INTERNATIONAL

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Standard ~~Test Method of Testing~~ Practice for ~~Top-Loading, Direct-Reading Laboratory Scales and Balances~~Calibration of Non-Automatic Weighing Instruments[1]

This standard is issued under the fixed designation E898; 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.

~~**INTRODUCTION**~~

~~This method is designed to test commonly used laboratory scales that read the entire range of weight up to the capacity without manual operation. In essence, the entire reading range is on-scale and no manipulation of weights, riders, or dials is required; except some scales with optical reading devices may require the operation of a micrometer dial to interpolate the final one or two significant figures.~~

~~1. Scope~~

~~1.1 This test method covers the determination of characteristics of top-loading, direct-reading laboratory scales and balances. Laboratory scales of the top-loading type may have capacities from a few grams up to several kilograms. Resolution may be from 1/1000 of capacity to 1/1 000 000 or more. This method can be used for any of these instruments and will serve to measure the most important characteristics that are of interest to the user. The characteristics to be measured include the following:~~

~~1.1.1 warm-up,~~
~~1.1.2 off center errors,~~
~~1.1.3 repeatability, reproducibility, and precision,~~
~~1.1.4 accuracy and linearity,~~
~~1.1.5 hysteresis,~~
~~1.1.6 settling time,~~
~~1.1.7 temperature effects,~~
~~1.1.8 vernier or micrometer calibration, and~~
~~1.1.9 resistance to external disturbances.~~

~~1.2 The types of scales that can be tested by this method are of stabilized pan design wherein the sample pan does not tilt out of a horizontal plane when the sample is placed anywhere on the pan surface. The pan is located generally above the measuring mechanism with no vertical obstruction, except for draft shields. Readings of weight may be obtained from an optical scale, from a digital display, or from a mechanical dial. Weighing mechanisms may be of the deflecting type, using gravity or a spring as the transducer, or may be a force-balance system wherein an electromagnetic, pneumatic, hydraulic, or other force is used to counterbalance the weight of the sample. Other force-measuring devices may be tested by this method as long as a sample placed on a receiving platform produces an indication that is substantially a linear function of the weight of the sample.~~

~~1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*~~

~~2. Summary of Method~~

~~2.1 Throughout this method, the instrument is used in the manner for which it is intended. One or more weights are used to test each of the characteristics, and the results are expressed in terms of the least count or ultimate readability of the display.~~

[1] This ~~test method~~ practice is under the jurisdiction of ASTM Committee E41 on Laboratory Apparatus and is the direct responsibility of Subcommittee E41.06 on ~~Weighing Devices~~Laboratory Instruments and Equipment.

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3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*[2]

3.1.1 *accuracy*—the degree of agreement of the measurement with the true value of the quantity measured.

3.1.2 *capacity*—the maximum weight load specified by the manufacturer. In most instruments, the maximum possible reading will exceed the capacity by a small amount.

3.1.3 *full-scale calibration*—the indicated reading when a standard weight equal to the full scale indication of the scale is placed on the sample pan after the device has been correctly zeroed. Usually some means is provided by the manufacturer to adjust the full scale indication to match the weight of the standard.

3.1.4 *linearity*—the degree to which a graph of weight values indicated by a scale vs. the true values of the respective test weights approximates a straight line. For a quantitative statement of linearity errors, the concept of terminal-based non-linearity is recommended, such as, the maximum deviation of the calibration curve (average of the readings at increasing and decreasing test load, respectively) from a straight line drawn through the upper and lower endpoints of the calibration curve.

3.1.5 *off-center errors*—differences in indicated weight when a sample weight is shifted to various positions on the weighing area of the sample pan.

3.1.6 *hysteresis*—difference in weight values indicated at a given test load depending on whether the test load was arrived at by an increase or a decrease from the previous load on the scale.

3.1.7 *repeatability*—closeness of agreement of the indicated values for successive weighings of the same load, under essentially the same conditions, approaching from the same direction (such as, disregarding hysteresis).

3.1.8 *reproducibility*—closeness of agreement of the indicated values when weighings of the same load are made over a period of time under essentially the same conditions but not limited to the same direction of approach (such as, hysteresis errors are included).

