Designation: ~~E617 – 97 (Reapproved 2008)~~ E617 – 13

Standard Specification for Laboratory Weights and Precision Mass Standards[1]

This standard is issued under the fixed designation E617; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers weights and mass standards used in laboratories, specifically classes 000, 00, 0, 1, 2, 3, 4, 5, 6 and 7. This specification replaces National Bureau of Standards Circular 547, Section ~~1,~~1, which is out of print.

~~1.2 This specification further recognizes that International Recommendation R111 exists, that describes classes E1, E2, F1, F2, M1, M2 and M3. Users may choose to reference either R111 or this specification, depending on requirements.~~

1.2 This specification contains the principal physical characteristics and metrological requirements for weights that are used.

1.2.1 For the verification of weighing instruments;

1.2.2 For the ~~verification~~calibration of weights of a lower class of accuracy; and

1.2.3 With weighing instruments.

1.3 ~~Tolerances~~ Maximum Permissible Errors (formerly tolerances) and design restrictions for each class are described in order that both individual weights or sets of weights can be chosen for appropriate applications.

1.4 The values stated in SI units are to be regarded as ~~the~~ standard.

1.5 Weight manufacturers must be able to provide evidence that all new weights comply with specifications in this standard (e.g., material, density, magnetism, surface finish, mass values, uncertainties). Statements of compliance by calibration laboratories during subsequent calibrations must meet the requirements of ISO/IEC 17025, 5.10.4.2 and indicate on the calibration report which sections have or have not been assessed.

2. Referenced Documents

~~2.1 *ANSI Standard:*~~

~~B 46.1-1995 Surface Texture (Surface Roughness, Waviness, and Lay) an American National Standard[2]~~

2.1 *ISO Standards:*[2]

~~International Vocabulary of Basic and General Terms in Metrology 1993, VIM,~~ISO/IEC 17025 ~~Geneve, Switzerland~~General Requirements for the Competence of Testing and Calibration Laboratories (2005)

~~Guide to the Expression of Uncertainty in Measurement[2]~~

~~ISO/DIS 4287-1, Edition 01-Jun-95, Geometric Product Specification (GPS), Determination of Surface Texture by Profiling Methods, Part 1: Terms, Definitions and Parameters[2]~~

[1] This specification is under the jurisdiction of ASTM Committee E41 on Laboratory Apparatusand is the direct responsibility of Subcommittee E41.06 on Weighing Devices.

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[2] Available from ~~American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.~~International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

~~2.3 *NCSL Standards:*~~
~~NCSL Glossary of Metrology—Related Terms[3]~~
~~NCSL Recommended Practice-12 Determining and Reporting Measurement Uncertainties[3]~~
~~ANSI/NCSL-Z540-1-1994 American National Standard for Calibration-Calibration Laboratories and Measuring and Test Equipment General Requirements[3]~~

2.2 *NIST Standards:*[3]
NIST ~~NVLAP Draft~~ Handbook ~~150-2~~143 ~~National Voluntary Laboratory Accreditation Program Calibration Laboratories Technical Guide~~State Weights and Measures Laboratories Program Handbook (2007)
NIST SP 811 Guide for the Use of the International System of Unit (SI) 2008 Edition
NIST ~~NVLAP Handbook 150~~SP 1038 ~~National Voluntary Laboratory Accreditation Program (NVLAP), NIST Handbook 150, Procedures and General Requirements~~The International System of Units (SI) – Conversion Factors for General Use (May 2006)
NISTIR 5672 Advanced Mass Calibration and Measurement Assurance Program for State Calibration Laboratories (2012)
NISTIR 6969 Selected Laboratory and Measurement Practices to Support Basic Mass Calibrations (2012)
NIST Technical Note 1297 (1994) Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results

2.3 *OIML ~~Standard:~~Standards:*[4]
OIML ~~Recommendation 33~~D 28 Conventional Value of the Result of Weighing in Air (2004)
OIML R111–1e04 Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3 Part 1: Metrological and Technical Requirements (2004)

2.4 *BIPM Standards:*
VIM: JCGM 200:2012 International Vocabulary of Metrology–Basic and General Concepts and Associated Terms
GUM: JCGM 100:2008 Evaluation of Measurement Data–Guide to the Expression of Uncertainty in Measurement

2.5 *EURAMET Standards:*
EURAMET/cg-18/V. 3.0 Guidelines on the Calibration of Non-Automatic Weighing Intruments (2011)

2.6 *Additional Reference Documents:*
CIPM-2007 Revised Formula for the Density of Moist Air, A. Picard, R. S. Davis, M. Glaser, and K. Fujii

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accuracy class of weights*—a class of weights that meets certain metrological requirements intended to keep the errors within specified limits.

3.1.2 *balance*—instument indicating apparent mass that is sensitive to the following forces:

$F_g = m \cdot g$ — Force due to gravity

$F_b = v \cdot \rho_a \cdot g = \frac{m}{\rho} \rho_a \cdot g$ — Air buoyancy equal to the weight of the displaced air.

$F_z = \mu_o \int\int\int_v (M + \chi H) \frac{\partial H}{\partial z} dV$ — Vertical component of the magnetic interaction between the weight and the balance or the environment, or both.

