NBSIR 78-1476

Precision Laboratory Standards of Mass and Laboratory Weights

A reprint of NBS Circular 547, Section 1
by Lashof and Macurdy, Aug. 1954

October 1978

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

PREFACE

National Bureau of Standards, Circular 547, Section 1, "Precision Laboratory Standards of Mass and Laboratory Weights," served for many years as a defining authority for various classes of weights and associated adjustment tolerances. Technological and organizational changes which occurred within a few years after the issuance gradually led to its obsolescence and consequently, it has been out of print for some time. In the interim, a new standard ASTM E617-78, "Lab Weights Precision Mass Standards," has been issued updating the same subject matter. There are still numerous requests for Circular 547 since it is widely referenced in the literature. While the document is reprinted in its entirety in NBS Handbook 77, this source is also out of print and available only at certain repository libraries. Because of technical content and historical value of Circular 547, it is being issued in the NBSIR series* of documents, to be available through NTIS. It should be noted, however, that for matters concerning calibration, one should refer to the latest copy of NBS SP-250, "Calibration and Test Services of the National Bureau of Standards", available from the Office of Measurement Services.

*Sections 5, 6, and 7, which refer to obsolete procedures, have been deleted.

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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

FOREWORD

National Bureau of Standards Circular 3, Design and Test of Standards of Mass, has been a basic reference on mass standards and weighing since its publication in 1918. The expanding needs of science, industry, and commerce call for the replacement of Circular 3 by a larger and more comprehensive document. Because of the time required to prepare a single large document, it is planned instead to prepare a series of publications covering the subject matter of Circular 3 and issue each as it is completed.

This first publication presents the specifications of the National Bureau of Standards for precision laboratory standards and other laboratory weights. It also presents the regulations governing the submission of these weights to the Bureau for test, and outlines the weight-calibration service of the Bureau. It supersedes chapters VI, VII, and XI and related portions of other chapters of Circular 3.

Other publications will present specifications for commercial standards of mass, methods of weighing, tests for sets of weights, a discussion of fundamental standards and concepts, and the design and test of balances and scales.

The material presented here is based not only on the third (1918) edition of Circular 3, prepared by A.T. Pienkowsky, but also on Mr. Pienkowsky's 1941 manuscript for a fourth edition. It also is based on suggestions and assistance received from manufacturers and suppliers of weights for scientific use at the 1952 Annual Meeting of the Scientific Apparatus Makers Association.

A.V. Astin, Director
1954

ERRATA TO CIRCULAR 547 SECTION 1, PRECISION LABORATORY STANDARDS OF MASS AND LABORATORY WEIGHTS

Page 10, Table 7, Acceptance tolerances[1] for class M weights is revised as follows:

1. The acceptance tolerance applies to both Class M and Class J weights.

2. The individual tolerances below 1 gram is changed to 0.010 mg.

3. The group tolerance for each group of weights in a particular decade below 1 gram is changed to 0.020 mg.

[1]All paragraphs referring to this table shall be revised to reflect these changes, in particular, the tolerance of 0.003 mg for Class J weights has been changed to 0.010 mg.

April 10, 1962

CONTENTS

Precision Laboratory Standards of Mass and Laboratory Weights

T. W. Lashof and L. B. Macurdy

This is the first part of the revision of National Bureau of Standards Circular 3, Design and Test of Standards of Mass, last revised in 1918. Laboratory standards of mass in order of decreasing precision are classes J, M, S, and S–1. The newly introduced class J weights, with a tolerance of 0.003 milligram for each weight, may be used for the calibration of equipment for ultramicroanalysis. Class M weights are reference standards for high-precision work and work demanding high constancy. Class S weights are laboratory working standards. Maintenance tolerances start at 0.0054 milligram for class M fractional weights and 0.014 milligram for the smallest class S weights, and decrease to 5 parts per million for the larger weights of both classes. Class S–1 are for use in routine analytical work with quick-weighing balances and are the most precise weights available in nonmetric units. Tolerances vary from 0.025 milligram for the smallest weights to 10 parts per million for the larger weights.

Classified for the first time are class P laboratory weights for routine analytical work, class Q for technical and student use, and class T for rough weighing operations. Maintenance tolerances for these weights start at 0.1 milligram for classes P and Q and 0.8 milligram for class T and decrease to 40, 100, and 300 parts per million, respectively, for the larger weights of these classes.

In addition to the tolerances, the denominations, composition, construction, marking, packing, and performance of weights of each class are fully described. Also described are the nature and precision of the tests available and other features of the Bureau's weight-calibration service. In general, the calibration service is intended primarily to provide standard weights for the calibration of other weights, for legal use, and for use in scientific work where the highest precision is required.

1. Introduction

The National Bureau of Standards throughout its history has been the center in the United States for the calibration of precision standards of mass. Because of its position, which stems from its custody of the national standards of mass, the Bureau has been the logical source of a system of classification for both commercial and scientific weights. Although the National Bureau of Standards is not invested with the authority to impose mandatory classifications and tolerances for weights, the classifications and tolerances that have been recommended by the Bureau have met with almost universal acceptance in this country.

The first classification issued by the National Bureau of Standards was given in Circular 3, in 1903. This was revised in 1907 and again in 1918. The 1918 revision of the Circular (although out of print for 25 years or more) has continued as a basic reference on mass standards up to the present time, even though additional classes of weights have been added to supplement the original ones.

During the 35 years that have passed since the publication of the third edition of Circular 3, a great expansion of scientific, technical, and commercial activity has taken place, bringing with it the need for new classes of weights and demands for improved constancy and accuracy in certain ranges of the established classes of weights. The major changes that have been made to meet these needs are:

1. The introduction of a new class J for very accurately adjusted microweights.
2. The use of tighter tolerances for classes M and S, especially for the smaller weights, in order that in semimicro and analytical work the corrections for these weights normally may be neglected.
3. The introduction of "group" tolerances in classes M and S, for the above purpose, and in order to prevent accumulation of errors when many small weights are used.
4. The separation of class S into an improved class S and a new class S–1, the latter being almost the equivalent of the class S of Circular 3, third edition, and these two classes conforming to the trade practice of double- and single-checked weights.
5. The provision of nonmetric denominations under class S–1, to meet the need for laboratory standards in these denominations.
6. The introduction of three classes, P, Q, and T, of rough laboratory weights, essentially equivalent to the classes of weights now available from the laboratory supply houses, in order to provide the standardization desired by the industry.
7. The use of a double tolerance scheme (acceptance tolerances for new or newly adjusted

weights and maintenance tolerances for weights that have been in use), which recognizes that weights of certain denominations and classes can and should be adjusted very closely so that they will remain within useful tolerances for a reasonable length of time.

8. A more detailed statement of the requirements, particularly with regard to material, design, and surface finish, and other factors that affect the constancy of weights, with a tightening of these requirements for classes M and S.

Several manufacturers are now making weights that meet the closer tolerances and other requirements for classes M and S mentioned above. As a matter of fact, the Bureau in 1951 increased the accuracy and precision with which it certified these weights. Modern research and the new quick-weighing devices demand the improved constancy and accuracy.

The Bureau will accept weights for certification under these new requirements, beginning 3 months after the date of this publication. For a period of a year after the date of this publication, the Bureau will continue to certify weights under the previous requirements of Circular 3. After the end of the 1-year period, noncommercial weights will be tested on the basis of these new requirements, and will be certified under one of the classes J, M, S, S–1, P, Q, and T, only when they meet all the requirements contained herein for the class for which they are submitted.

Although every effort has been made to meet present needs and to anticipate future needs for scientific mass standards and other laboratory weights, situations undoubtedly will arise that will indicate the need for amendments and additions to the material contained in this publication. The staff of the National Bureau of Standards will consider suggestions for modifications of these specifications. Recommendations for changes should be submitted to the National Bureau of Standards in writing, with sufficient detail and with the information, research documents, etc., necessary to establish the need for the recommended changes.

2. Classification of Weights

Weights may be divided into four groups according to their use, namely, precision laboratory standards, laboratory weights, commercial standards, and trade weights. Precision laboratory standards include weights used in scientific and technical laboratories as standards of mass for the calibration of other weights and weighing equipment or as precision laboratory weights for analytical work. Laboratory weights include weights used for rough analytical work and for general laboratory and technical work. Commercial standards include the State, office, and working standards used in law enforcement. Trade weights include weights used in the purchase and sale of goods both by the Government and in ordinary trade.

Table 1 lists the classes of weights under each of these groups except the trade group. The classification, specifications, and regulations for trade weights (as adopted by the National Conference of Weights and Measures and recommended by the National Bureau of Standards for promulgation by the several States) are covered in NBS Handbook 44,[1] revised to date, or its successor.

The intended use or purpose of weights of each of the laboratory classes is given at the beginning of chapters 3 and 4; that for each of the commercial classes (A, B, and C) is given in Circular 3.[2]

Table 1. *National Bureau of Standards classification of weights*

Class	Application
Precision Laboratory Standards	
J	Microweight standards (microbalance work).
M	High-precision scientific standards (reference, high-precision, and high-constancy work).
S	Scientific standards (reference, calibration, and precision analytical work).
S–1	Laboratory standards (routine analytical and precision nonmetric work).
Laboratory Weights	
P [1]	Analytical and precise technical weights.
Q	General laboratory, technical, and student weights.
T	Utility weights.
Commercial Standards (reference, working, and field standards used in law enforcement)	
A [2]	State primary standards.
B [2]	State working standards.
C [2]	Test weights.
Trade Weights (weights used in the sale of commodities and services)	
	See classes listed in NBS Handbook 44.

