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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Construction Materials Testing[1]

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1. Scope*

1.1 This specification provides minimum requirements for general-purpose scales, balances, and standard masses used in testing soil, rock, and related construction materials.

1.2 This specification provides guidance for evaluating, selecting, and specifying general purpose scales, balances, and standard masses used in testing soil, rock, and related construction materials.

1.3 The accuracy requirements for balances and scales are specified in terms of the combined effect of all sources of error contributing to overall balance performance. The measurement of specific sources of error and consideration of details pertaining to balance construction have been intentionally avoided.

1.4 This specification does not include requirements for balances and scales that have accuracies greater than those generally required in normal soil, rock, and related construction materials.

1.5 This specification does not apply to nongraduated balances.

1.6 This specification does not address the methods used to verify or quantify specific parameters dealing with balances and scales. For a description of tests used in evaluating balance performance, see NIST Handbook 44.

1.7 This specification is not intended to be used as a specification for the purchase of balances and scales.

NOTE 1—The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), and the International Organization of Legal Metrology (OIML) publish standards or practices that specify construction requirements as well as performance specifications for balances. ASTM, OIML, and NIST publish construction standards and tolerances for standard masses.

NOTE 2—The terms "mass" and "determine the mass of" are used in this standard instead of the more commonly used terms "weight" and "weigh" to comply with standard metric practice. In addition, the term "standard mass(es)" is used instead of "weight(s)" when referring to a piece of material of known specified mass used to compare or measure the mass of other masses.

2. Referenced Documents

2.1 *ASTM Standard:*

E 617 Specification for Laboratory Weights and Precision Mass Standards[2]

2.2 *National Institute of Standards and Technology Documents:*

NIST Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices[3]

NIST Handbook 105-1 Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures[3]

2.3 *International Organization for Legal Metrology (OIML):*

International Recommendation No. 20 Weights of Accuracy Classes E_1, E_2, F_1, F_2, M_1 from 50 kg to 1 mg[4]

International Recommendation No. 3[4]

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *accurate*—a balance is "accurate" when its performance (its indication as determined by tests made with suitable standards) conforms to the standard within the applicable tolerances and other performance requirements. Balances that fail to conform are "inaccurate."

3.1.2 *balance*—an instrument for determining the mass of an object by the action of gravity on the object. See *scale*.

NOTE 3—In this specification the terms balance and scale are used interchangeably as is often done. The term balance is more often used in scientific fields of application. See Note 7.

3.1.3 *basic condition*—a basic condition is a condition that must be met before a basic measurement for evaluating a balance can be performed.

3.1.4 *basic measurement (of error)*—a basic measurement for evaluating a balance is performed by (*1*) determining the change of indication of the balance when a load of known mass is added to or subtracted from any load already on the balance; and (*2*) taking the difference between the change in the indication determined and the known value of the mass.

3.1.5 *basic tolerance*—basic tolerances are those tolerances that are established by a particular code for a particular device under all normal tests, whether maintenance or acceptance. Basic tolerances include minimum tolerance

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] Available from the International Standards, National Institute of Standards and Technology, US Department of Commerce, Gaithersburg, MD 20899.

[4] Available from the Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

*** A Summary of Changes section appears at the end of this specification.**

values when these are specified. Special tolerances, identified as such and pertaining to special tests, are not basic tolerances.

3.1.6 *capacity—of a balance*, the maximum load recommended by the manufacturer, disregarding any additional capability supplied by a taring device.

3.1.7 *general-purpose balance*—any balance used to make a general purpose determination of mass. See *general-purpose determination of mass.*

3.1.8 *general-purpose determination of mass*—a single determination of mass using a balance (not a special purpose determination of mass involving repeat determinations of mass, averages, standard deviations, corrections etc.).

3.1.9 *general-purpose standard mass*—a standard mass used with a balance to make a general purpose determination of mass. See *general-purpose determination of mass.*

3.1.10 *hysteresis*—the difference between indications obtained when the value of the applied load is reached by adding mass or by removing mass from the load receiving element of a balance.

3.1.11 *linearity error*—plus or minus deviation from the theoretically straight-lined (linear) course of two interdependent values. In balances, this expression is applied to the plus or minus deviation of the indicated measurement value from the true (actual) value of the load.