H and *M* are vectors; *z* is the vertical cartesian coordinate. If magnetic effects are negligible, i.e. the permanent magnetization (*M*) of the weight and the magnetic susceptibility (χ) are sufficiently small, and the balance is calibrated with reference weights of well-known mass, the balance can be used to indicate the conventional mass, m_c, of a body under conventionally chosen conditions.

3.1.3 ~~*calibration*—~~*calibration (of weights)*—the acts of determining the mass difference between a standard of known mass value and an "unknown" test weight or set of weights, establishing the mass value and conventional mass value of the ~~"unknown",~~"unknown," and of determining a quantitative estimate of the uncertainty to be assigned to the stated mass or conventional mass value of the ~~"unknown", or both. Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards.~~"unknown," or both, and providing metrological traceability to the "unknown."

[4] Available from Organisation Internationale de Metrologie Legale, 11 Rue Turgot, 75009 Paris, France.
[3] Available from ~~NCSL,~~ National ~~Conference of Standards Laboratories, 1800 30th Street, Suite 305B, Boulder, Colorado 80301.~~Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.
~~[4] Available from NIST/NVLAP, National Voluntary Laboratory Accreditation Program, NIST, Gaithersburg, Maryland 20899. HB 150 available on-line: http://ts.nist.gov/nvlap and Technical Note 1297 available on-line: http://physics.nist.gov/Pubs/guidelines/outline.html.~~

3.1.3.1 *calibration (generally)*—set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards.

~~3.1.3 *certificate of tolerance test*—document that certifies that the subject weights are within specified tolerances.~~

~~3.1.3.1 *Discussion*—~~

~~If traceability is claimed, some level of uncertainty must be addressed.~~

3.1.4 ~~*certificate or report of calibration*—~~*calibration certificate*—~~document that presents calibration results and other information relevant to~~certificate issued by calibration laboratories to document the results of a calibration.

3.1.5 *conventional mass*—conventional value of the result of weighing in air, in accordance to International Recommendation OIML ~~R 33.~~ D 28. For a weight taken at 20°C, the conventional mass is the mass of a reference weight of a density of 8000 kg/m^3 which it balances in air of density of 1.2 kg/m^3.

~~3.1.5.1 *Discussion*—~~

~~Formerly known as apparent mass versus 8.0 g/cm^3.~~

3.1.6 *correction*—mass values are traditionally expressed by two numbers, one being the nominal mass of the weight, and the second being a correction. The mass of the weight is the assigned nominal value plus the assigned correction. Positive corrections indicate that the weight embodies more mass than is indicated by the assigned nominal value. Negative corrections indicate that the weight embodies less mass than is indicated by the assigned nominal value. The correction is equivalent to the "error."

3.1.7 *international prototype kilogram*—the platinum-iridium cylinder maintained at the International Bureau of Weights and Measures (BIPM), at Sevres, France with an internationally accepted defined mass of 1 kg.

3.1.8 *magnetism*—effect that generates an attractive or repulsive force.

3.1.8.1 *(volume) magnetic susceptibility (χ)*—measure of the ability of a medium to modify a magnetic field. It is related to the magnetic permeability (μ) by the relation: $\mu/\mu_0 = 1 + \chi$. The quantity μ/μ_0 is sometimes referred to as the relative permeability, μ_r.

3.1.8.2 *(permanent) magnetization (M)*—parameter that specifies a magnetic state of material bodies such as weights, in the absense of an external magnetic field (most generally, magnetization is a vecotr whose magnitude and direction are not necessarily constant within the material). The magnetization of a body generates an inhomogeneous magnetic field in space and thus may produce magnetic forces on other materials.

3.1.9 *mass*—physical quantity, which can be ascribed to any material object and which gives a measure of its quantity of matter. The unit of mass is the kilogram.

3.1.10 *maximum permissible errors*—the maximum amount by which the sum of the conventional mass of the weight, its deviation from nominal value and its associated uncertainty is allowed to deviate from the assigned nominal value.

3.1.11 *metrological traceability*—property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty. Metrological traceability requires an established calibration hierarchy. Elements for confirming metrological traceability to be an unbroken chain to an international measurement standard or a national measurement standard (IPK or NPS), shall include a documented measurement uncertainty, a documented measurement procedure, accredited technical competence, metrological traceability to the SI, and established calibration intervals (see current VIM: JCGM 200).

3.1.12 *reference standard*—a standard, generally of the highest metrological quality available at a given location, from which measurements made at that location are derived.

3.1.13 *roughness parameter or R-parameter (R_a or R_z)*—parameter that describes the assessed roughness profile of a sample. The letter R is indicative of the type of assessed profile, in this case R for roughness profile. The assessed profile of a sample can be in terms of different profile types: a roughness profile or R-parameter, primary profile or P-parameter, a waviness profile or W-parameter.

3.1.14 *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.

3.1.15 *temperature (t)*—in degrees Celsius, is related to the absolute thermodynamic temperature scale, called the Kelvin scale, by $t = T - 273.15$ K.