3.1.9 *precision*—the smallest amount of weight difference between closely similar loads that a balance is capable of detecting. The limiting factor is either the size of the digital step of the indicator readout or the repeatability of the indicated values.

3.1.10 *standard deviation*—used as a quantitative figure of merit when making statements on the repeatability, reproducibility or precision of a balance.

3.1.11 *readability*—the value of the smallest unit of weight that can be read without estimation. In the case of digital instruments, the readability is the smallest increment of the least significant digit (for example, 1, 2 or 5). Optical scales may have a vernier or micrometer for subdividing the smallest scale division. In that case, the smallest graduation of the vernier or micrometer represents the readability.

3.1.12 *standard weight*—any weight whose mass is given. Since weights are not always available with documented corrections, weights defined by class may be used if the class chosen has sufficiently small limits and there is an understanding that errors perceived as being instrumental in nature could be attributed to incorrectly adjusted weights.

4. Significance and Use

4.1 This method will enable the user to develop information concerning the precision and accuracy of weighing instruments. In addition, results obtained using this method will permit the most advantageous use of the instrument. Weaknesses as well as strengths of the instrument should become apparent. It is not the intent of this method to compare similar instruments of different manufacture, but to enable the user to choose a suitable instrument.

5. Apparatus

5.1 *Manufacturer's Manual.*

5.2 *Standard Weights*—A set of weights up to the capacity of the scale with sufficient subdivisions of weight so that increments of about 10 % of the capacity up to the capacity can be tested.

5.3 *Thermometer,* room temperature, with a resolution of at least 1 °C.

5.4 *Stop-Watch,* reading to ⅕ s.

6. Preparation

6.1 Make sure that the scale and weights are clean.

6.2 Place the standard weights near the instrument.

6.3 Place the thermometer on the bench in such a position that it can be read without being touched.

6.4 Allow the instrument and the weights to sit undisturbed for at least 2 h with the balance turned off. Monitor the temperature during this time to make sure that there is no more than approximately 2°C variation over the last hour before beginning the test.

6.5 Read the manufacturer's instructions carefully. During each step of the test procedure, the instrument should be used in the manner recommended by the manufacturer. Know the location of any switches, dials, or buttons as well as their functions.

7. Test Procedure

7.1 *Warm-up Test:*

7.1.1 If it is required in the normal operation of the scale to turn it "on" as an operation separate from weighing, perform that operation simultaneously with the starting of the stop-watch.

7.1.2 If a zeroing operation is required, do it promptly. Record the temperature.

7.1.3 At the end of 1 min, read and record the indication with the pan empty.

7.1.4 At the center of the sample pan place a standard weight nearly equal to but not exceeding 98 % of the capacity of the scale. If the scale allows no weight readings above the stated nominal capacity, then this test should be performed with standard weights equal to 90 % of capacity. When the indication is steady, record the indication and remove the weight from the pan.

7.1.5 At the end of 5 min, repeat steps 7.1.3 and 7.1.4 without rezeroing.

7.1.6 At the end of 30 min, repeat again.

7.1.7 At the end of 1 h, repeat again. Record the temperature.

7.1.8 Compute for each measurement as follows:

$$k_t = W/(I_w - I_o) \quad (1)$$

where:

I_w = indication with the standard weight on the pan,
I_o = indication with pan empty,
W = known or assumed value of the standard weight, and
k_t = calibration factor for time t.

7.1.9 Plot the values of k_t against the time (1 min, 5 min, 30 min, and 60 min). The time at which k_t apparently no longer drifts in one direction can be assumed to be the warm-up time required.

7.1.10 If there is a user-adjustable full-scale calibration procedure recommended by the manufacturer, this adjustment should be made after the warm-up time determined in 7.1.9.

7.1.11 If the calibration cannot be adjusted by the user, the factor k_t can be used as a multiplier for an indicated weight to correct to true weight.

7.1.12 Plot I_o as a function of time to determine the zero drift. For individual measurements of weight, the zero can be monitored or corrected prior to a weighing. However, if the change in weight of a sample as a function of time is of importance, and if the sample cannot be removed for zeroing, it is also important to know the course of the zero as a function of time.