NOTE 4—The term linearity implies that the deviation from the true values are a continuous function of the applied load. Thus, obtaining enough values of the true applied load versus balance reading to establish a relation between applied load and output should give the error that will occur at any applied load. Linearity, then, is a statement about the systematic (nonrandom) error of a balance. Superimposed on the linearity are precision and other effects, such as off-center errors, temperature effects, etc. Linearity is a measure of balance performance over its full range, and on most balances adjustments can be made to alter the useableness of a balance with a given linearity for weighings within a particular range of use.

3.1.12 *nongraduated balance*—balances not fitted with a scale numbered in units of mass.

3.1.13 *off-center error—of a top loading or platform balance*, the difference in indicated value when a mass is shifted to various positions on the loading area (pan or platform); eccentric load error.

NOTE 5—The test for off-center error is called the shift test, or off-center-load test. Information about balance performance under eccentric loadings is not normally found in product literature but such information can usually be obtained by contacting the manufacturers directly.

3.1.14 *precision of a balance*—the degree of agreement between the indications of a balance for repeated determinations of mass of the same mass under essentially the same conditions. It is usually expressed quantitatively as a standard deviation of a series of weighings, or as a function of the range of several determinations of mass. See *repeatability type II, reproducibility.*

3.1.15 *readability type I*—the value of the smallest unit of mass that can be read without estimation over the given range of measurement either directly or by use of a vernier or micrometer.

3.1.16 *readability type II*—the value of the smallest unit of mass that can be read *with* estimation over the given range of measurement.

3.1.17 *readability type III*—the value of the smallest unit of mass that can be read while the balance is in use, but not smaller than readability Type I.

NOTE 6—Readability Type III refers to the smallest unit of mass that can be read when in-service conditions such as draft, vibration, and other environmental conditions affect the balance.

3.1.18 *repeatability type I*—the degree of agreement between the indications of a balance for repeated determinations of the same mass under essentially the same conditions. The degree of agreement (qualitatively).

3.1.19 *repeatability type II*—see *precision.*

3.1.20 *reproducibility*—see *precision.*

3.1.21 *scale*—see *balance.*

NOTE 7—The term scale usually refers to instruments intended for commercial or industrial applications, and when so used, usually implies an instrument of lesser performance than a balance.

3.1.22 *sensitivity*—the ratio of the deflection (ΔL) of the balance indicator or self-indicating display to the load (ΔM) causing the deflection; $S = \Delta L/\Delta M$ at a given load.

NOTE 8—Values for sensitivity are sometimes seen expressed in terms of mass units. When used in this way in reference to a non-self-indicating balance, sensitivity refers to the reciprocal of sensitivity or the change in mass required to change the position of equilibrium (rest point) a specified amount, usually one division on the balance indicator. When used in reference to self-indicating balances, it refers to the change in mass required to change the indication by one scale division.

3.1.23 *standard mass*—an object of specified mass and construction used with balances, and for the verification of balances and other masses.

3.1.24 *taring range*—a range within which it is possible to reset the display to zero by means of the tare device.

3.1.25 *tolerance*—a value fixing the limit of allowable error or departure from true performance or value.

NOTE 9—For additional terms used in this specification related to balances and standard masses, see NIST Handbook 44 or OIML IR No. 3.

4. Significance and Use

4.1 This specification provides those writing and using test standards related to soil, rock, and related construction materials, with a means for determining the balance capabilities required for a particular test method and for describing the balance selected in a uniform fashion.

4.2 This specification provides agencies conducting soil, rock, and related construction materials, testing with guidance for selecting and evaluating general purpose balances and standard masses.

4.3 This specification provides inspection organizations with criteria for evaluating general purpose balances and standard masses.

5. Requirements for General-Purpose Balances

5.1 General-purpose balances shall be judged accurate for a given class if their indications meet the basic tolerances shown in Table 1.

6. Requirements for General-Purpose Weights

6.1 General-purpose standard masses for use in testing of soil and rock should conform to the requirements in Specification E 617 for Type I or Type II, Grade S, O, or P standard masses and have tolerance limits equal to or better than those for Class 6 standard masses except that the maintenance tolerances given in Specification E 617 for

TABLE 1 Requirements for General-Purpose Balances

Class	Test Mass,[A] g	Basic Tolerance	Readability Type I,[B] g
GP1	≥20	±0.1 %	0.01
	<20	±0.02 g	0.01
GP2	≥200	±0.1 %	0.1
	<200	±0.2 g	0.1
GP5	≥2000	±0.1 %	1
	<2000	±2 g	1
GP10	≥5000	±0.1 %	5
	<5000	±5 g	5
GP100	≥50 000	±0.1 %	50
	<50 000	±50 g	50

[A] The known mass which is added to or subtracted from any load already on the balance when making a basic measurement (of error).
[B] Not readability Type II.