3.1.16 ~~*tolerance (adjustment tolerance test weight (m_t or maximum permissible errors)*—~~)—~~the maximum amount by which the conventional mass of the weight is allowed to deviate from the assigned nominal value.~~weight that is to be tested according to this standard.

3.1.17 *tolerance test*—verification that the conventional mass of the weights and their corresponding uncertainties as tested are correct within the maximum permissible errors of the respective weight class.

~~3.1.12 *traceability*—property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.~~[7]

~~3.1.12.1 *Discussion*—~~

~~For more information see 3.1.14.~~

3.1.18 *uncertainty*—non-negative parameter ~~associated with the result of a measurement, that characterizes the~~ characterizing the dispersion of the ~~values that could reasonably be attributed to the measurand.~~quantity values being attributed to a measurand, ~~The range of values within which the true value is estimated to lie.~~based on the information used.

3.1.19 *units*—the units used are: *(1)* for mass, the milligram (mg), the gram (g) and the kilogram (kg); *(2)* for density, the kilogram per cubic meter (kg m^{-3}).

3.1.20 *U.S. National prototype standard*—~~platinumiridium~~platinum-iridium kilogram identified as K20, maintained at the National Institute of Standards and Technology, with value assigned relative to the International Prototype Kilogram provides the United States access to the mass unit.

3.1.21 ~~*weight (mass standard)*—~~*weight*—~~a~~ material measure of mass, regulated in regard to its physical and metrological characteristics: shape, ~~dimension,~~dimensions, material, surface quality, nominal value, density, magnetic properties and maximum permissible error.

~~3.1.15.1 *Discussion*—~~

~~Not to be confused with a gravitational force.~~

NOTE 1—The term "weight" is also used as the physical quantity of the gravitational force of a body. From the context it is usually clear in which sense the term is used. If the sense is not clear, one may use the words "weight force" or "weight piece," depending on its meaning.

3.2 *Symbols:*

Symbol	Unit	Definition
A	–	represents weighing the reference weight in a weighing cycle
B	–	represents weighing the test weight in a weighing cycle
C	–	correction factor for air buoyancy
D	kg	difference of balance readings between minimum and maximum values from eccentricity test
d	kg	scale interval
d_1	m	estimated distance between centers of weights during loading
d_2	m	estimated distance from the center of the load receptor to one of the corners
F_b	N	air buoyancy equal to the weight of the displaced air
F_g	N	gravitational force
F_z	N	magnetic force between a mass comparator and a weight in the vertical or z-direction
g	m s^{-2}	gravitational acceleration
H	A m^{-1}	magnetizing field strength
hr	%	relative humidity
I	kg	indication of the weighing instruments (scale division)
ΔI	kg	indication difference of the balance, where $\Delta I = I_t - I_r$
ΔI_1	kg	indication difference using an automatic exchange mechanism with weights in first position
ΔI_2	kg	indication difference using an automatic exchange mechanism with weights in reversed position
ΔI_s	kg	change in indication of balance due to sensitivity weight
i	–	subscript used as an index in summations
j	–	subscript for number of test weights or number of series of measurements
k	–	coverage factor, typically 2 or 3

Symbol	Unit	Definition
M	A m^{-1}	permanent magnetization (see also $\mu_0 M$)
m	kg	mass of a rigid body (weight)
Δm	kg	mass difference, usually between test and reference weight
δm	kg	maximum permissible error on the weights
m_0	kg	mass, nominal value of the weight (e.g. 1 kg)
m_c	kg	conventional mass of the weight
Δm_c	kg	conventional mass difference between test weight and reference weight
$\overline{\Delta m_c}$	kg	average conventional mass difference between test weight and reference weight
m_{cr}	kg	conventional mass of the reference weight
m_{ct}	kg	conventional mass of the test weight
m_s	kg	mass of the sensitivity weight
m_t	kg	mass of the test weight
n	–	subscript for number of measurement sequences
p	Pa	barometric pressure
R_a	µm	mean height of roughness profile (R-parameter)
R_z	µm	maximum height of roughness profile (R-parameter)
r	–	subscript for reference weight
s	–	subscript for sensitivity weight
s	kg	standard deviation
s^2	kg^2	variance
T	K	thermodynamic temperature using the International Temperature Scale of 1990 (ITS-90)
ΔT^*	°C	initial difference between weight temperature and laboratory temperature
t	–	subscript for test weight
t	°C	temperature in degrees Celsius, where $t = T – 273.15$ K
U	kg	uncertainty, expanded uncertainty
u	kg	uncertainty, standard uncertainty
u_b	kg	uncertainty of air buoyancy correction
u_{ba}	kg	uncertainty of the balance
u_c	kg	combined standard uncertainty
u_d	kg	uncertainty due to the display resolution of a digital balance
u_E	kg	uncertainty due to eccentricity
u_F	kg m^{-3}	uncertainty of the formula used to calculate air density
u_{hr}	%	uncertainty in relative humidity
u_{inst}	kg	uncertainty due to instability of the reference weight
u_{ma}	kg	uncertainty due to magnetism
u_p	Pa	uncertainty in barometric pressure
u_s	kg	uncertainty due to the sensitivity of the balance
u_t	°C	uncertainty in temperature
u_w	kg	uncertainty due to the weighing process
V	m^3	volume of a solid body (weight)
z	m	vertical cartesian coordinate
µ	N A^{-2}	magnetic permeability
μ_0	N A^{-2}	magnetic constant (magnetic permeability of vacuum), $\mu_0 = 4\pi \times 10^{-7}$ N A^{-2}
$\mu_0 M$	T	magnetic polarization
μ_r	–	relative magnetic permeability (μ/μ_0)
ν_{eff}	–	effective degrees of freedom
ρ	kg m^{-3}	mass of a rigid body (weight)
ρ_0	kg m^{-3}	density of air as a reference value equal to 1.2 kg m^{-3}
ρ_a	kg m^{-3}	density of moist air
ρ_{al}	kg m^{-3}	density of moist air during the last (previous) calibration of the reference weight
ρ_r	kg m^{-3}	density of a reference weight with mass m_r

