

Mass Standards Handbook — Physical Characteristics

This section is a summary of the more widely used and accepted weight specifications. The most pertinent sections of these specifications are listed and not all of the contents of these specifications are included.

ANSI/ASTM E 617 – The information that follows is an overview of the specifications in ANSI/ASTM E 617-97 (2003), Standard Specification for Laboratory Weights and Precision Mass Standards.

Reference:

Available from: Henry Troemner LLC, 201 Wolf Drive P.O. Box 87, Thorofare, New Jersey, 08086-0087 USA, 856-686-1600 or American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania, 19428-2959 USA

Maximum Permissible Error (Tolerances)

For classes 0, 1, 2, 3, 4, 5, 6, and 7 weights, the expanded uncertainty U at 95% confidence of the conventional mass shall be less than or equal to one-third of the maximum permissible error given in the Tolerance Table 9 (page 66). For each weight, the absolute value of the conventional mass correction along with its associated uncertainty shall not be greater than the maximum permissible error for the weight's given class as given in the Tolerance Table 9 (page 66).

Construction

Type - Weights are divided into two types based upon design:

- **Type I** - These weights are of one-piece construction and contain no added adjusting material. They must be specified when weights are to be used as standards for the calibration of weights of Classes 0, 1, 2, and 3, and where maximum stability is required. A precise measurement of density can only be made for one-piece weights.
- **Type II** - Weights of this type can be of any appropriate design such as screw knob, ring, or sealed plug. Adjusting material can be used as long as it is of a material at least as stable as the base material and is contained in such a way that it will not become separated from the weight.

Design - A weight may have any shape that does not introduce features that reduce the reliability. All weights shall be free of ragged or sharp edges or ends. Both sheet metal and wire weights shall be free of cracks such as those that may be formed from bending.

Surface Area - For Classes 0, 1, 2, 3, and 4 the surface area is not to exceed twice the area of a cylinder of equal height and diameter for weights 1 g and above. Sheet metal weights or wire weights may be used below 1 g.

Material

Class 0, 1, 2, and 3 Weights - The hardness of this material and its resistance to wear and corrosion shall be similar to or better than that of austenitic stainless steel.

Class 4, 5, 6, and 7 Weights - The hardness and brittleness of the materials used for weights of these classes shall be at least equal to that of drawn brass.

Magnetism

Weights shall not exceed maximum permissible magnetic properties as listed in Table 1 below for any portion of the weight.

Table 1 - Magnetic Properties

CLASS	VOLUME MAGNETIC SUSCEPTIBILITY (χ)	MAXIMUM MAGNETIC FIELD	
		μ T	mG
0	0.01	2.0	20
1	0.03	4.0	40
2, 3, 4	0.05	6.0	60
5, 6, 7	*	*	*

*Requirements for these classes have not been developed.

Density

Because of the effect of the buoyant force of air on a weight, precision measurements of mass require that the volume of the weight be known, as well as the density of the air in which it is being measured, so that appropriate corrections can be made. For

Table 2 - Minimum and Maximum Limits for Density (ρ_{min} , ρ_{max} (kg/m³))

NOMINAL VALUE	CLASS 0	CLASS 1 AND 2	CLASS 3 THROUGH 6	CLASS 7
>5 kg	7934 to 8060	7700 to 8200	7000 to 9100	\geq 7000
1 g to 5 kg	7920 to 8080	7700 to 8200	7700 to 9100	\geq 7000
<1 g to 50 mg	7700 to 8200	7700 to 8200	2300 to 8200	\geq 2000
50 mg to 1 mg	2300 to 8200	2300 to 8200	2300 to 8200	\geq 2000

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weights of higher precision, the range of density is limited to values at or near the density of well-established standards, such as are used by primary calibration laboratories. As lower precision of measurement is required, so the range of density is broadened. See Table 2.

Finish

The surface of the weights (including the base and corners) shall be smooth, the edges shall be rounded, and the weights shall not be porous. The surface quality of a weight shall not exceed maximum values of surface roughness, R_A and R_Z through visual inspection using a hand held gauge. (See Table 3 below).

For weights with recessed areas for easier handling, their recessed area and handle should have a finish with surface roughness no greater than $R_Z=0.67 \mu\text{m}$ and $R_A=0.05 \mu\text{m}$. The outer diameter, top and bottom surface roughness must meet Table 3 below.

Markings

Class 0 - Class 0 weights shall not bear any indication of nominal value.

Numerical Value for Classes 1, 2, 3, 4, 5, 6, and 7 - The nominal value of each weight shall appear on the surface of each weight. Only the numerical portion of the weight value needs to be on the surface of the weights. Weights made of wire are too small to be marked and shall not be marked, but should be identifiable by their shape or number of bends.

Unit of Weight - Weights 100 g and greater may be marked with the unit name or abbreviation. In the case of sets of non-metric weights, at least the largest weight of a particular set should be marked with the unit name or abbreviation. In any case the unit shall not be included where such marking would be illegible.

Multiple Weights - Multiple weights of the same nominal value included in a set of weights shall have distinguishing marks.

Depth of Markings - Markings shall be clear, shallow, relatively broad, and free of burrs and sharp angles. Markings shall not perforate or crack sheet metal weights.