7.2 *Off-Center Errors*—The geometry of the stabilizing mechanism for the sample pan determines whether or not the scale is sensitive to the position of the load on the pan. This effect is measured by placing the load in various positions on the pan and observing any difference in indication. Place the standard weight (100 % or 90 % of capacity, as per 7.1.4) in 5 positions on the pan, noting the indication for each position: center-front-back—right-left; or center and corners. The difference between the lowest and the highest indication is the maximum off-center error.

7.3 *Repeatability*—A computation of the standard deviation (σ) of a series of observations at the same load apapproached from the same direction provides a measure of precision. The computation of 3σ will indicate with a high degree of assurance that any single measurement will fall within that limit of error, providing hysteresis is negligible. A control chart can be generated by periodically remeasuring the standard deviation and plotting it as a function of time (perhaps by date). Any time that the standard deviation falls outside of a pattern of values (control limits) there may be a reason to investigate the instrument or the measuring technique to determine whether adjustments may be required.

7.4 *Hystersis*—Balances do not usually have problems with hysteresis. Nevertheless the test for hysteresis is simple and should be performed on newly-acquired balances. Perform the test as follows:

7.4.1 Zero the balance,

7.4.2 Place a weight or weights equal to about one-half the balance capacity on the pan and record the reading once it is stable,

7.4.3 Add more weights to the balance pan until 90 % to 100 % of full capacity is reached. Wait for a stable reading, although the actual value need not be recorded.

7.4.4 Remove the weights which were added in 7.4.3 and record the balance reading once it is stable.

7.4.5 Remove the rest of the weights from the balance and record the reading as soon as it is stable. The five operations can be shown in tabular form:

Operation	Weight on Pan	Balance Reading
1	nil	0
2	½ capacity	W1
3	full capacity	W2
4	½ capacity	W1'
5	nil	Z

If the quantity $W1 - W1' + Z/2$ differs significantly from zero, the difference can be attributed to hysteresis. The test may be repeated several times and the results averaged to reduce measurement scatter.

7.5 *Precision*—To calculate the balance precision, combine the uncertainties due to lack of repeatability and to hysteresis.

7.6 *Accuracy and Linearity*—These tests are made together because they represent the same thing. Since accuracy represents the proximity to true value, the nonlinearity is a point-by-point measure of accuracy if the zero point and the full-scale calibration point have been set true. Set the zero and full-scale indications as described in 7.1.10 if possible. Place weights on the pan in increasing increments of about 10 % of the capacity and observe the indications. Plot the indicated values against the known or assumed value of the weight. The difference at any point is the inaccuracy. Keep in mind that the accuracy cannot be better than the precision and that every observation includes an uncertainty of as much as 3σ so that specifying a higher accuracy may be misleading. However, a procedure that includes multiple observations at each point and which minimizes any hysteresis effects and off-center errors can improve the precision, and therefore produce an accuracy measurement which is more significant.

7.7 *Settling Time*—The time for an indication to reach a stable value after the application of a load is a measure of how soon an indication may be read. This time is controlled by several factors including the moment of inertia of the system, the degree of damping or, in the case of digital instruments, the time-constant of the digital conversion rate. In addition, some digital designs may permit a flicker between two or more digits because of hunting in a servo loop. A knowledge of the time required may prevent a reading in error. Zero the scale in accordance with the manufacturer's instructions. Place a standard weight equal to the capacity of the scale on the pan simultaneously starting the stop-watch. Stop the watch when it appears that the indication is steady. Record the elapsed time. Repeat several times to ensure that there is reasonable correlation between measurements.

7.8 *Temperature Effects*—The ambient temperature may have an effect on the zero as well as the full-scale calibration. If means are available to test the instrument at various temperatures, such a test can be valuable, especially if the location in which the instrument is used is subject to variable temperature. Precaution should be taken to avoid moving the instrument from one location to another in order to take advantage of different existing temperatures. Moving the instrument may introduce other effects which could mask the variability with temperature.