Class 6 standard masses are to be considered acceptance tolerances for purposes of this specification and the maintenance tolerances twice those values. The tolerances given in Table 2 correspond to the minimum acceptable maintenance tolerances under this specification.

NOTE 10—Former NIST Class J, M, S, S-1, P, and Q standard masses meet this specification, as do OIML Class M_1 standard masses (IR No. 20).

7. Evaluation of General-Purpose Balances

7.1 *Basic Tolerance*—Table 1 shows the basic tolerances for all classes of general-purpose balances used in soil or rock testing that are covered by this specification. The basic tolerances shown apply to basic measurements made when evaluating a balance.

7.1.1 A basic measurement for evaluating a balance is performed by determining the change of indication of the balance when a known mass is added to or subtracted from any load already on the balance, and then taking the difference between the change in the indication determined and the known value of the mass. To evaluate a balance, the basic tolerances shown in Table 1 are applied to the known value of the mass used in the basic measurement. The result of a basic measurement must fall within the error allowed by the basic tolerance.

NOTE 11—For nearly all determinations of mass encountered in soils testing, the value of interest is the difference between two determinations of mass. In cases where the difference between the two determinations of mass is small, relative to the total masses determined, it is desirable to specify a tolerance based on the difference between the two determinations of mass to relieve what might otherwise be an excessively stringent tolerance.

NOTE 12—A no load condition may be treated as a load of 0.0 g and may be considered a load on the balance.

7.1.2 The basic tolerance for a balance should apply to all values of loading within the range of the balance without regard to whether the balance is properly zeroed or a tare mass is being used, and should apply under all usual and customary methods of operation. Furthermore, the basic tolerance must be met in the environment in which the balance is to be used.

7.1.3 A balance shall not be considered acceptable if the result of basic measurements involving any combination of poise locations, counterpoise masses, pan loading, and scale positions, or unit masses are not within the basic tolerances shown in Table 1.

7.1.4 When evaluating top loading balances, results of basic measurements under off-center loading must also meet basic tolerances.

TABLE 2 Tolerances for General-Purpose Standard Masses

Denomination	Tolerance,[A] mg
20 kg	4000
10 kg	2000
5 kg	1000
3 kg	600
2 kg	400
1 kg	200
500 g	100
300 g	60
200 g	40
100 g	20
50 g	14
30 g	10
20 g	6
10 g	4
5 g	4
3 g	4
2 g	4
1 g	4
500 mg	2
300 mg	2
200 mg	2
100 mg	2

[A] Acceptance tolerances on new general-purpose standard masses are one-half the maintenance tolerances shown in this table.

NOTE 13—The possibility of off-center error and linearity error should be considered when making basic measurements.

7.1.5 Standard masses meeting or exceeding the requirements given in Specification E 617 for weights of Type I or Type II, Grades S or O, and Class 2 are suggested in Specification E 617 for use as working standards for calibration and precision analytical work and are recommended in this specification for use in evaluating general purpose balances. The use of standard masses of lesser quality for calibration purposes is discouraged because of the tendency to think of them as accurate once they are labeled "standard masses for calibration."

7.2 *Balance Classification*—A balance is classified by reference to its readability Type I (see Table 1).

NOTE 14—Capacity is not to be considered when classifying a balance. Balance classification in this specification is based on balance performance, not on use requirements. When selecting a balance, the anticipated loads which the balance is expected to measure will dictate the capacity required.

7.3 *Basic Conditions*—A basic condition is a condition which must be met before a basic measurement for evaluating a balance can be performed. In general, basic conditions require that a balance give a clear and stable indication under any condition of loading including the indication at no load. Both the useable readability (readability Type III) and the repeatability Type I must be adequate to perform the basic measurements described in 7.1.

NOTE 15—For example, when a determination of mass is made with a beam balance, if the smallest poise is moved by an amount equal to the readability Type I, the indicating pointer must move clearly off balance (usually at least one division on the pointer scale). This is an indication of the adequacy of the sensitivity of a balance.

