2 + \left(\frac{\partial \rho_a}{\partial t} u_t\right)^2 + \left(\frac{\partial \rho_a}{\partial hr} u_{hr}\right)^2 =$		

STANDARD UNCERTAINTY OF THE BALANCE, u_{ba}, TYPE B (C.6.4)

Standard uncertainty due to the sensitivity of the balance, u_s, Type B (C.6.4.2)

Quantity	Value	Unit
$\overline{\Delta m_c}$		
$u(m_s)$		
m_s		
$u(\Delta I_s)$		
ΔI_s		

Equation *(C.6.4-1)*:	$u_s^2 = \left(\overline{\Delta m_c}\right)^2 \left(\frac{u^2(m_s)}{m_s^2} + \frac{u^2(\Delta I_s)}{\Delta I_s^2} \right) =$		

Standard uncertainty due to the display resolution of a digital balance, u_d, Type B (C.6.4.3)

Quantity	Value	Unit
d		

Equation *(C.6.4-2)*:	$u_d = \left(\frac{d/2}{\sqrt{3}} \right) \times \sqrt{2} =$		

Standard uncertainty due to eccentric loading, u_E, Type B (C.6.4.4)

☐ Balance **without** automatic exchange mechanism (C.6.4.4.1)

Quantity	Value	Unit
d_1		
d_2		
Maximum value from test		
Minimum value from test		
D		

Equation *(C.6.4-3)*:	$u_E = \frac{\frac{d_1}{d_2} \times D}{2 \times \sqrt{3}} =$		

☐ Balance **with** automatic exchange mechanism (C.6.4.4.2)

Quantity	Value	Unit
Position 1, ΔI_1		
Position 2, ΔI_2		

Equation *(C.6.4-4)*:	$u_E = \frac{\lvert \Delta I_1 - \Delta I_2 \rvert}{2} =$		

STANDARD UNCERTAINTY OF THE BALANCE, u_{ba}, TYPE B (C.6.4) (continued)

Standard uncertainty due to magnetism of the test weight, u_{ma}, Type B (C.6.4.5)

☐ Weight satisfies the requirements of this Recommendation. Therefore, the uncertainty due to magnetism, u_{ma}, is assumed to be zero.

Quantity	Value	Unit
u_{ma} =		

Combined standard uncertainty of the balance, u_{ba} (C.6.4.6)

Quantity	Value	Unit
u_s		
u_d		
u_E		
u_{ma}		

Equation *(C.6.4-5)*:

$u_{ba} = \sqrt{u_s^2 + u_d^2 + u_E^2 + u_{ma}^2} =$		

EXPANDED UNCERTAINTY, $U(m_{ct})$ (C.6.5)

Quantity	Value	Unit
$u_w(\overline{\Delta m_c})$		
$u(m_{cr})$		
u_b		
u_{ba}		

Equation *(C.6.5-1)*:

$u_c(m_{ct}) = \sqrt{u_w^2(\overline{\Delta m_c}) + u^2(m_{cr}) + u_b^2 + u_{ba}^2} =$		

Quantity	Value	Unit
$u_c(m_t)$		
k (usually k=2)		

Equation *(C.6.5-3)*:

$U(m_{ct}) = k\, u_c(m_{ct}) =$		

Note: Use copies of pages 27 to 37 for additional test weights