Symbol	Unit	Definition
ρ_t	kg m^{-3}	density of the weight being tested
χ	–	magnetic susceptibility

4. Maximum Permissible Errors ~~(Tolerances)~~

4.1 For each weight, the expanded uncertainty U at approximately 95 % confidence (See ~~Annex~~Section 9~~B of OIML R 111) of~~) of the conventional mass shall be less than or equal to one-third of the maximum permissible error given in Table 1 as defined in Section 9.

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

$$m_o - (\delta m - U) \leq (m_c) \leq m_o + (\delta m - U) \quad (1)$$

4.2 Maximum permissible errors ~~(tolerances) on verification~~ for classes 000, 00, 0, 1, 2, 3, 4, 5, 6 and 7 are given in Table 1. These maximum permissible errors ~~are related~~ apply to conventional mass values.

~~NOTE 1—Consistent with OIML R 111 the concept of group tolerances has been dropped in the 1997 revision of this specification.~~

NOTE 2—~~Tolerances~~ Maximum Permissible Errors for weights of ~~denominations~~denomination intermediate between those ~~listed can be determined as follows. If the unit of measure is non-metric use the conversion factor from the Abbreviations of Terms table in Appendix X3 to convert the nominal value to a metric unit. For weights that are intermediate between those listed, the tolerance for the next lower weight shall be applied.~~ listed, the maximum permissible error shall be proportional to the values shown.

~~NOTE 3—Class 0 is a new designation with tolerances that are 50 % of Class 1, with physical characteristics the same as those of OIML R 111 Class E1.~~

~~NOTE 4—Class 7 is a new designation with the same tolerances as the former Class T in NBS Circular 3 (out of print).~~

4.3 For class 000, 00 and 0 weights, which are always accompanied by certificates giving the mass values and uncertainties, the deviation from the nominal value, $m_c - m_0$, shall be taken into account by the user.

5. Physical Characteristics

5.1 *Construction:*

5.1.1 *Type*—Weights are divided into two types based upon the design:

5.1.1.1 *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 000, 00, 0, 1, 2 and 3, and where maximum stability is required. A precise measurement of density can only be made for one-piece weights.

5.1.1.2 *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.

5.1.2 Class ~~0 must~~000, 00 and 0 shall be Type I, one piece construction. Weights with nominal values less than 1 g shall have unique shapes to differentiate the weights from one another. See Table 2. The shape of weights smaller than 1 mg shall be discussed and verified with the customer.

5.1.3 Class 1, 2, 3, 4, 5, 6 and 7 ~~can~~may be either Type I or Type II depending on the application.

5.2 *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 may be formed from bending.

5.3 *Surface Area*—For classes 000, 00, 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. For Classes 5, 6 and 7 the total surface areas should be minimized to the extent possible.

5.4 *Material:*

5.4.1 *Class 000, 00, 0, 1, ~~2 and 3~~2, 3, 4, and 5 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.

5.4.2 ~~*Class 4, 5,*~~ *Classes 6 and 7*—~~The hardness and brittleness of the materials used for weights of Classes 4, 5, 6, and 7 shall be at least equal to that of drawn brass.~~Cylindrical class 6 and 7 weights below 5 kg and class 6 and 7 weights below 100 g shall be made of steel or a material whose hardness and resistance to corrosion is similar or better than that of steel. Other cylindrical class 6 and 7 weights of 5 kg or greater 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. The surface of the weights may be treated with a suitable coating in order to improve their corrosion resistance. This coating shall withstand shocks and outdoor weather conditions.

5.5 *Magnetism*—Weights shall not exceed maximum permissible magnetic properties as listed in ~~Table 2~~Tables 3 and 4 for any portion of the ~~weight:~~weight. If the values of all local measurements of magnetization and susceptibility are less than these limits, then it may be assumed that the uncertainty components due to the magnetism of the weight are negligible. The maximum permanent magnetization and magnetic susceptibilities given in Tables 3 and 4 are such that, at magnetic fields and magnetic field gradients possibly present on balance pans, they produce a change of the conventional mass of less than 1/10 of the maximum permissible error of the test weight.