[1] Formerly class S–2.
[2] This classification is being revised.

[1] NBS Handbook 44, Specifications, tolerances, and regulations for commercial weights and measures, and weighing and measuring devices, for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $1.25.

[2] NBS Circular 3, 3d ed., Design and test of standards of mass (1918.) Out of print, but available in many libraries.

3. Requirements for Precision Laboratory Standards of Mass—Classes J, M, S, and S–1

Class J. These are metric weights designed primarily as standards for the calibration of weighing equipment used in the precise determination of very small masses in ultramicroanalysis. The effect of changes in relative humidity will be small for properly constructed class J weights.

Class M. These are metric weights designed for use as reference standards, for work of the highest precision, and for investigations demanding a high degree of constancy over a period of time. Tolerances for class M weights up to 5 g have been so selected that for most semimicro and microchemical work the corrections for the individual weights may be neglected.

When used with care, properly constructed class M weights will be constant within considerably less than the prescribed tolerances. As a group, these weights should be constant for several years within the indicated accuracy of the high-precision class M calibration (see 5.1, class M (a)).

Class S. These are metric weights designed as working standards for the calibration of other weights or as high-precision analytical weights for the more precise weighings in physical and chemical laboratories and in assay work. The tolerances for class S weights are such that the weights may be used without corrections, other than allowance for air buoyancy, for most analytical work and as keyboard or dial-controlled weights in quick-weighing analytical balances having a 200-g capacity.

Class S weights may be used also as reference standards. However, they may not be expected to remain as constant as class M weights.

Class S–1. These are designed for use as precision laboratory weights in routine analytical work with balances using quick-weighing devices, such as a chain. Class S–1 weights bridge the area between the best laboratory weights (class P) and the precision laboratory standards. Class S–1 includes weights in avoirdupois, apothecary, troy, and certain other units (see table 4), as well as those in metric units. Weights that meet class S–1 specifications are the most precise laboratory working standards currently available in nonmetric units.

3.1. Material

3.1.1. Hardness

Class J. Weights shall be constructed of hard, nonporous material, resistant to abrasion, and not likely to chip or spall in use. The Knoop hardness number of this material when determined at a test load of 100 g shall be 165 or greater (e. g., platinum-iridium or tantalum).

Classes M, S, and S–1. The hardness requirement shall apply to the material of which the body (including knob) of the weight is constructed and also to the plating of a plated weight, except as noted below under 3.1.1.1. The Knoop hardness number shall be as follows: (a) 125 or greater at a test load of 200 g for weights above 30 mg or equivalent (brass and harder materials, such as stainless steel); (b) 55 or greater at a test load of 100 g for weights 30 mg and below (aluminum and harder materials).

3.1.1.1. Option

Classes M and S. At the option of the purchaser, if class M or S weights are to be used as reference standards, the surface of weights 1 g and above may be protected with gold.

3.1.2. Corrosion Resistance

Classes J, M, S, and S–1. Weights shall be constructed of material that is resistant to oxidation or corrosion, except as follows:

Classes M, S, and S–1. Brass and materials similarly susceptible to oxidation and corrosion may be used for weights 1 g and above, provided that the surface is suitably protected in accordance with 3.3.3. Aluminum, aluminum alloys, and other metals that have resistance to oxidation and corrosion, depending largely on the surface condition of the metal, may be used only when the surface will take and hold a high polish.

3.1.2.1. Adjusting Material

Classes S and S–1. Tantalum, copper, aluminum, tin, or material equally resistant to oxidation and corrosion shall be used if adjusting material is required. Materials that readily oxidize and corrode (lead, dirt, powdered materials, organic materials, such as paper and oil, etc.) shall not be used in adjusting cavities.

3.1.2.2. Contamination

Classes J, M, S, and S–1. All surfaces, exterior and interior (including the adjusting cavity and threads of the knob) shall be free of deposits, residues, and other contaminating substances, such as residues from electroplating and cleaning solutions.

3.1.3. Magnetic Properties

Classes J, M, S, and S–1. Weights shall be constructed of nonmagnetic material. Neither ferromagnetic nor strongly paramagnetic materials may be used.

Classes S and S–1. Nonmagnetic stainless-steel alloys (including type 18–8) may be used, provided the nickel content is at least 50 percent by weight of the chromium content.

3.1.4. Density

Classes J and M. No requirements.

Classes S and S–1. The total volume, including any air-tight cavity, shall be such that the average density is within the ranges shown in table 2.

TABLE 2. *Density for class S and S–1 weights*

Weights	Allowed density
	g/cm³
Greater than 1 g (or equivalent)	7.8 to 9.1
1 g to 50 mg, inclusive (or equivalent)	4.5 and up
Less than 50 mg	2.6 and up

3.2. Design

3.2.1. GENERAL SHAPE

Classes J, M, S, and S–1. A weight may have any shape that does not introduce features that reduce the reliability of the weight. All weights shall be free of ragged or sharp edges or ends. Wire weights shall not be excessively long and shall not be tightly coiled or otherwise shaped so as to have a tendency to catch and hold lint or dust. Both sheet-metal and wire weights shall be free from cracks such as may be formed in bending.

3.2.2. THICKNESS

Classes J, M, S, and S–1. Sheet-metal weights shall not be unnecessarily thin. In particular, the weights shall not be so thin that the surface tension of water will bend them out of shape.

Class J. The nominal thicknesses of the material from which sheet-metal weights are formed shall be equal to or greater than the values in table 3. The actual thickness shall be not less than 90 percent of the nominal thickness.

3.2.3. NUMBER OF PIECES

Classes J, M, S, and S–1. The entire weight shall be a single piece and homogeneous, except as follows:

Class M. Surface protection in accordance with 3.3.3; gold adjusting material fused on the upper surface of sheet-metal weights.

Classes S and S–1. Surface protection (3.3.3); means of adjustment (such as a screw knob covering an adjusting cavity); adjusting material in adjusting cavity; gold adjusting material fused on the upper surface of sheet-metal weights.

TABLE 3. *Nominal thickness for class J sheet-metal weights*

(Minimum values)

Weight	Thickness	Weight	Thickness
mg	*in.*	*mg*	*in.*
50	0.0059	1	0.0009
30	.0047	0.5	.0006
20	.0042	.3	.00045
10	.0031	.2	.00037
5	.0023	.1	.00026
3	.0015	.05	.00019
2	.0013		

3.3. Surface

3.3.1. IRREGULARITIES

Classes J and M. The entire surface of the weight shall be smooth, except for such markings as are allowed under 3.5, and shall be highly polished.

Classes S and S–1. The entire surface of the weights shall be smooth, except for such markings as are required under 3.5, and shall be carefully polished or have equivalent finish.

3.3.2. POROSITY

Classes J, M, S, and S–1. When subjected to unaided visual inspection, the surface shall appear free from pits and pores and shall show no effects of porosity.

3.3.3. PROTECTION

(a) LARGER WEIGHTS (i. e., weights other than sheet-metal or wire weights)

Class M. Weights of brass, bronze, or other metals that tarnish on exposure to the atmosphere shall be plated with platinum, rhodium, or other suitable metal. Gold plating may be used at option of purchaser (3.1.1.1). There shall be no darkening of the surface and no formation of spots of any kind when the weights are boiled for 3 half-hour periods in distilled water and cooled in distilled water between boilings, or when the weights are subsequently dried at a temperature of 110° C for 1 hour.

Classes S and S–1. Unless the surface material is at least as resistant to atmospheric corrosion as aluminum, it shall be plated with metals such as platinum or rhodium, or shall be lacquered. Lacquer, if used, shall be hard, of only moderate thickness, transparent, and not easily chipped. Lacquer shall not be used, however, on weights that are made of, or are plated with, a material that normally need not be protected against oxidation or corrosion. Gold plating shall not be used as the final coating, except that class S weights that are to be used as reference standards may be gold plated at option of purchaser (3.1.1.1).

(b) SHEET-METAL AND WIRE WEIGHTS

Classes J, M, S, and S–1. Sheet-metal and wire weights shall be made of a material that requires no surface protection. If these weights are adjusted by fusing or plating, the adjusting material shall require no surface protection. Lacquer or other coatings, other than electroplating, shall not be used.

3.4. Denominations

3.4.1. SYSTEM IN WHICH DENOMINATIONS ARE EXPRESSED.

Classes J, M, and S. The system shall be metric.

Class S–1. The system shall be metric, avoirdupois, apothecary, troy, or certain other units as set forth in table 4.

3.4.2. Individual Weights.

Classes J, M, S, and S–1. The denominations shall be selected from table 4, except when weights are intended for a special application.

3.4.3. Sets of Weights.

Classes J, M, S, and S–1. The weights included in a set shall be sufficient for each weight of the set to be compared directly with another weight of the set or with a summation of other weights of the set.