7.9 *Vernier or Micrometer Calibration*—Some optical scales are equipped with a device for subdividing the smallest increment of the main scale. In order to subdivide correctly, the full range of the subdividing device must exactly equal one scale graduation. In the case of a vernier, this can be accomplished by carefully zeroing the instrument and observing the coincidence of the first and last line of the vernier with the corresponding lines on the main scale. Usually, if the first (zero) line of the vernier is coincident with the zero line of the main scale, the last line of the vernier should be coincident with the line of the main scale which is one less than the number of graduations on the vernier (for example, 10 graduations on the vernier corresponding with 9 graduations on the main scale). In the case of a micrometer which may subdivide a scale division into 100 parts, this test is not as simple because the micrometer usually is limited to 99 subdivisions in order to avoid ambiguities in reading. Therefore, the range of the micrometer cannot be examined by turning it through its entire range. One test which can be performed is to set the micrometer to read 00. Zero the instrument to some scale line higher than zero. Operate the micrometer to read 99. It should not be possible to bring the next lower line of the main scale into coincidence with the cursor. If possible, check the micrometer more precisely by using a test weight equal to 99 readable units. Combinations of small weights can be used to make up this value. Zero the instrument. Place the weights on the pan and operate the micrometer to bring the cursor into coincidence. Observe the displayed weight and compare with the true value of the weights on the pan. If the displayed weight is in error by more than one readable unit, adjust the display if such an adjustment is recommended by the manufacturer.

7.10 *Resistance to External Effects*—Some digital devices can show disturbances in the display due to RFI (radio frequency interference). Quantitative testing is difficult but operating a citizens band radio transmitter near the instrument can give some information about the susceptibility to RFI. Electromagnetic force-balance instruments may have insufficient shielding and may, therefore, react to the influence of strong magnetic fields nearby. Passing a small permanent magnet around the instrument and observing changes in display will give information about this effect. Moving the instrument from a metal topped bench to one which is nonmagnetic and observing a difference in full-scale calibration will give some qualitative information about any sensitivity in this area.

8. Interpretation of Results

8.1 Each of the tests listed are designed to give pertinent information about the instrument. The importance of any one test will depend on the needs of the user. If the tests are to be used for qualifying an instrument for a procedure, those tests which are pertinent to that procedure should, obviously, be performed.

9. Precision and Bias

9.1 For statements on precision and bias, refer to 7.5 and 7.6.

10. Keywords

10.1 balances; direct reading; laboratory; scales; top-loading

1. Scope

1.1 This practice applies to the calibration of electronic non-automatic weighing instruments. A non-automatic weighing instrument is a measuring instrument that determines the mass of an object by measuring the gravitational force acting on the object. It requires the intervention of an operator during the weighing process to decide whether the weighing result is acceptable.

1.2 Non-automatic weighing instruments have capacities from a few grams up to several thousand kilograms, with a scale interval typically from 0.1 micrograms up to 1 kilogram. Note that non-automatic weighing instruments are usually referred to as either balances or scales. In this practice, for brevity, non-automatic weighing instruments will be referred to as balances; however, the scope of this practice also includes scales.

1.3 This practice only covers electronic non-automatic weighing instruments where the indication is obtained from a digital display. The measuring principle is usually based on the force compensation principle. This principle is realized either by elastic deformation, where the gravitational force of the object being weighed is measured by a strain gauge that converts the deformation into electrical resistance, or by electromagnetic force compensation, where the gravitational force is compensated for by an electromagnetic counterforce that holds the load cell in equilibrium.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to be suitable as the sole testing process for weighing systems designated for commercial service under weights and measures regulation. The legal requirements for such instruments vary from region to region, and also depend on specific applications. To determine applicable legal requirements, contact the weights and measures authority in the region where the device is located.*

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E617 Specification for Laboratory Weights and Precision Mass Standards

2.2 *ISO Standards:*[3]

ISO 9001 Quality Management Systems – Requirements

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *OIML Documents and Recommendations:*[4]

D28 Conventional Value of the Result of Weighing in Air

R76-1 Non-automatic Weighing Instruments – Part 1: Metrological and Technical Requirements – Tests

[2] ANSI/ISA S51.1 "Process Instrumentation Technology". Available from American National For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[4] Available from the Organisation Internationale de Métrologie Légale (OIML), 11 Rue Turgot, 75009 Paris, France, https://www.oiml.org/en.