Table 3 - Maximum Value of Surface Roughness

	CLASSES 0 AND 1	CLASSES 2, 3, 4	Classes 5, 6, 7
R_A (μm)	0.025	0.05	0.8
R_Z (μm)	0.35	0.67	3.2



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OIML INTERNATIONAL RECOMMENDATION NO. R 111 –

The information that follows is an overview of the specifications outlined in OIML R 111 for weights of classes E₁, E₂, F₁, F₂, M₁, M₂, M₃.

Reference:

Available from: Henry Troemner LLC, 201 Wolf Drive P.O. Box 87, Thorofare, New Jersey, 08086-0087 USA 856-686-1600 or Organisation Internationale De Metrologie Legale, 11 Rue Trugot – F-75009, Paris, France

Maximum Permissible Error (Tolerance) –

The maximum permissible errors for Class E₁, E₂, F₁, F₂, M₁, M₂, and M₃ are provided in the Tolerance Table 9 (page 66). The uncertainty associated with the maximum permissible error shall be less than or equal to 1/3 of the maximum permissible error.

Shape – Weights 1 g and below may be polygonal shapes or wires and shall conform to Table 4 below.

Weights 1 g to 50 kg may have the external dimensions as shown in OIML R 111 Annex A. Weights of a set shall have the same shape except for weights 1 g and below.

Construction – Class E₁ and E₂ are to be made with one-piece construction with no adjusting cavities. Classes F₁, F₂, M₁, M₂, and M₃ may be made of more than one piece from the same material and may contain an adjusting cavity.

Material – Class E₁ and E₂ weights equal or greater to 1 g, the hardness of material and its resistance to wear shall be similar to or better than that of austenitic stainless steel.

For Class F₁ and F₂ weights equal to or greater than 1 g, the material shall be at least as hard as drawn brass.

Material used for rectangular weights for Class M₁ from 5 kg to 50 kg shall have a corrosion resistance that is equal to that of gray cast iron. Class M₁ cylindrical weights 10 kg and below shall be made of brass or of

another material whose quality is similar or better than brass.

Material used for rectangular weights for Class M₂ and M₃ 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. Class M₂ and M₃ cylindrical weights 10 kg and below shall be made of material, which has hardness and corrosion resistance at least equal to cast brass, and brittleness not exceeding that of gray cast iron. Gray cast iron shall not be used for weights below 100 g.

Magnetism – The magnetism should not exceed the maximum values given in Table 5 below.

The magnetic susceptibility of a weight should not exceed the maximum values given in Table 6 below.

Table 4 - Shape of Weights 1 g or Less

NOMINAL VALUES (mg)	POLYGONAL SHEETS	WIRES
5 – 50 – 500	Pentagon	Pentagon or 5 segments
2 – 20 – 200	Square	Square or 2 segments
1 – 10 – 100 – 1000	Triangle	Triangle or 1 segment

Table 5 - Maximum Permanent Magnetism, $\mu_0 M$ (μT)

WEIGHT CLASS	E ₁	E ₂	F ₁	F ₂	M ₁	M ₂	M ₃
Maximum Magnetism, $\mu_0 M$ (μT)	3	10	30	100	300	1000	3000

Table 6 - Maximum Susceptibility, χ

WEIGHT CLASS	E ₁	E ₂	F ₁	F ₂
Nominal mass \geq 100 g	0.01	0.03	0.07	0.21
Nominal mass < 100 g	0.025	0.075	0.25	0.75
Nominal mass \leq 1 g	0.12	0.37	1.2	-

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Density – The density of the material used for weights shall be such that a deviation of 10% from the specified air density (1.2 kg/m³) does not produce an error exceeding one quarter of the maximum permissible error. These limits are given in Table 7.

Surface Conditions – The surface of the weights shall be smooth and edges shall be rounded. The surface of Class E₁, E₂, F₁, and F₂ weights shall not appear to be porous and shall present a glossy appearance when visually examined. The maximum values of surface roughness shall be observed to determine the surface quality in Table 8.

Marking – Class E₁ and E₂ weights shall not bear any markings of nominal value or class reference.

Class F₁ shall bear nominal value not followed by a symbol or unit. Nominal value 1 g up to and including 500 g shall indicate numerals representing grams. Weight 1 kg and above shall bear numerals representing kilograms. For example, a 10 g weight will be marked with a “10”. A 1 kg weight will be marked with a “1”. Sheet metal weights shall not bear any indication of nominal value or class reference.

Class F₂ weights will be marked similar to class F₁ except the letter “F” will appear below the numerical value.

Class M₁, M₂, and M₃ will be marked with nominal value and unit of measure (ex. 10 g, 1 kg, 10 kg, etc...). Class M₁ will also bear an M or M₁, class M₂ shall also bear an M₂ or no class designation, and class M₃ shall also bear an M₃ or X.

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

Table 7 - Minimum and Maximum Limits for Density (ρ_{min}, ρ_{max} (10³ kg/m³))

NOMINAL VALUE	CLASS E ₁	CLASS E ₂	CLASS F ₁	CLASS F ₂	CLASS M ₁	CLASS M ₂	CLASS M ₃
> 50 kg					≥ 4.4	≥ 2.1	> 4.4
100 g to 50 kg	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						
50 mg	≥ 3.4						
20 mg	≥ 2.3						

Table 8 - Maximum Values of Surface Roughness (R_z)

CLASS	E ₁	E ₂	F ₁	F ₂
R _z (μm)	0.5	1	2	5
R _a (μm)	0.1	0.2	0.4	1