3.4.3.1. Optional Series.

Classes J, M, S, and S–1. The weights of a set may be arranged in one or more of the following series: 5–2–1–1–**1**; 5–2–2–1–**1**; 5–3–2–1–**1**; or 8–4–2–1–**1**; or equivalent as specified in 3.4.3. The unit in boldface represents a summation of smaller weights of the set. When there are no smaller weights in the set, the unit in boldface represents an additional weight that is required by 3.4.3 in the 5–2–1–1–**1** and 8–4–2–1–**1** series, but which may be omitted in the 5–2–2–1–**1** or 5–3–2–1–**1** series.

Table 4. *Preferred denominations for precision laboratory standards of mass*

Classes										
J	M	S	S–1	S–1 (nonmetric)						
Metric				Avoirdupois		Apothecary	Troy	Grain	Carat	
mg	*kg*	*kg*	*kg*	*lb*	*oz*	*oz ap*	*oz t*	*Grain*	*c*	
50	25	50	50	100	10	12	1, 000	10, 000	2, 500	
30	20	25	25	50	8	10	500	5, 000	2, 000	
20	10	20	20	25	5	8	300	3, 000	1, 000	
10	5	10	10	20	4	6	200	2, 000	500	
5	3	5	5	10	3	5	100	1, 000	300	
3	2	3	3	8	2	4	50	500	200	
2	1	2	2	5	1	3	30	300	100	
1		1	1	4	½	2	20	200	50	
0. 5	*g*			3	¼	1	10	100	30	
. 3	500	*g*	*g*	2	⅛		5	50	20	
. 2	300	500	500	1	1/16	*dr ap*	3	30	10	
. 1	200	300	300	0. 5	1/32	6	2	20	5	
. 05	100	200	200	. 3	1/64	5	1	10	3	
	50	100	100	. 2	0. 5	4	0. 5	5	2	
	30	50	50	. 1	. 3	3	. 3	3	1	
	20	30	30	. 05	. 2	2	. 2	2	0. 5	
	10	20	20	. 03	. 1	1	. 1	1	. 3	
	5	10	10	. 02	. 05	½	. 05	0. 5	. 2	
	3	5	5	. 01	. 03		. 03	. 3	. 1	
	2	3	3	. 005	. 02	*s ap*	. 02	. 2	. 05	
	1	2	2	. 003	. 01	2	. 01	. 1	. 03	
		1	1	. 002	. 005	1	. 005	. 05	. 02	
	mg			. 001	. 003		. 003	. 03	. 01	
	500	*mg*	*mg*	. 0005	. 002		. 002	. 02	Assay ton	
	300	500	500	. 0003	. 001		. 001	. 01		
	200	300	300	. 0002	. 0005		. 0005	. 005	*A.T.*	
	100	200	200	. 0001	. 0003		. 0003		4	
	50	100	100	. 00005	. 0002		. 0002		2	
	30	50	50	. 00003	. 0001		. 0001		1	
	20	30	30	. 00002					0. 5	
	10	20	20	. 00001			*dwt*		. 2	
	5	10	10				10, 000		. 1	
	3	5	5				5, 000		. 05	
	2	3	3				3, 000			
	1	2	2				2, 000		Factor weights	
	0. 5	1	1				1, 000			
	. 3	0. 5	0. 5				500			*g*
	. 2	. 3	. 3				300		Carbon	2. 7273
	. 1	. 2	. 2				200		½ carbon	1. 3636
	. 05	. 1	. 1				100		¼ silicon	1. 1680
		. 05	. 05				50		1/10 silicon	0. 4672
							30		Phosphorus	1. 630
							20			
							10		Sugar	52
							5			26
							3			13
							2			
							1			

TABLE 5. *Maximum and minimum denominations of commonly used sets of precision laboratory standards of mass*

Class and purpose	From maximum	To minimum
Class J:		
Microbalance	50 mg	0.05 mg
Classes M and S:		
GENERAL PURPOSE		
Analytical balance	100 g	1 mg
Semimicro-balance	50 g	1 mg
Microanalytical balance	20 g	1 mg
Assay balance	1 g	1 mg
BALANCE WITH BUILT-IN WEIGHTS (100 mg to 1 mg)		
Analytical balance	100 g	100 mg
Semimicro balance	50 g	100 mg
Microanalytical balance	20 g	100 mg
Class S–1:		
GENERAL PURPOSE (metric)		
Large-capacity balance	20, 5, 2, or 1 kg	1 g or 5 mg
Large-capacity analytical balance	500 or 200 g	5 mg
Analytical balance	100 g	5 mg
ANALYTICAL BALANCE		
With chain	100 g	100 mg
With chain and rider or with chain and built-in weights	100 g	1 g
GENERAL PURPOSE (customary)		
Avoirdupois	50, 10, 5, 2, or 1 lb or 8 oz	$\frac{1}{32}$ oz
Do	50, 10, 5, 2, or 1 lb	0.001 lb
Do	10 oz	0.001 oz
Apothecary	12 oz ap or 4 dr ap	0.1 grain
Troy	500 oz t	0.1 grain
Do	500 oz t	0.001 oz t
Grain	1,000 grain	0.1 grain
Carat	(with two 200-c weights) 200 c	0.01 c
Assay ton	4 or 1 A.T.	$\frac{1}{20}$ A.T.

3.4.3.2. OPTIONAL MAXIMUM AND MINIMUM DENOMINATIONS.

Classes J, M, S, and S–1. Maximum and minimum denominations of commonly used sets of laboratory standards of mass are given in table 5.

3.5. Marking of Weights

3.5.1. DENOMINATION

Classes J, M, S, and S–1. Weights shall be marked with the number and unit, as specified in 3.5.1.1 and 3.5.1.2

3.5.1.1. NUMBER

By "number" is meant the number representing the nominal mass or "value" of each weight as expressed in terms of some acceptable unit.

Class J. If the shape or size of a weight does not distinguish it from other weights of the set, it may be marked with small shallow dots or other distinguishing marks. The numbers may be marked on the larger weights, and, if marked, shall be expressed in milligrams.

Class M. The numbers may be marked on the weights, and if marked, shall be expressed in kilograms, grams, or milligrams.

Class S. The number shall be plainly marked upon each weight, except in the case of riders and other wire weights, and shall be expressed in kilograms, grams, or milligrams.

Class S–1. The number shall be plainly marked upon each weight, except in the case of riders and other wire weights, and shall be expressed in terms of one of the units listed in appendix 2.

3.5.1.2. UNIT

Classes J, M, S, and S–1. The unit (in terms of which the nominal value of each weight is expressed) shall be as specified in 3.5.1.1 for each class. The name of the unit, if abbreviated, shall be abbreviated in accordance with appendix 2. The abbreviation shall not include a period.

Classes J and M. The unit shall not be marked on weights less than 100 g.

Classes S and S–1 (metric). The unit may be marked on the larger sheet-metal and cylindrical weights.

Class S–1 (nonmetric). The markings shall include the name of the unit or its accepted abbreviation in accordance with appendix 2, except that on cylindrical weights below ½ oz or equivalent and on sheet-metal weights below 1 grain or equivalent, the name of the unit may be omitted when space does not permit its inclusion in legible form.

3.5.2. Duplicate Weights

Classes J, M, S, and S–1. Duplicate weights shall each be marked with one or more distinguishing marks.

3.5.3. Unnecessary Markings

Classes J, M, S, and S–1. Markings other than those required or allowed in 3.5.1.1, 3.5.1.2, and 3.5.2 shall not be used.

3.5.4. Depth of Markings

Classes J, M, S, and S–1. Markings shall be shallow, relatively broad, and free from burrs and sharp angles. The markings shall not perforate or crack sheet-metal weights.

3.6. Lifters

Classes J, M, S, and S–1. Special lifters or forceps shall be provided for sets of weights. Lifters or forceps shall be provided for individual weights when specified by the purchaser.

3.6.1. Design of Lifters

Classes J, M, S, and S–1. The lifters or forceps shall hold securely the weights for which they are designed. Additional pressure shall not cause the dropping of small weights or the forceful ejection of large weights.

(a) For weights 500 g and larger the parts of the lifters that may come into contact with the weights shall be covered with some material softer than the surface of the weight, such as plastic, velvet, or chamois skin from which the grease has been removed.

(b) For smaller weights the lifters may be of the same design, where practicable, or may be of a material softer than the weights, such as ivory, close-grained wood, or plastics that are not affected by alcohol. When the parts of the lifters or forceps that come in contact with the weights are not covered with a soft material, they shall be smooth and polished and the edges on which weights may be partially or wholly lifted shall be well rounded.

(c) If forceps are used solely for lifting sheet-metal weights, steel forceps with gold-plated tips may be used.

3.6.2. Warping of Lifters

Classes J, M, S, and S–1. Forceps shall be so constructed that with use or with storage in a closed position they will not warp enough to interfere with their performance.

3.7. Case

Classes J, M, S, and S–1. One or more suitable cases shall be provided with each set of weights. The case shall be so designed that, as long as the lid remains closed, the weights cannot get out of their pockets (3.7.1). The hinges and locks shall be adequate to hold the lid closed with any reasonable handling. There shall be no discoloration of the weights due to the lining or the case, such as might result from long storage in a warm or damp location.

Class J. The case shall be dustproof.