TABLE 1 Maximum ~~Tolerances~~

colname="col2" colwidth="0.67in"> colname="col3" colwidth="0.67in"> colname="col4" colwidth="0.67in"> colname="col5" colwidth="0.67in"> colname="col6" colwidth="0.67in"> colname="col7" colwidth="0.67in"> colname="col8" colwidth="0.67in"> colname="col9" colwidth="0.67in">

Denomination	ASTM Tolerance Table ±mg except as noted							
	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
5000 kg	...	...	...	...	100 g	250 g	500 g	750 g
3000 kg	...	...	...	...	60 g	150 g	300 g	450 g
2000 kg	...	...	...	...	40 g	100 g	200 g	300 g
1000 kg	...	...	...	...	20 g	50 g	100 g	150 g
500 kg	...	...	...	...	10 g	25 g	50 g	75 g
300 kg	...	...	...	...	6.0 g	15 g	30 g	45 g
200 kg	...	...	...	...	4.0 g	10 g	20 g	30 g
100 kg	...	...	...	...	2.0 g	5 g	10 g	15 g
50 kg	63	125	250	500	1.0 g	2.5 g	5 g	7.5 g
30 kg	38	75	150	300	600 mg	1.5 g	3 g	4.5 g
25 kg	31	62	125	250	500	1.2 g	2.5 g	4.5 g
20 kg	25	50	100	200	400	1.0 g	2 g	3.8 g
10 kg	13	25	50	100	200	500 mg	1 g	2.2 g
5 kg	6	12	25	50	100	250	500 mg	1.4 g
3 kg	3.8	7.5	15	30	60	150	300	1.0 g
2 kg	2.5	5.0	10	20	40	100	200	750 mg
1 kg	1.3	2.5	5.0	10	20	50	100	470
500 g	0.60	1.2	2.5	5.0	10	30	50	300
300 g	0.38	0.75	1.5	3.0	6.0	20	30	210
200 g	0.25	0.50	1.0	2.0	4.0	15	20	160
100 g	0.13	0.25	0.50	1.0	2.0	9	10	100
50 g	0.060	0.12	0.25	0.60	1.2	5.6	7	...
30 g	0.037	0.074	0.15	0.45	0.90	4.0	5	44
20 g	0.037	0.074	0.10	0.35	0.70	3.0	3	33
10 g	0.025	0.050	0.074	0.25	0.50	2.0	2	21
5 g	0.017	0.034	0.054	0.18	0.36	1.3	2	13
3 g	0.017	0.034	0.054	0.15	0.30	0.95	2.0	9.4
2 g	0.017	0.034	0.054	0.13	0.26	0.75	2.0	7.0
1 g	0.017	0.034	0.054	0.10	0.20	0.50	2.0	4.5
500 mg	0.005	0.010	0.025	0.080	0.16	0.38	1.0	3.0
300 mg	0.005	0.010	0.025	0.070	0.14	0.30	1.0	2.2
200 mg	0.005	0.010	0.025	0.060	0.12	0.26	1.0	1.8
100 mg	0.005	0.010	0.025	0.050	0.10	0.20	1.0	1.2
50 mg	0.005	0.010	0.014	0.042	0.085	0.16	0.50	0.88
30 mg	0.005	0.010	0.014	0.038	0.075	0.14	0.50	0.68
20 mg	0.005	0.010	0.014	0.035	0.070	0.12	0.50	0.56
10 mg	0.005	0.010	0.014	0.030	0.060	0.10	0.50	0.4
5 mg	0.005	0.010	0.014	0.028	0.055	0.080	0.20	...
3 mg	0.005	0.010	0.014	0.026	0.052	0.070	0.20	...
2 mg	0.005	0.010	0.014	0.025	0.050	0.060	0.20	...
1 mg	0.005	0.010	0.014	0.025	0.050	0.050	0.10	...

TABLE 1 Maximum Permissible Errors

NOTE 1—Maximum Permissible Errors are reported in SI units, typically milligrams.

NOTE 2—The "grain" is the same in avoirdupois, troy and apothecaries units of mass.

NOTE 3—See NIST SP 811 and NIST SP 1038 for conversion and units of measure.

Denomination	±mg except as noted									
Metric	Class 000	Class 00	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
5000 kg					25 g	50 g	100 g	250 g	500 g	750 g
3000 kg					15 g	30 g	60 g	150 g	300 g	450 g
2000 kg					10 g	20 g	40 g	100 g	200 g	300 g
1000 kg					5 g	10 g	20 g	50 g	100 g	150 g
500 kg					2.5 g	5 g	10 g	25 g	50 g	75 g
300 kg					1.5 g	3 g	6.0 g	15 g	30 g	45 g
200 kg					1 g	2 g	4.0 g	10 g	20 g	30 g
100 kg					500 mg	1 g	2.0 g	5 g	10 g	15 g
50 kg	13 mg	25 mg	63 mg	125 mg	250	500 mg	1.0 g	2.5 g	5 g	7.5 g
30 kg	7.5	15	38	75	150	300	600 mg	1.5 g	3 g	4.5 g
25 kg	6.25	12.5	31	62	125	250	500	1.2 g	2.5 g	4.5 g
20 kg	5.0	10	25	50	100	200	400	1.0 g	2 g	3.8 g
10 kg	2.5	5.0	13	25	50	100	200	500 mg	1 g	2.2 g
5 kg	1.3	2.5	6.0	12	25	50	100	250	500 mg	1.4 g
3 kg	0.75	1.5	3.8	7.5	15	30	60	150	300	1.0 g
2 kg	0.5	1.0	2.5	5.0	10	20	40	100	200	750 mg
1 kg	0.25	0.5	1.3	2.5	5.0	10	20	50	100	470
500 g	0.13	0.25	0.60	1.2	2.5	5.0	10	30	50	300
300 g	0.075	0.15	0.38	0.75	1.5	3.0	6.0	20	30	210
200 g	0.05	0.10	0.25	0.50	1.0	2.0	4.0	15	20	160