7.3.1 Readability Type I (not Type II) establishes the balance's class for determining the appropriate basic tolerance. If environmental or other factors cause the usable readability (readability Type III) to be poorer than the

readability Type I then the balance cannot meet the basic tolerance for its class.

7.3.2 The repeatability Type I of the balance being evaluated must be such that the difference between the highest and lowest values in a group of several determinations of mass of the same load shall not be greater than twice the balance's readability Type I.

7.4 *Balance Testing*—Three types of testing may be performed when evaluating the performance of a balance.

7.4.1 *Maintenance Testing*—Maintenance testing should be performed on balances in service. The basic measurement for evaluating a balance is performed in an environment that meets the manufacturer's recommendations. Maintenance testing is performed to determine whether a balance should be repaired. A tolerance equal to or better than the basic tolerance should apply to all basic measurements for this test.

7.4.2 *In-Use Testing*—In-use testing should be performed on balances in service. The basic measurement for evaluating a balance should be performed as and where the balance is used to make general purpose determinations of mass. In-use tests are intended to indicate the quality of usual and customary mass determinations that are made or may be made when using a general-purpose balance. The basic tolerance should apply to basic measurements for this test.

7.5 *Rejection*—If a balance fails when in-use tests are performed then maintenance tests should be performed. If a balance fails both in-use and maintenance tests, it should be removed from service and repaired or replaced. If a balance fails the in-use test but passes the maintenance test, the environment in which the balance is located must be improved.

8. Evaluation of General-Purpose Standard Masses

8.1 General-purpose standard masses should be tested on a precision balance. Standard masses meeting or exceeding the requirements given in Specification E 617 for standard masses of Type I or Type II, Grades S or O, and Class 2 are suggested in Specification E 617 for use as working standards for calibration and precision analytical work and are recommended in this specification for use in evaluating general purpose standard masses. The use of standard masses of lesser quality for calibration purposes is discouraged because of the tendency to think of them as accurate once they are labeled "standard masses for calibration."

8.2 General-purpose standard masses that fail to meet the requirements specified in Section 6 should be removed from service and either adjusted to meet acceptance tolerances or replaced.

9. Selecting and Specifying Balances

9.1 *Selecting Balances*—The selection of a balance is based on the proposed use. A balance must have a capacity sufficient to accommodate all anticipated test loads, and its performance must be good enough so as not to be a cause of test error. The accuracy desired in test results should be used to establish the allowable balance tolerances.

9.1.1 The precision of a balance (a term frequently found in manufacturer's specifications), expressed as a standard deviation, shall not be greater than twice the readability Type I (not Type II).

9.1.2 When listed by the manufacturer, the linearity error of a balance shall not be greater than twice the readability Type I (not Type II).

9.1.3 If the maximum error of indication contributed by off-center loading can be obtained from the manufacturer, it should be no greater than twice the readability Type I (not Type II).

9.1.4 In cases where a test requires that more than one test result be determined, several balances having different capabilities may be required.

NOTE 16—The following example explains how a balance is selected: assume that a test method requires that a sample of soil be graded and that the fractions be reported to the nearest 0.1 %. If the sample mass is 1000 g, then a balance having a minimum capability of determining the mass of each fraction to the nearest 1.0 g (0.1 % of the total sample mass) will be required. If the sample mass is 5000 g, then a balance having a minimum capability of determining the mass of each fraction to the nearest 5.0 g (0.1 % of the total sample mass) will be required.

9.2 *Specifying Balances*—An example of the wording that may be used to specify balances in ASTM standards is as follows:

9.2.1 *Balance*—A balance having a minimum capacity of ____ g or kg and meeting the requirements of Specification D 4753 for a balance of ____ g readability.

9.2.2 *Balance*—A balance or scale conforming to the requirements of Specification D 4753 readable (with no estimation) to 0.1 % of the test mass, or better.

NOTE 17—Special consideration may be required when specifying the readability of balances used to determine masses of less than 20 g.

10. Keywords

10.1 balance; scale

SUMMARY OF CHANGES

This section identifies the location of changes to this specification that have been incorporated since the last issue. Committee D-18 has highlighted those changes that affect the technical interpretation or use of this specification.

(1) Section 7.4.1 on acceptance testing was deleted.

(2) The requirement was changed in Sections 9.1.1, 9.1.2, and 9.1.3 from "one-half the readability" to "twice the readability."