3.7.1. Pockets

Classes J, S, and S–1. A separate pocket shall be provided for lifters or forceps and for each weight, and all pockets shall be large enough so that no appreciable frictional force will be encountered in inserting or removing weights. If the cover is not lined, the individual holes in the cover for the knobs of the weights shall be smooth or lined. Pockets for weights 1 g or equivalent and larger shall be lined with some soft material, such as velvet.

Class M. Either a lined pocket shall be provided, as specified for classes J, S, and S–1, or the position of the weight may be determined by a shallow ring or plate. If a guard ring or plate is used, the diameter of the unlined pocket or opening shall be at least 10 percent larger (and in all instances at least 2 mm larger) than the diameter of the weight, and all parts of the case shall be designed so that the weights can be inserted or removed without danger of rubbing on any part of the case.

3.7.2. Marking of Case

Classes J, M, S, and S–1. The class and the unit or system of units shall be marked conspicuously on the case. In addition, denominations shall be marked as follows:

Class J. Each pocket of the case shall be marked with the denomination of the weight to be kept in the pocket.

Class M. If the denomination is not marked on the weight (3.5.1), it shall be marked beside the pocket in which the weight is kept.

Classes S and S–1. The denominations may be marked beside the pockets in which the weights are kept.

3.8. Tolerances

The tolerance of a weight is the maximum allowable departure of the weight from its nominal value.

3.8.1. Basis For Adjustment

Classes J, M, S, and S–1. Ordinarily, weights shall be adjusted according to their "apparent mass versus brass" values. However, in those cases in which the larger weights of a set are of

TABLE 6. *Tolerances for class S–1 weights*

Not more than one-third of the weights of a set of new or newly adjusted weights may be in error by more than one-half of these tolerances, and all weights shall be correct within these tolerances.

Avoirdupois						Troy						Apothecary		
Denomination	Tolerance		Denomination	Tolerance		Denomination	Tolerance		Denomination	Tolerance		Denomination	Tolerance	
lb	*mg*	*lb*	*oz*	*mg*	*Grain*	*oz t*	*mg*	*Grain*	*dwt*	*mg*	*Grain*	*oz ap*	*mg*	*Grain*
100	450	.0010	10	2.8	0.043	1,000	310	4.8	10,000	160	2.5	12	3.8	0.059
			8	2.3	.035							10	3.1	.048
		Grain	5	1.4	.022	500	160	2.5	5,000	78	1.2	8	2.5	.039
50	230	3.5				300	91	1.4	3,000	47	0.73			
25	110	1.7	4	1.1	.017	200	62	0.96	2,000	31	.48	6	1.9	.029
20	91	1.4	2	0.65	.010	100	31	.48	1,000	16	.24	5	1.6	.025
10	45	0.70	1	.43	.0066							4	1.2	.019
						50	16	.25	500	7.8	.12			
8	36	.56	½	.30	.0046	30	9.1	.14	300	4.7	.072	3	0.91	.014
5	23	.35	¼	.21	.0032	20	6.2	.096	200	3.1	.048	2	.70	.011
4	18	.28	⅛	.16	.0025	10	3.1	.048	100	1.6	.025	1	.45	.0069
3	14	.21	1/16	.12	.0018	5	1.6	.025	50	0.80	.012	*dr ap*		
2	9.1	.14	1/32	.095	.0015	3	0.91	.014	30	.58	.0090	6	.38	.0059
1	4.5	.070	1/64	.078	.0012	2	.70	.011	20	.45	.0071	5	.34	.0053
						1	.45	.0069	10	.31	.0048	4	.31	.0048
						0.5	.31	.0048	5	.22	.0034			
lb	*mg*	*Grain*	*oz*	*mg*	*Grain*	.3	.24	.0037	3	.17	.0026	3	.27	.0042
0.5	2.3	0.035	0.5	0.30	0.0046	.2	.20	.0031	2	.15	.0023	2	.22	.0034
.2	0.91	.014	.3	.23	.0035	.1	.15	.0023	1	.12	.0019	1	.16	.0025
.1	.58	.0089	.2	.19	.0029									
			.1	.14	.0022	.05	.12	.0019				⅓	.13	.0020
.05	.38	.0059				.03	.097	.0015						
.02	.24	.0037	.05	.11	.0017	.02	.085	.0013				*s ap*		
.01	.17	.0026	.03	.095	.0015	.01	.070	.0011				2	.14	.0022
			.02	.080	.0012							1	.11	.0017
.005	.13	.0020	.01	.066	.0010	.005	.056	.00086						
.002	.096	.0015				.003	.049	.00076						
.001	.076	.0012	.005	.055	.00085	.002	.044	.00068						
			.003	.048	.00074	.001	.038	.00059						
.0005	.062	.00096	.002	.044	.00068									
.0002	.049	.00076	.001	.038	.00059	.0005	.033	.00051						
.0001	.041	.00063				.0003	.030	.00046						
			.0005	.032	.00049	.0002	.028	.00043						
.00005	.036	.00056	.0003	.029	.00045	.0001	.026	.00040						
.00002	.030	.00046	.0002	.028	.00043									
.00001	.028	.00043	.0001	.026	.00040									

TABLE 6. *Tolerances for class S–1 weights*—Continued

Grain			Metric				Carat		Assay ton	
Denomination	Tolerance		Denomination	Tolerance	Denomination	Tolerance	Denomination	Tolerance	Denomination	Tolerance
Grain	*mg*	*Grain*	*kg*	*mg*	*g*	*mg*	*c*	*mg*	*A.T.*	*mg*
10, 000	6. 5	0. 10	50	500	5	0. 18	2, 500	5. 0	4	1. 2
			25	250	3	. 15	2, 000	4. 0	2	0. 70
5, 000	3. 2	. 050	20	200	2	. 13	1, 000	2. 0	1	. 44
2, 000	1. 3	. 020	10	100	1	. 10				
1, 000	0. 72	. 011					500	1. 0	0. 5	. 30
			5	50	*mg*		200	0. 52	. 2	. 19
500	. 48	. 0074	3	30	500	. 080	100	. 35	. 1	. 15
200	. 28	. 0043	2	20	300	. 070				
100	. 20	. 0031	1	10	200	. 060	50	. 25	. 05	. 12
					100	. 050	20	. 16		
50	. 15	. 0023	*g*				10	. 13		
20	. 11	. 0017	500	5. 0	50	. 042			Factor weights	
10	. 086	. 0013	300	3. 0	30	. 038	5	. 10		
			200	2. 0	20	. 035	2	. 075	Denomination	Tolerance
5	. 072	. 0011	100	1. 0	10	. 030	1	. 060		
2	. 054	. 00083							*g*	*mg*
1	. 045	. 00070	50	0. 60	5	. 028	0. 5	. 050	Carbon 2. 7293	0. 14
			30	. 45	3	. 026	. 2	. 040	½ carbon 1. 3636	. 11
0. 5	. 039	. 00060	20	. 35	2	. 025	. 1	. 035	¼ silicon 1. 1680	. 11
. 2	. 032	. 00050	10	. 25	1	. 025			1/10 silicon 0. 4672	. 08
. 1	. 028	. 00043					. 05	. 030	Phosphorus 1. 630	. 12
					0. 5	. 025	. 02	. 027		
. 05	. 026	. 00040			. 3	. 025	. 01	. 025		
. 02	. 025	. 00038			. 2	. 025			Sugar 52	. 62
. 01	. 025	. 00038			. 1	. 025			26	. 41
									13	. 28
. 005	. 025	. 00038								

some material having a density markedly different from brass, all the weights of the set may be adjusted (at the option of the purchaser) according to the apparent mass vs. platinum, tantalum, gold, or whatever is the material of the larger weights.

"Apparent mass vs. brass" values are those that the weights would be assigned on the basis of a comparison at 20° C in normal air against normal brass standards. "Apparent mass vs. other material" values are those that the weights would be assigned on the basis of a comparison at 20° C in normal air against the true mass of standards of this other material. In both cases, no corrections would be applied for the buoyant effect of the "normal air" (defined as air having a density of 1.2 mg/cm³), and values would be derived from the true mass of the standards (normal brass standards being defined as standards composed of brass having a density of 8.4 g/cm³ at 0° C and a coefficient of cubical expansion of 0.000054 per deg Celsius (centigrade)).

3.8.2. Acceptance Tolerances

Classes J, M, S, and S–1. New and newly adjusted weights shall meet the tolerance requirements specified in 3.8.2.1 and 3.8.2.2.

3.8.2.1. Tolerances For Individual Weights

Class J. For weights that can be intercompared readily in a series (i. e., weights of the preferred denominations listed in table 4), the tolerance for each weight shall be 0.003 mg. For weights the denominations of which are of irregular amounts not readily intercomparable in a series, the tolerance for each weight shall be specified by the purchaser, but normally shall be not less than the tolerances for the class M weights nearest it in value.

Class M. Individual weights shall be correct within the tolerances prescribed in table 7 in the column marked "Individual."

Class S. Individual weights shall be correct within the tolerances prescribed in table 8 in the column marked "Individual."

Class S–1. Weights shall be correct within the tolerances prescribed in table 6, and, in addition, not more than one-third of the weights of a set of new or newly adjusted weights may be in error by more than one-half of these prescribed tolerances.