TABLE 1 *Continued*

Denomination Metric	±mg except as noted Class 000	Class 00	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
100 g	0.025	0.05	0.13	0.25	0.50	1.0	2.0	9	10	100
50 g	0.015	0.030	0.060	0.12	0.25	0.60	1.2	5.6	7	62
30 g	0.014	0.026	0.037	0.074	0.15	0.45	0.90	4.0	5	44
20 g	0.013	0.025	0.037	0.074	0.10	0.35	0.70	3.0	3	33
10 g	0.010	0.020	0.025	0.050	0.074	0.25	0.50	2.0	2	21
5 g	0.005	0.010	0.017	0.034	0.054	0.18	0.36	1.3	2	13
3 g	0.005	0.010	0.017	0.034	0.054	0.15	0.30	0.95	2.0	9.4
2 g	0.005	0.010	0.017	0.034	0.054	0.13	0.26	0.75	2.0	7.0
1 g	0.005	0.010	0.017	0.034	0.054	0.10	0.20	0.50	2.0	4.5
500 mg	0.002	0.003	0.005	0.010	0.025	0.080	0.16	0.38	1.0	3.0
300 mg	0.002	0.003	0.005	0.010	0.025	0.070	0.14	0.30	1.0	2.2
200 mg	0.002	0.003	0.005	0.010	0.025	0.060	0.12	0.26	1.0	1.8
100 mg	0.002	0.003	0.005	0.010	0.025	0.050	0.10	0.20	1.0	1.2
50 mg	0.002	0.003	0.005	0.010	0.014	0.042	0.085	0.16	0.50	0.88
30 mg	0.002	0.003	0.005	0.010	0.014	0.038	0.075	0.14	0.50	0.68
20 mg	0.002	0.003	0.005	0.010	0.014	0.035	0.070	0.12	0.50	0.56
10 mg	0.002	0.003	0.005	0.010	0.014	0.030	0.060	0.10	0.50	0.40
5 mg	0.002	0.003	0.005	0.010	0.014	0.028	0.055	0.080	0.20	
3 mg	0.002	0.003	0.005	0.010	0.014	0.026	0.052	0.070	0.20	
2 mg	0.002	0.003	0.005	0.010	0.014	0.025	0.050	0.060	0.20	
1 mg	0.002	0.003	0.005	0.010	0.014	0.025	0.050	0.050	0.10	
0.5 mg	0.002	0.003	0.005	0.010	0.014	0.025	0.050	0.050	0.10	
0.3 mg	0.002	0.003	0.005	0.010	0.014	0.025				
0.2 mg	0.002	0.003	0.005	0.010	0.014					
0.1 mg	0.002	0.003	0.005	0.010						
0.05 mg	0.002	0.003	0.005							
Avoirdupois Pound			Class 0 mg	Class 1 mg	Class 2 g & mg	Class 3 g & mg	Class 4 g & mg	Class 5 g & mg	Class 6 g & mg	Class 7 g & mg
10000 lb					23 g	45 g	90 g	227 g	454 g	680 g
5000 lb					11 g	22 g	44 g	113 g	227 g	340 g
3000 lb					7 g	14 g	28 g	68 g	136 g	204 g
2500 lb					6 g	12 g	24 g	57 g	113 g	170 g
2000 lb					4.5 g	9 g	18 g	45 g	91 g	136 g
1000 lb					2.3 g	4.5 g	9 g	23 g	45 g	68 g
500 lb					1.7 g	2.3 g	4.6 g	11 g	23 g	34 g
100 lb			57 mg	110 mg	230 mg	460 mg	920 mg	2.3 g	4.5 g	6.8 g
50 lb			29	57	110	220	440	1.1 g	2.3 g	4.1 g
30 lb			17	34	68	140	260	680 mg	1.4 g	3 g
25 lb			14	28	56	110	220	570	1.1 g	2.5 g
20 lb			12	23	46	92	180	450	910 mg	2 g
10 lb			5.5	11	22	44	88	230	450	1.3 g
5 lb			2.7	5.4	11	22	43	110	230	760 mg
3 lb			1.7	3.4	6.8	14	27	68	140	510
2 lb			1.2	2.3	4.6	9.2	18	45	91	430
1 lb			0.55	1.1	2.2	4.4	8.8	27	45	270
0.5 lb			0.27	0.54	1.1	2.2	4.3	15	23	160
0.3 lb			0.17	0.34	0.68	1.4	2.7	10	14	110
0.2 lb			0.12	0.23	0.46	0.92	1.8	8.1	9.7	91
0.1 lb			0.055	0.11	0.22	0.44	1.1	5.1	6.8	56
0.05 lb			0.027	0.054	0.11	0.36	0.77	3.0	4.5	33
0.03 lb			0.017	0.034	0.068	0.32	0.59	2.0	3.2	22
0.02 lb			0.017	0.034	0.046	0.23	0.45	1.8	2.3	19
0.01 lb			0.012	0.023	0.034	0.16	0.34	1.2	1.4	12
0.005 lb			0.0075	0.015	0.024	0.14	0.27	0.86	0.91	7
0.003 lb			0.0075	0.015	0.024	0.11	0.22	0.64	0.91	5
0.002 lb			0.0075	0.015	0.024	0.091	0.19	0.50	0.91	4
0.001 lb			0.0075	0.015	0.024	0.068	0.15	0.36	0.91	3
0.0005 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.0003 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.0002 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.0001 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.00005 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.00003 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.00002 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
0.00001 lb			0.009	0.023	0.07	0.15	0.3	0.9	3	
Avoirdupois Ounce			Class 0 mg	Class 1 mg	Class 2 mg	Class 3 mg	Class 4 mg	Class 5 mg	Class 6 mg	Class 7 mg
10 oz			0.4	0.7	1.4	2.8	5.4	19	45	320
8 oz			0.3	0.6	1.2	2.3	4.5	16	23	180
5 oz			0.18	0.35	0.70	1.4	2.8	12	16	160
4 oz			0.14	0.28	0.55	1.1	2.3	9.5	11	110
3 oz			0.12	0.23	0.45	0.91	1.8	8.2	8.1	73
2 oz			0.07	0.13	0.26	0.64	1.3	5.9	5.4	48
1 oz			0.04	0.07	0.14	0.42	0.86	3.9	3.2	28