R111-1 Weights of classes E_1, E_2, F_1, F_2, M_{1-2}, M_2, M_{2-3} and M_3 – Part 1: Metrological and Technical Requirements

2.4 *EURAMET Guide:*[5]

Calibration Guide No. 18 Guidelines on the Calibration of Non-automatic Weighing Instruments

2.5 *JCGM Guides:*[6]

JCGM 100 Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement (GUM)

JCGM 200 International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)

2.6 *ILAC Guideline:*[7]

ILAC-G24 Guidelines for the Determination of Calibration Intervals of Measuring Instruments, ILAC-G24

2.7 *USP General Chapters:*[8]

USP General Chapter 41 Balances

USP General Chapter 1251 Weighing on an Analytical Balance

2.8 *UKAS Guide:*[9]

UKAS LAB 14, Edition 5 In-house Calibration and Use of Weighing Machines

2.9 *Code of Federal Regulations:*[10]

CFR Part 58 Good Laboratory Practice for Nonclinical Laboratory Studies

CFR Part 211 Current Good Manufacturing Practice for Finished Pharmaceuticals

2.10 *FDA Guidance:*[11]

FDA Questions and Answers on Current Good Manufacturing Practices, Good Guidance Practices, Level 2 Guidance – Equipment

For dated references, only the dated version applies to this practice. For undated references, the latest edition (including all amendments) applies to this practice.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 In this section, the official definitions of the terms are provided, as are, where appropriate, simplified definitions that relate the terms to the scope of this practice.

3.1.2 *accuracy class of weights, n*—class designation of a weight or weight set which meets certain metrological requirements intended to maintain the mass values within specified limits.[12]

3.1.3 *calibration, n*—operation that establishes a relation between the indication of the weighing instrument and the reference weights, including the associated measurement uncertainties.

3.1.3.1 *Discussion—*

An operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.[13]

3.1.4 *conventional mass value, n*—mass value indicated in the calibration certificate of the weight.

3.1.4.1 *Discussion—*

The conventional mass value of a body is equal to the mass of a standard that balances this body under conventionally chosen conditions, that is, at 20 °C, a density of the standard of 8000 kg/m^3 in air of density 1.2 kg/m^3.[14]

3.1.5 *coverage factor (k), n*—number larger than one by which a combined standard measurement uncertainty is multiplied to obtain an expanded measurement uncertainty.

3.1.5.1 *Discussion—*

[5] Available from EURAMET e.V., Bundesallee 100, 38116 Braunschweig, Germany, https://www.euramet.org.
[6] Available from the Bureau International des Poids et Mesures, Pavillon de Breteuil, 92312 Sèvres, France, https://www.bipm.org.
[7] Available from the International Laboratory Accreditation Cooperation, ILAC Secretariat, PO Box 7507, Silverwater NSW 2128, Australia, https://ilac.org.
[8] Available from U.S. Pharmacopeial Convention (USP), 12601 Twinbrook Pkwy., Rockville, MD 20852-1790, http://www.usp.org.
[9] Available from the United Kingdom Accreditation Service (UKAS), 2 Pine Trees, Chertsey Lane, Staines-upon-Thames, TW18 3HR, UK, https://www.ukas.com.
[10] Available from the United States Federal Register, https://www.archives.gov/federal-register.
[11] Available from U.S. Food and Drug Administration (FDA), 10903 New Hampshire Ave., Silver Spring, MD 20993, http://www.fda.gov.
[12] Definition from OIML R111-1.
[13] Definition from JCGM 200 (VIM).
[14] Definition from OIML D28.

The coverage factor (*k*) is typically calculated based on the applicable degrees of freedom (ν).[13]

3.1.6 *eccentric loading error, n*—error when the load is not placed in the center of the weighing platform.

3.1.6.1 *Discussion—*

The deviation in the measurement value caused by asymmetrical placement of the center of gravity of the load relative to the load receptor.[15]

3.1.7 *error, n*—difference between the indicated quantity and the applied quantity.

3.1.7.1 *Discussion—*

Error is the measured quantity value minus a reference quantity value.[13]

3.1.8 *linearity, n*—ability of a weighing instrument to follow the linear relationship between a load and the indication.[15]

3.1.9 *maximum capacity, n*—maximum weighing capacity, that is, the maximum capacity whose weight can be determined on a balance.[16]

3.1.10 *maximum permissible error (mpe), n*—limit by which the measured quantity indication can deviate from the nominal applied value.