Classes M, S, and S–1. For an individual weight of a denomination not listed in the tables, the tolerance shall be determined by proportional interpolation between tolerances given for weights of the next larger and next smaller amounts.

3.8.2.2. Group Tolerances

Classes M and S. The corrections of the individual weights shall be such that no combination of weights that is intended to be used in a weighing shall differ from the sum of the nominal values by more than the amount listed under the group tolerance. The group tolerances and the weights to which they apply are as follows:

Class M. Weights of a set that include weights less than 10 g shall conform to the group tolerances prescribed in table 7 in the column marked "Group."

Class S. Weights of a set that include weights smaller than 50 g shall conform to the group tolerances prescribed in table 8 in the column marked "Group."

3.8.3. Maintenance Tolerances

Classes J, M, S, and S–1. Weights that have been in use shall meet the tolerance requirements specified in 3.8.2.1. and 3.8.2.2., except as follows:

Class M. Maintenance tolerances for weights from 500 mg to 100 mg shall be 0.0105 mg for individual weights and 0.020 mg for the group.

Class S. Maintenance tolerances for weights 100 mg and larger shall be twice the acceptance tolerances for these weights, as shown in table 8 both for individual weights and for decade groups.

Table 7. *Acceptance tolerances* [1] *for class M weights*

Denomination	Individual	Group
kg	mg	mg
25	125	
20	100	
10	50	
5	25	
3	15	
2	10	
1	5. 0	
g		
500	2. 5	
300	1. 5	
200	1. 0	
100	0. 50	
50	. 25	
30	. 15	
20	. 10	
10	. 050	
5	. 034	0. 065
3	. 034	
2	. 034	
1	. 034	
mg		
500	. 0054	0. 0105
300	. 0054	
200	. 0054	
100	. 0054	
50	. 0054	0. 0105
30	. 0054	
20	. 0054	
10	. 0054	
5	. 0054	0. 0105
3	. 0054	
2	. 0054	
1	. 0054	
0. 5	. 0054	0. 0105
. 3	. 0054	
. 2	. 0054	
. 1	. 0054	
. 05	. 0054	0. 0105

[1] Maintenance tolerances are the same as acceptance tolerances, except that the maintenance tolerances for weights from 500 mg to 100 mg are 0.0105 mg for individual weights and 0.020 mg for the group.

TABLE 8. *Acceptance tolerances [1] for class S weights*

Denomination	Individual	Group
kg	*mg*	*mg*
25	62	
20	50	
10	25	
5	12	
3	7.5	
2	5.0	
1	2.5	
g		
500	1.2	
300	0.75	
200	.50	
100	.25	
50	.12	
30	.074	0.154
20	.074	
10	.074	
5	.054	0.105
3	.054	
2	.054	
1	.054	
mg		
500	.025	0.055
300	.025	
200	.025	
100	.025	
50	.014	0.034
30	.014	
20	.014	
10	.014	
5	.014	0.034
3	.014	
2	.014	
1	.014	
0.5	.014	0.034
.3	.014	
.2	.014	
.1	.014	
.05	.014	0.034

[1] Maintenance tolerances for weights below 100 mg are the same as the acceptance tolerances. For weights 100 mg and above the maintenance tolerances are twice the acceptance tolerances.

3.9. Constancy Under Variations in Humidity

Classes S and S–1. When the relative humidity of the surrounding atmosphere is kept at 30 percent for 3 days, raised to 70 percent and kept there for 4 days, and then brought back to 30 percent and kept there for 2 days, neither the mean variation nor the net gain shall be more than the amounts specified or calculated in accordance with table 9.

TABLE 9. *Tolerances on variability and net gain caused by variations in atmospheric humidity from 30 percent to 70 percent for weights of classes S and S–1*

Denomination	Maximum allowable variation and net gain for—	
	Class S	Class S–1
g	*mg*	*mg*
Σ221	0.22	0.65
Σ200	.20	.60
Σ121	.15	.44
Σ100	.13	.38
Σ50	.085	.25
100	.070	.21
50	.050	.14
30	.030	.090
20	.025	.075
10	.016	.048
5	.011	.032
3	.009	.028
2	.007	.020
1	.005	.015

The "mean variation" is defined as the average of the quantities B–A and C–D, and the "net gain" is defined as the quantity D–A, where A, B, C, and D are the measured masses (corrected for the buoyant effect of the air) of the weights under the following conditions: (A) After the first 3 days at 30 percent relative humidity, (B) after 1 day at 70 percent, (C) after 4 days at 70 percent, and (D) after again being at 30 percent for 2 days.

For individual weights of denominations listed in table 9, the allowable variation and net gain shall be as listed in the table. For individual weights of denominations not listed in the table, the allowable variations and net gain shall be determined by proportional interpolation between values given for weights of the next larger and next smaller amounts.

For all ordinary sets and for groups the sum of which does not exceed 250 g or equivalent, the allowable variation and net gain shall be applied to the sum of the weights. Larger groups shall be divided in any appropriate manner into groups of 250 g or smaller. For sets or groups of weights listed in table 9, the allowable variation and net gain shall be as listed. For sets or groups of weights not listed in the table, the allowable variation and net gain shall be equal to the sum of the amounts allowable on weights of the denominations actually in the group.

3.10. Packaging

This section applies to new or newly adjusted weights.

3.10.1. Separate Package

Classes J, M, S, and S–1. Each set of weights

and each individual weight not part of a set shall be packaged separately.

3.10.2. Seal

Classes J, M, S, and S–1. The package shall be sealed by the manufacturer or adjuster so that the weights cannot be removed from the package without destroying the seal. The weights shall be packed in accordance with 6.4 before sealing.

3.10.3. Marking

Classes J, M, S, and S–1. The sealed package shall be marked with the class of weight, the maximum and minimum denominations contained therein, the unit or system of units, the name of the manufacturer, the manufacturer's type number, a caution against breaking the seal, and any other appropriate information.

3.10.4. Manufacturer's Information Sheet

Classes J, M, S, and S–1. A manufacturer's information sheet shall be packaged with new weights. It shall list the density to two or three significant figures and also the composition of the alloy, commercial grade, or accepted trade name of the material of which the weights are composed. (See 3.1 for specifications as to density and composition.) The nature of the surface protection (3.3.3) and the construction (one-piece, screw-knobs, screw-knob pinned, driven knob, etc.) shall also be described on the information sheet.

4. Requirements for Laboratory Weights—Classes P, Q, and T

Class P (formerly class S–2). These weights are designed for routine analytical work in the scientific or technical laboratory.

Class Q. These weights are designed for use with precision pressure gages and for the technical work of commercial and student laboratories. Weights of this class are suitable for the laboratory dispensing of chemicals and pharmaceuticals, rough determination of mass in the elementary physics laboratory, etc.

Class T. These weights are designed for rough weighing operations in the physical and chemical laboratories, such as with force-measuring apparatus.

4.1. Material

4.1.1. Hardness

Classes P, Q, and T. The Knoop hardness number shall be as follows: (a) 125 or greater at a test load of 200 g for weights above 5 g or ¼ oz or equivalent (brass and harder materials); (b) 55 or greater at a test load of 100 g for weights of 5 g or equivalent and below (aluminum and harder materials).

4.1.1.1. Option

Classes P, Q, and T. If the weights are to receive rough use, the hardness requirement may be changed at the option of the purchaser to read: The Knoop hardness number shall be 225 or greater at a test load of 500 g for all weights (cast iron and stainless or dense steel).

4.1.2. Corrosion Resistance

Classes P, Q, and T. Weights shall be constructed of material that is resistant to oxidation or corrosion. Lead shall not be used. Cast iron and other metals with similar rates of oxidation may be used for weights of class T but shall not be used for weights of the other classes. Iron and steel shall not be used for weights of 5 g or ¼ oz or equivalent and below, except that stainless steel may be used for weights of all denominations.

4.1.2.1. Adjusting Material

Classes P, Q, and T. Brass, copper, aluminum, tin, or material equally resistant to oxidation and corrosion shall be used if adjusting material is required.

Classes P and Q. Lead shall not be used.

4.1.2.2. Contamination

Classes P, Q, and T. All surfaces, exterior and interior (including the adjusting cavity and threads of the knob) shall be free of deposits, residues, and other contaminating substances, such as cutting oil and residues from electroplating and cleaning solutions.

4.1.3. Magnetic Properties

Class P. Weights shall be constructed of nonmagnetic material, with the following exceptions or provisions:

(a) Nickel may be used for surface protection.

(b) Nonmagnetic stainless steel alloys may be used, provided the nickel content is at least 50 percent by weight of the chromium content.

(c) Dense steel, rolled or otherwise worked, may be used for weights of 10 kg or 20 lb or equivalent and above.

Class Q. Class P specifications apply except that dense steel, rolled or otherwise worked, may be used for weights above 5 g or ¼ oz or equivalent.

Class T. Class Q specifications apply except that cast iron may be used for weights of 100 g or 4 oz or equivalent and above.

4.1.4 Density

Classes P, Q, and T. Weights shall be constructed of materials having densities within the ranges shown in table 10.