TABLE 1 *Continued*

Denomination	±mg except as noted									
Metric	Class 000	Class 00	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
1/2 oz			0.02	0.04	0.08	0.3	0.59	2.5	2.3	25
1/4 oz			0.015	0.03	0.06	0.2	0.43	1.5	1.4	9.1
1/8 oz			0.015	0.029	0.058	0.16	0.31	1.1	0.91	4.3
1/16 oz			0.013	0.025	0.050	0.12	0.24	0.73	0.91	4.3
1/32 oz			0.008	0.015	0.030	0.095	0.19	0.5	0.91	4.3
1/64 oz			0.006	0.012	0.024	0.077	0.15	0.36	0.91	4.3
0.50 oz					0.080	0.3	0.59	2.5	2.3	25
0.3 oz					0.068	0.23	0.45	1.8	1.4	9.1
0.2 oz					0.057	0.19	0.38	1.4	0.91	5.9
0.1 oz					0.050	0.14	0.29	0.91	0.91	4.3
0.05 oz					0.050	0.11	0.23	0.64	0.91	2.0
0.03 oz					0.030	0.095	0.19	0.45	0.91	2.0
0.02 oz					0.023	0.077	0.18	0.4	0.91	2.0
0.01 oz					0.023	0.064	0.14	0.3	0.91	2.0
0.005 oz					0.023	0.054	0.11	0.23	**	**
0.003 oz					0.023	0.05	0.095	0.19	**	**
0.002 oz					0.023	0.044	0.086	0.16	**	**
0.001 oz					0.023	0.038	0.077	0.13	**	**
0.0005 oz					0.023	0.031	0.064	0.11	**	**
0.0003 oz					0.023	0.029	0.059	0.095	**	**
0.0002 oz					0.023	0.027	0.054	0.086	**	**
0.0001 oz					0.023	0.026	0.05	0.073	**	**
Troy Ounce			Class 0	Class 1	Class 2 mg	Class 3 mg	Class 4 mg	Class 5 g & mg	Class 6 g & mg	Class 7
1000 oz t					160 mg	310 mg	620 mg	1.6 g	3.2 g	
500 oz t					80	160	310	770 mg	1.5 g	
300 oz t					45	90	190	470	940 mg	
200 oz t					31	62	120	310	620	
100 oz t					16	31	62	160	320	
50 oz t					8	16	31	77	150	
30 oz t					4.6	9.1	19	47	94	
20 oz t					3.1	6.2	12	35	58	
10 oz t					1.6	3.1	6.2	21	32	
5 oz t					0.8	1.6	3.1	12	16	
3 oz t					0.46	0.91	1.9	8.4	9.3	
2 oz t						0.71	1.4	6.4	8.0	
1 oz t						0.45	0.91	4.2	4.2	
0.5 oz t						0.31	0.62	2.6	2.6	
0.3 oz t						0.24	0.49	1.9	1.9	
0.2 oz t						0.20	0.40	1.5	2.3	
0.1 oz t						0.15	0.30	0.97	2.0	
0.05 oz t						0.12	0.23	0.65	2.0	
0.03 oz t						0.097	0.19	0.49	2.0	
0.02 oz t						0.084	0.17	0.41	1.1	
0.01 oz t						0.071	0.14	0.31	1.0	
0.005 oz t						0.056	0.11	0.23	1.0	
0.003 oz t						0.049	0.097	0.19	1.0	
0.002 oz t						0.044	0.091	0.17	0.50	
0.001 oz t						0.038	0.078	0.14	0.50	
0.0005 oz t						0.033	0.065	0.11	0.50	
0.0003 oz t						0.030	0.060	0.097	0.50	
0.0002 oz t						0.028	0.056	0.084	0.50	
0.0001 oz t						0.026	0.052	0.071	0.50	
Pennyweight			Class 0	Class 1	Class 2	Class 3	Class 4 g & mg	Class 5 g & mg	Class 6 g & mg	Class 7
10000 dwt							0.31 g	0.78 g	1.5 g	
5000 dwt							0.16 g	0.39 g	0.78 g	
3000 dwt							91 mg	0.23 g	0.46 g	
2000 dwt							62	0.16 g	0.32 g	
1000 dwt							31	78 mg	0.16 g	
500 dwt							16	41	82 mg	
300 dwt							9.1	28	56	
200 dwt							6.2	21	42	
100 dwt							3.1	12	24	
50 dwt							1.6	7.8	16	
30 dwt							1.2	5.3	11	
20 dwt							0.91	4.2	8.4	
10 dwt							0.62	2.6	5.2	
5 dwt							0.44	1.7	3.4	
3 dwt							0.34	1.3	2.6	
2 dwt							0.3	0.97	1.9	
1 dwt							0.23	0.65	1.3	
Grain			Class 0	Class 1	Class 2	Class 3	Class 4 mg	Class 5 mg	Class 6 mg	Class 7