Table 10. *Density for laboratory weights*

Class	Weights	Allowed density
		g/cm³
P, Q	2 g or 1/16 oz or 30 grains and greater	7.2 to 10.0
	Less than 2 g or 1/16 oz	2.6 and up
T	100 g or 4 oz and greater	7.0 to 10.0
	Less than 100 g or 4 oz and greater than 30 g or 1 oz	2.6 and up
	30 g or 1 oz and smaller	1.0 and up

4.2. Design

4.2.1. Edges and Corners

Classes P, Q, and T. A weight shall have no sharp edges or corners or other features, such as perforations or cracks, that introduce danger of excessive change with ordinary use. Sheet-metal weights shall not be unnecessarily thin.

4.2.2. Rings

Classes P, Q, and T. A weight shall have no movable parts, except as follows:

Class T. A weight of this class may have a ring provided that the ring is not split or removable.

4.2.3. Knobs

Classes P, Q, and T. A knob shall be held in place tightly enough to prevent its working loose with ordinary handling.

4.2.4. Shape

Classes P, Q, and T. A weight shall be shaped so as not to be susceptible to undue variability, in particular:

Classes P and Q. A weight of these classes shall not have a coin shape, unless the weight meets the hardness requirement for rough use as specified in 4.1.1.1.

4.2.5. Adjusting Material

Classes P, Q, and T. Adjusting material shall be securely contained and shall not project beyond the surface of the weight.

4.3. Surface

4.3.1. Irregularities

Classes P, Q, and T. Any irregularities of the surface shall be slight and not of sharp contour. The surface shall be free from pits or pores visible to the unaided eye.

4.3.2. Protection

Classes P, Q, and T. A weight shall be resistant to corrosion or tarnishing by the air or by handling with the bare hands. When the base metal is of such material that protection is required, a plating such as nickel or a thin coating of transparent paint or lacquer shall be used. If transparent paint or lacquer is used, it shall be hard and not likely to chip. No lacquer or paint of any kind shall be used on sheet-metal weights or on weights composed of a material needing no surface protection. If sheet-metal weights are adjusted by fusing or plating, the adjusting material shall require no surface protection. Opaque paint may be used as follows:

Classes P and Q. On weights above 50 kg or 100 lb.

Class T. On all weights, except as noted above.

4.4. Denominations

4.4.1. Individual Weights

Classes P, Q, and T. Except when weights are intended for a special application, the denominations of the weights shall be selected from table 11.

4.4.2 Sets of Weights

Classes P, Q, and T. A set of weights shall include the duplicates necessary to permit weighing of any load within the range of the set.

4.4.2.1. Optional Maximum and Minimum Denominations

Classes P, Q, and T. Maximum and minimum denominations of commonly used sets of laboratory weights are given in table 12.

4.5. Marking of Weights

4.5.1. Designation of Value

Classes P, Q, and T. The nominal mass or "value" of each weight shall be plainly marked upon it, except in the case of riders and other wire weights. Wire weights shall be bent in such forms as to suggest the denomination, unless they are to be used as riders or for other purposes that demand special forms. Nominal values shall be expressed in terms of one of the units listed in appendix 2.

4.5.2. Designation of Unit

Classes P, Q, and T. The marking shall include the name of the unit or its accepted abbreviation in accordance with appendix 1, except that on knob weights below 10 g or ½ oz or equivalent and on sheet-metal weights below 100 mg or 1 grain or equivalent the name of the unit may be omitted when space does not permit its inclusion in legible form. The abbreviation shall not include a period. In the case of weights of the troy or apothecary systems for which the nominal values

TABLE 11. *Preferred denominations for laboratory weights*

Classes F, Q, and T			Classes P and Q				Class P
Metric	Avoirdupois		Apothecary	Troy		Grain	Carat
kg	*lb*	*oz*	*oz ap*	*oz t*	*dwt*	*Grain*	*c*
1, 000	2, 500	10	12	1, 000	10, 000	10, 000	2, 500
500	2, 000	8	10	500	5, 000	5, 000	2, 000
200	1, 000	5	8	300	3, 000	3, 000	1, 000
100	500	4	6	200	2, 000	2, 000	500
50	200	3	5	100	1, 000	1, 000	300
25	100	2	4	50	500	500	200
20	50	1	3	30	300	300	100
10	25	1/2	2	20	200	200	50
5	20	1/4	1	10	100	100	30
3	10	1/8		5	50	50	20
2	8	1/16	*dr ap*	3	30	30	10
1	5	1/32	6	2	20	20	5
	4	1/64	5	1	10	10	3
g	3		4	0. 5	5	5	2
500	2	0. 5	3	. 3	3	3	1
300	1	. 3	2	. 2	2	2	0. 5
200		. 2	1	. 1	1	1	. 3
100	0. 5	. 1	1/2	. 05		0. 5	. 2
50	. 3	. 05		. 03		. 3	. 1
30	. 2	. 03	*s ap*	. 02		. 2	. 05
20	. 1	. 02	2	. 01		. 1	. 03
10	. 05	. 01	1	. 005		. 05	. 02
5	. 03	. 005		. 003		. 03	. 01
3	. 02	. 003		. 002		. 02	
2	. 01	. 002		. 001		. 01	
1	. 005	. 001		. 0005		. 005	
	. 003	. 0005		. 0003			
mg	. 002	. 0003		. 0002			
500	. 001	. 0002		. 0001			
300	. 0005	. 0001					
200	. 0003						
100	. 0002						
50	. 0001						
30	. 00005						
20	. 00003						
10	. 00002						
5	. 00001						
3							
2							
1							
0. 5							
. 3							
. 2							
. 1							
. 05							

are expressed in pounds, ounces, drams, or scruples, the identification letter "t" or "ap" shall be used in addition to the name or abbreviation of the unit.

4.5.3. UNNECESSARY MARKINGS

Classes P, Q, and T. Markings other than those required or allowed in 4.5.1 and 4.5.2 shall not be used, except as follows: (a) On weights of 25 kg or 50 lb or equivalent and above, unnecessary markings such as the name or the trade mark of maker or dealer shall be limited to no more than the shortest name by which the firm commonly is known, and the numbers or letters composing the marking shall be no larger than those of the denomination. (b) On weights less than 25 kg or 50 lb or equivalent, unnecessary markings shall be relatively inconspicuous as compared with the denomination.

4.5.4. DEPTH OF MARKING

Classes P, Q, and T. Raised or depressed letters or figures shall not be deeper than 0.04 inch (1 mm).

4.6. Lifters

Class P. Special lifters or forceps shall be provided for weights of a set. All parts of the lifters that come in contact with the weights shall be smooth, and shall have no sharp or rough edges. Forceps shall be so constructed that with use or with storage in a closed position they will not warp so as to interfere with their performance.

TABLE 12. *Maximum and minimum denominations of commonly used sets of laboratory weights*

Class and system	From maximum	To minimum
Class P (formerly S2):		
Metric	100 or 50 g	1 g or 5 mg
	500 mg	5 mg
Avoirdupois	50, 10, 5, or 2 lb	1/32 oz
Apothecary	12 oz ap or 4 dr ap	0.1 grain
Grain	10 grain	0.1 grain
Troy	5 oz t	0.1 grain
Carat	(with two 200-c weights) 200 c	0.01 c
Class Q:		
Metric	5, 2, or 1 kg	1 g
	500, 200, or 100 g	1 g
	2 or 1 kg, 500, 200, or 100 g	10 mg
	50, 10, or 1 g, or 500 mg	10 mg
Avoirdupois	8, 4, 2, or 1 lb, or 8 oz	1/16 oz
Apothecary	8, 4, or 2 dr ap	1/2 grain
Grain	20 grain	1 grain
Troy	50, 20, or 5 oz t	1/2 grain
Class T:		
Metric	20, 5, 2, or 1 kg	10 g
Avoirdupois	50, 8, 4, 2, or 1 lb	1/2 oz

4.7. Case

Classes P, Q, and T. When a closed case is required or provided, it shall be so designed that as long as the lid remains closed the weights cannot get out of their pockets (4.7.1). The hinges and locks shall be adequate to hold the lid closed with any reasonable handling.

Class P. A closed case or box shall be provided with each set of weights.

Classes Q and T. A closed or an open case may be provided for weights of these classes.

4.7.1. POCKETS

Classes P, Q, and T. When a case is provided, it shall contain a separate pocket for lifters or forceps and for each weight, and all pockets shall be large enough so that no appreciable frictional force will be encountered in inserting or removing the weights. Deep pockets either shall be lined with some soft material, such as velvet, or shall be smooth, free from grit or hard specks or streaks, and of fine-grained wood or other material not likely to scratch the weights.

4.7.2. MARKING OF CASE

Classes P, Q, and T. The name of the class and the name of the unit or system of units shall be conspicuously marked on the case.

4.8. Tolerances

4.8.1. BASIS FOR ADJUSTMENT

Classes P, Q, and T. The weights shall be adjusted on the basis of their apparent mass as determined by comparison with brass standards in air.

4.8.2. ACCEPTANCE TOLERANCES

Classes P, Q, and T. New and newly adjusted weights shall be correct within the tolerances prescribed in table 13. The tolerance for a weight less than those listed in table 13 shall be 5 percent of the nominal value of the weight. The tolerance for other weights not listed in the table shall be determined by proportional interpolation between tolerances given for weights of the next larger and the next smaller denomination.

4.8.3. MAINTENANCE TOLERANCES

Classes P, Q, and T. Weights that have been in use shall be correct within twice the acceptance tolerances prescribed in table 13.

4.9. Packaging

This section applies to new or newly adjusted weights.

4.9.1. SEPARATE PACKAGE

Classes P, Q, and T. Each set of weights and each individual weight not part of a set shall be packaged separately.

Classes P and Q. For weights of these classes, the package shall be sealed by the manufacturer or adjuster so that the weights cannot be removed from the package without destroying the seal. The weights shall be packed in accordance with 6.4 before sealing.

4.9.2. MARKING

Classes P, Q, and T. The package shall be marked with the class of weight, the maximum and minimum denominations contained therein, the unit or system of units, the name of the manufacturer, the manufacturer's type number, and any other appropriate information.

TABLE 13. *Acceptance tolerances [1] for laboratory weights*

Avoirdupois													
Denomination	P	Q	T	P	Q	T	Denomination	P	Q	T	P	Q	T
lb	*g*	*g*	*g*	*lb*	*lb*	*lb*	*oz*	*mg*	*mg*	*mg*	*Grain*	*Grain*	*Grain*
2, 500	23	56	170	0. 050	0. 12	0. 38	10	5. 6	19	200	0. 086	0. 29	3. 1
2, 000	18	45	140	. 040	. 10	. 30	8	4. 5	16	170	. 069	. 25	2. 6
1, 000	9. 1	23	68	. 020	. 050	. 15	5	2. 8	12	130	. 043	. 19	2. 0
500	4. 5	11	34	. 010	. 025	. 075	4	2. 3	9. 6	110	. 035	. 15	1. 7
200	1. 8	4. 5	14	. 0040	. 010	. 030	2	1. 3	6. 1	70	. 020	. 094	1. 1
	mg						1	0. 86	3. 9	42	. 013	. 060	0. 65
100	910	2. 3	7. 0	. 0020	. 0050	. 015							
				Grain	*Grain*	*Grain*	½	. 59	2. 5	27	. 0091	. 039	. 42
50	450	1. 1	4. 1	7. 0	17	63	¼	. 43	1. 6	17	. 0066	. 025	. 26
		mg					⅛	. 31	1. 1	10	. 0048	. 017	. 15
25	230	570	2. 4	3. 5	8. 8	37							
20	180	450	2. 0	2. 8	7. 0	31	1/16	. 24	0. 70	6. 5	. 0037	. 011	. 10
15	140	340	1. 7	2. 1	5. 2	26	1/32	. 19	. 48	4. 2	. 0029	. 0074	. 065
10	91	230	1. 3	1. 4	3. 5	20	1/64	. 15	. 36	2. 8	. 0023	. 0056	. 043
8	73	180	1. 1	1. 1	2. 8	17							
			mg										
5	45	110	810	0. 70	1. 7	12	*oz*	*mg*	*mg*	*mg*	*Grain*	*Grain*	*Grain*
4	36	91	700	. 56	1. 4	11	0. 5	0. 59	2. 5	27	0. 0091	0. 039	0. 42
							. 3	. 46	1. 8	19	. 0071	. 028	. 29
3	27	68	580	. 42	1. 0	9. 0	. 2	. 38	1. 4	14	. 0059	. 022	. 22
2	18	46	440	. 28	0. 71	6. 8	. 1	. 29	0. 92	9. 0	. 0045	. 014	. 14
1	9. 1	27	270	. 14	. 42	4. 2							
							. 05	. 23	. 62	5. 7	. 0035	. 0096	. 088
							. 03	. 19	. 47	4. 1	. 0029	. 0072	. 063
							. 02	. 17	. 40	3. 2	. 0026	. 0062	. 049
lb	*mg*	*mg*	*mg*	*Grain*	*Grain*	*Grain*	. 01	. 14	. 30	2. 2	. 0022	. 0046	. 034
0. 5	4. 5	16	170	0. 069	0. 25	2. 6							
. 2	1. 8	8. 3	94	. 028	. 13	1. 5	. 005	. 11	. 23	1. 5	. 0017	. 0035	. 023
. 1	1. 1	5. 3	59	. 017	. 082	0. 91	. 003	. 095	. 19	1. 1	. 0015	. 0029	. 017
							. 002	. 087	. 16	0. 92	. 0013	. 0025	. 014
. 05	0. 75	3. 4	37	. 012	. 052	. 57	. 001	. 075	. 13	. 66	. 0012	. 0020	. 010
. 02	. 48	1. 9	20	. 0074	. 029	. 31							
. 01	. 34	1. 2	12	. 0052	. 019	. 19	. 0005	. 064	. 11	. 47	. 00099	. 0017	. 0073
							. 0003	. 058	. 095	--------	. 00090	. 0015	--------
. 005	. 27	0. 81	7. 7	. 0042	. 013	. 12	. 0002	. 055	. 085	--------	. 00085	. 0013	--------
. 002	. 19	. 49	4. 2	. 0029	. 0076	. 065	. 0001	. 050	. 069	--------	. 00077	. 0011	--------
. 001	. 15	. 36	2. 9	. 0023	. 0056	. 045							
. 0005	. 13	. 27	2. 0	. 0020	. 0042	. 031							
. 0002	. 097	. 18	1. 2	. 0015	. 0028	. 019							
. 0001	. 083	. 16	0. 83	. 0013	. 0025	. 013							
. 00005	. 072	. 13	. 60	. 0011	. 0020	. 0093							
. 00002	. 060	. 097	--------	. 00093	. 0015	--------							
. 00001	. 055	. 079	--------	. 00085	. 0012	--------							

TABLE 13. *Acceptance tolerances*[1] *for laboratory weights*—Continued

Apothecary					Grain				
Denomination	P	Q	P	Q	Denomination	P	Q	P	Q
oz ap	*mg*	*mg*	*Grain*	*Grain*	*Grain*	*mg*	*mg*	*Grain*	*Grain*
12	7. 5	28	0. 12	0. 43	10, 000	13	36	0. 20	0. 56
10	6. 2	21	. 096	. 32					
8	5. 0	18	. 077	. 28	5, 000	6. 5	22	. 10	. 34
					2, 000	2. 6	11	. 040	. 17
6	3. 8	14	. 059	. 22	1, 000	1. 4	6. 6	. 022	. 10
5	3. 1	12	. 048	. 19					
4	2. 5	10	. 039	. 15	500	0. 93	4. 3	. 014	. 066
					200	. 57	2. 3	. 0088	. 035
3	1. 9	8. 4	. 029	. 13	100	. 40	1. 5	. 0062	. 023
2	1. 4	6. 5	. 022	. 10					
1	0. 90	4. 2	. 014	. 065	50	. 30	1. 0	. 0046	. 015
					20	. 22	0. 58	. 0034	. 0090
dr ap					10	. 17	. 42	. 0026	. 0065
6	. 76	3. 4	. 012	. 052					
5	. 69	3. 1	. 011	. 048	5	. 14	. 31	. 0022	. 0048
4	. 62	2. 6	. 0096	. 040	2	. 11	. 22	. 0017	. 0034
					1	. 090	. 17	. 0014	. 0026
3	. 54	2. 2	. 0083	. 034					
2	. 44	1. 7	. 0068	. 026	0. 5	. 078	. 14	. 0012	. 0022
1	. 32	1. 1	. 0049	. 017	. 2	. 064	. 11	. 00099	. 0017
½	. 26	0. 72	. 0040	. 011	. 1	. 056	. 088	. 00086	. 0014
					. 05	. 052	. 072	. 00080	. 0011
s ap									
2	. 28	. 87	. 0043	. 013	. 02	. 050	----------	. 00077	----------
1	. 22	. 58	. 0034	. 0090	. 01	. 050	----------	. 00077	----------

[1] Maintenance tolerances are twice the acceptance tolerances.

TABLE 13. *Acceptance tolerances [1] for laboratory weights*—Continued

Troy									
Denomination	P	Q	P	Q	Denomination	P	Q	P	Q
oz t	*mg*	*g*	*Grain*	*Grain*	*dwt*	*mg*	*mg*	*Grain*	*Grain*
1, 000	620	1. 6	9. 6	24	10, 000	310	780	4. 8	12
		mg			5, 000	160	390	2. 5	6. 0
500	310	780	4. 8	12	3, 000	93	230	1. 4	3. 6
300	190	470	2. 9	7. 2	2, 000	62	160	0. 96	2. 4
200	120	310	1. 9	4. 8	1, 000	31	78	. 48	1. 2
100	62	160	0. 96	2. 4					
					500	16	41	. 24	0. 63
50	31	78	. 48	1. 2	300	9. 3	28	. 14	. 43
30	19	47	. 29	0. 73	200	6. 2	21	. 096	. 32
20	12	35	. 19	. 54	100	3. 1	12	. 048	. 19
10	6. 2	21	. 096	. 32					
					50	1. 6	7. 5	. 025	. 12
5	3. 1	12	. 048	. 19	30	1. 2	5. 3	. 019	. 082
3	1. 9	8. 4	. 029	. 13	20	0. 90	4. 2	. 014	. 065
2	1. 4	6. 5	. 022	. 10	10	. 62	2. 6	. 0096	. 040
1	0. 90	4. 2	. 014	. 065					
					5	. 44	1. 7	. 0068	. 026
0. 5	. 62	2. 6	. 0096	. 040	3	. 34	1. 3	. 0052	. 020
. 3	. 49	1. 9	. 0076	. 029	2	. 30	1. 0	. 0046	. 015
. 2	. 40	1. 5	. 0062	. 023	1	. 23	0. 65	. 0035	. 010
. 1	. 30	1. 0	. 0046	. 015					
. 05	. 23	0. 65	. 0035	. 010					
. 03	. 19	. 49	. 0029	. 0076					
. 02	. 17	. 41	. 0026	. 0063					
. 01	. 14	. 31	. 0022	. 0048					
. 005	. 11	. 23	. 0017	. 0035					
. 003	. 097	. 19	. 0015	. 0029					
. 002	. 089	. 17	. 0014	. 0026					
. 001	. 076	. 14	. 0012	. 0022					
. 0005	. 066	. 11	. 0010	. 0017					
. 0003	. 060	. 10	. 00093	. 0015					
. 0002	. 056	. 087	. 00086	. 0013					
. 0001	. 052	. 071	. 00080	. 0011					