TABLE 1 *Continued*

Denomination	±mg except as noted									
Metric	Class 000	Class 00	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
10000 gr							13	36	36	
5000 gr							6.5	22	22	
3000 gr							3.9	15	15	
2000 gr							2.6	11	11	
1000 gr							1.4	6.3	6.3	
500 gr							0.91	3.2	3.2	
300 gr							0.65	2.3	2.3	
200 gr							0.57	1.4	1.4	
100 gr							0.4	0.91	0.91	
50 gr							0.3	0.91	0.91	
30 gr							0.25	0.71	0.71	
20 gr							0.21	0.58	0.58	
10 gr							0.17	0.42	0.42	
5 gr							0.14	0.31	0.31	
3 gr							0.12	0.25	0.25	
2 gr							0.11	0.22	0.22	
1 gr							0.091	0.17	0.17	
0.5 gr							0.078	0.14	0.14	
0.3 gr							0.071	0.12	0.12	
0.2 gr							0.064	0.11	0.11	
0.1 gr							0.056	0.091	0.091	
0.05 gr							0.052	0.071	0.071	
0.03 gr							0.051	0.071	0.071	
0.02 gr							0.05	0.071	0.071	
0.01 gr							0.05	0.071	0.071	
Carat			Class 0	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
						mg	mg	mg	mg	mg
5000 c						10	20	50	100	470
3000 c						6.0	12	36	60	334
2000 c						4.0	8.0	27	44	287
1000 c						2.0	4.0	15	20	160
500 c						1.0	2.0	9	10	100
300 c						0.69	1.3	6	8	70
200 c						0.52	1.0	4.4	5	44
100 c						0.35	0.7	3	3	33
50 c						0.25	0.50	2	2	21
30 c						0.19	0.40	1.4	2	13
20 c						0.16	0.33	1	2	13
10 c						0.13	0.26	0.75	2	13
5 c						0.10	0.20	0.5	2	13
3 c						0.086	0.17	0.39	1	3
2 c						0.075	0.15	0.32	1	3
1 c						0.060	0.12	0.26	1	3
0.5 c						0.050	0.10	0.2	1	3
0.3 c						0.044	0.089	0.18	0.5	0.88
0.2 c						0.040	0.080	0.15	0.5	0.88
0.1 c						0.035	0.070	0.12	0.5	0.88
0.05 c						0.030	0.060	0.1	0.5	0.88
0.03 c						0.028	0.056	0.08	0.2	
0.02 c						0.027	0.053	0.07	0.2	
0.01 c						0.025	0.050	0.06	0.2	
Apothecary Ounce										
12 oz ap							7.5	15	45	290
10 oz ap							4.5	9	36	280
6 oz ap							3.5	7	23	184
5 oz ap							3.0	6	18	144
4 oz ap							2.5	5	16	128
3 oz ap							1.50	3	11	110
2 oz ap							1.00	2	9.1	91
1 oz ap							0.60	1.2	4.5	40
Apothecary Dram										
6 dr ap							0.40	0.8	3.6	36
5 dr ap							0.30	0.6	2.7	27
4 dr ap							0.27	0.55	2.3	23
3 dr ap							0.20	0.4	1.8	18
2 dr ap							0.20	0.4	1.8	18
1 dr ap							0.17	0.35	1.4	14
Apothecary Scruple										
2 s ap							0.17	0.35	1.4	14
1 s ap							0.15	0.30	0.91	9.1