TABLE 13. *Acceptance tolerances* [1] *for laboratory weights*—Continued

Metric								Carat	
Denomination	P	Q	T	Denomination	P	Q	T	Denomination	P
kg	*g*	*g*	*g*	*g*	*mg*	*mg*	*mg*	*c*	*mg*
1, 000	20	50	150	50	1. 2	5. 6	62	2, 500	10
				30	0. 90	4. 0	44	2, 000	8. 0
500	10	25	75	20	. 70	3. 0	33	1, 000	4. 0
200	4. 0	10	30	10	. 50	2. 0	21		
100	2. 0	5. 0	15					500	2. 0
				5	. 36	1. 3	13	200	1. 0
50	1. 0	2. 5	7. 5	3	. 30	0. 95	9. 4	100	0. 70
	mg			2	. 26	. 75	7. 0		
25	500	1. 2	4. 5	1	. 20	. 50	4. 5	50	. 50
20	400	1. 0	3. 8					20	. 33
		mg		*mg*				10	. 26
10	200	500	2. 2	500	. 16	. 38	3. 0		
				300	. 14	. 30	2. 2	5	. 20
5	100	250	1. 4	200	. 12	. 26	1. 8	2	. 15
3	60	150	1. 0	100	. 10	. 20	1. 2	1	. 12
			mg						
2	40	100	750	50	. 085	. 16	0. 88	0. 5	. 10
1	20	50	470	30	. 075	. 14	. 68	. 2	. 080
				20	. 070	. 12	. 56	. 1	. 070
g				10	. 060	. 10	. 40		
500	10	30	300					. 05	. 060
300	6. 0	20	210	5	. 055	. 080	----------	. 02	. 053
200	4. 0	15	160	3	. 052	. 070	----------	. 01	. 050
100	2. 0	9. 0	100	2	. 050	. 060	----------		
				1	. 050	. 050	----------		

[1] Maintenance tolerances are twice the acceptance tolerances.

Appendix 1. Conversion Factors for Units of Mass

Values in boldface are exact values

Units of mass less than pounds and kilograms

Unit	Grains	Apothecaries' scruples	Pennyweights	Avoirdupois drams	Apothecaries' drams	Avoirdupois ounces
1 grain =	**1**	**0.05**	0.041 666 67	0.036 571 43	0.016 666 7	0.002 285 71
1 apothecary scruple =	**20**	**1**	0.833 333 3	0.731 428 6	0.333 333	0.045 714 3
1 pennyweight =	**24**	**1.2**	**1**	0.877 714 3	**0.4**	0.054 857 1
1 avoirdupois dram =	**27.343 75**	**1.367 187 5**	1.139 323	**1**	0.455 729 2	**0.062 5**
1 apothecary dram =	**60**	**3**	**2.5**	2.194 286	**1**	0.137 142 9
1 avoirdupois ounce =	**437.5**	**21.875**	18.229 17	**16**	7.291 67	**1**
1 apothecary or troy ounce =	**480**	**24**	**20**	17.554 28	**8**	1.097 142 9
1 apothecary or troy pound =	**5 760**	**288**	**240**	210.651 4	**96**	13.165 714
1 avoirdupois pound =	**7 000**	**350**	291.666 7	**256**	116.666 7	**16**
1 milligram =	0.015 432 356	0.000 771 618	0.000 643 014 8	0.000 564 383 3	0.000 257 205 9	0.000 035 273 96
1 gram =	15.432 356	0.771 618	0.643 014 85	0.564 383 3	0.257 205 9	0.035 273 96
1 kilogram =	15 432.356	771.617 8	643.014 85	564.383 32	257.205 94	35.273 96

Unit	Apothecaries' or troy ounces	Apothecaries' or troy pounds	Avoirdupois pounds	Milligrams	Grams	Kilograms
1 grain =	0.002 083 33	0.000 173 611 1	0.000 142 857 1	64.798 918	0.064 798 918	0.000 064 798 9
1 apothecary scruple =	0.041 666 7	0.003 472 222	0.002 857 143	1 295.978 4	1.295 978 4	0.001 295 978
1 pennyweight =	**0.05**	0.004 166 667	0.003 428 571	1 555.174 0	1.555 174 0	0.001 555 174
1 avoirdupois dram =	0.056 966 146	0.004 747 178 8	**0.003 906 25**	1 771.845 4	1.771 845 4	0.001 771 845
1 apothecary dram =	**0.125**	0.010 416 667	0.008 571 429	3 887.935 1	3.887 935 1	0.003 887 935
1 avoirdupois ounce =	0.911 458 3	0.075 954 861	**0.062 5**	28 349.527	28.349 527	0.028 349 53
1 apothecary or troy ounce =	**1**	0.083 333 33	0.068 571 43	31 103.481	31.103 481	0.031 103 48
1 apothecary or troy pound =	**12**	**1**	0.822 857 1	373 241.77	373.241 77	0.373 241 77
1 avoirdupois pound =	14.583 333	1.215 277 8	**1**	**453 592.427 7**	**453.592 427 7**	**0.453 592 427 7**
1 milligram =	0.000 032 150 74	0.000 002 679 23	0.000 002 204 62	**1**	**0.001**	**0.000 001**
1 gram =	0.032 150 74	0.002 679 23	0.002 204 62	**1 000**	**1**	**0.001**
1 kilogram =	32.150 742	2.679 228 5	2.204 622 341	**1 000 000**	**1 000**	**1**

Units of mass greater than avoirdupois ounces

Units	Avoirdupois ounces	Avoirdupois pounds	Short hundredweights	Short tons	Long tons	Kilograms	Metric tons
1 avoirdupois ounce =	**1**	**0.062 5**	**0.000 625**	**0.000 031 25**	0.000 027 901 79	0.028 349 53	0.000 028 349 53
1 avoirdupois pound =	**16**	**1**	**0.01**	**0.000 5**	0.000 446 428 6	**0.453 592 427 7**	0.000 453 592 43
1 short hundredweight =	**1 600**	**100**	**1**	**0.05**	0.044 642 86	45.359 243	0.045 359 243
1 short ton =	**32 000**	**2 000**	**20**	**1**	0.892 857 1	907.184 86	0.907 184 86
1 long ton =	**35 840**	**2 240**	**22.4**	**1.12**	**1**	1 016.047 04	1.016 047 04
1 kilogram =	35.273 957	2.204 622 34	0.022 046 223	0.001 102 311 2	0.000 984 206 4	**1**	**0.001**
1 metric ton =	35 273.957	2 204.622 34	22.046 223	1.102 311 2	0.984 206 40	**1 000**	**1**

Appendix 2. Units and Abbreviations for Marking Weights

Name of unit	Accepted abbreviation
Assay ton (29.1667 g)	AT [1]
Carat (200 mg)	c
Dram, apothecaries'	dr ap
Grain	GN [1]
Gram	g
Kilogram	kg
Milligram	mg
Ounce, apothecaries' (480 grain)	oz ap
Ounce, avoirdupois (437.5 grain)	oz
Ounce, troy (480 grain)	oz t
Pennyweight	dwt
Pound, avoirdupois	lb
Scruple, apothecaries'	s ap

[1] In descriptive material the abbreviation for "assay ton" should be written A. T., and "grain" should be spelled out.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

National Bureau of Standards, Circular 547, Section 1, "Precision Laboratory Standards of Mass and Laboratory Weights," served for many years as a defining authority for various classes of weights and associated adjustment tolerances. Technological and organizational changes which occurred within a few years after the issuance gradually led to its obsolescence and consequently, it has been out of print for some time. In the interim, a new standard ASTM E617-78, "Lab Weights Precision Mass Standards," has been issued updating the same subject matter. There are still numerous requests for Circular 547 since it is widely referenced in the literature. While the document is reprinted in its entirety in NBS Handbook 77, this source is also out of print and available only at certain repository libraries. Because of technical content and historical value of Circular 547, it is being issued in the NBSIR series* of documents, to be available through NTIS. It should be noted, however, that for matters concerning calibration, one should refer to the latest copy of NBS SP250, "Calibration and Test Services of the National Bureau of Standards," available from the Office of Measurement Services.

* Sections 5, 6 and 7, which refer to obsolete procedures, have been deleted.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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