3.1.10.1 *Discussion—*

The extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system.[13]

3.1.11 *measurement standard, n*—realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference.[13]

3.1.12 *measurement uncertainty, n*—parameter that quantifies how far a measurement value might be away from the true (unknown) value.

3.1.12.1 *Discussion—*

The non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used.[13]

3.1.13 *minimum weight, n*—smallest sample weight required for a weighment to just achieve a specified relative accuracy of weighing.[15]

3.1.14 *nominal capacity, n*—nominal value of the weighing capacity, derived from the maximum capacity by rounding it down to a number with less significant digits.[15]

3.1.15 *repeatability, n*—ability of a weighing instrument to provide indications that are close together when weighing the same object several times under reasonably constant test conditions.

3.1.15.1 *Discussion—*

The ability of an instrument to provide results that agree one with the other when the same load is deposited several times and in a practically identical way on the load receptor under reasonably constant test conditions.[16]

3.1.16 *scale interval, n*—the difference between two consecutive indicated values.[16]

3.1.17 *sensitivity, n*—change in indication divided by change in the applied quantity.

3.1.17.1 *Discussion—*

The quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured.[13]

[15] Nater, R., Reichmuth, A., Schwartz, R., Borys, M., and Panagiotis, Z., *Dictionary of Weighing Terms*, Springer, ISBN 978-3-642-02013-1, 2009.

[16] Definition from OIML R76-1.

3.2 *Symbols:*

d—scale interval

D—drift, value change with time

d_1—smallest scale interval

E—error of indication

I —indication

k—coverage factor

L—load

m —object mass

Max—maximum capacity

Max_1—upper limit of partial weighing range with smallest scale interval

m_c—conventional value of mass

m_{min}—minimum weight

m_N—nominal mass

mpe—maximum permissible error of a measured quantity

m_{ref}—reference mass

n—number of repeated weighings

R—reading

s—standard deviation

SF—safety factor

T—temperature (unit K)

u—standard uncertainty

U—expanded uncertainty

u_c—combined standard uncertainty

α—intercept (for uncertainty in use)

β—slope (for uncertainty in use)

v—degrees of freedom

v_{eff}—effective degrees of freedom for combined standard uncertainty

ρ—density

ρ_0—reference density of air, ρ_0 = 1.2 kg/m^3

ρ_c—reference density of mass, ρ_c = 8000 kg/m^3

ρ_S—density of standard weights

3.3 *Symbol Subscripts and Definitions*

Subscript	Related
B	air buoyancy
conv	convection
D	drift
L	load
N	nominal value
dig	digitization
ecc	load in different locations on the weighing pan
i, j	number
max	maximum
min	minimum
ref	reference
rep	repeatability
0	no load

4. Significance and Use

4.1 This practice will enable calibration laboratories and the user to calibrate electronic non-automatic weighing instruments and quantify the error of the balance throughout the measurement range, usually from zero to maximum capacity. The error of indication is accompanied by a statement on measurement uncertainty, which is individually estimated for every measurement point. This practice is based on the test procedures and uncertainty estimation described in the EURAMET calibration guide cg-18. However, while EURAMET cg-18 allows for a very flexible execution of the measurements, the test procedures described in this practice are more fixed to enable a better comparability between calibrations executed by different calibration laboratories or users. This practice may also serve as basis for accreditation of calibration laboratories for calibration of electronic non-automatic weighing instruments.

4.2 This practice allows the user to decide whether the calibrated balance is fit for its intended purpose, based on the assessment of the calibration results. Usually, this assessment is done by ensuring that the measurement uncertainty of all weighings the user performs on the instrument is smaller than a specified relative tolerance established by the user. This approach is commensurate to assuring that the smallest net amount of substance that the user weighs on the instrument (so-called smallest net weight) is larger than the minimum weight, which is derived from the calibration results.

4.3 This practice, in Appendix X2, provides information on the periodic performance verification on the balance that should be carried out by the user between the calibrations. Calibration together with periodic performance verification allows the user to ensure with a very high degree of probability that the balance meets the user requirements during its day-to-day usage. It helps users comply with requirements from other standards or regulations that stipulate periodic tests and calibrations of quality-relevant instruments.

5. Calibration Conditions

5.1 *Standard Weights*

5.1.1 *General Requirements*—Test loads shall consist of standard weights that are traceable to the SI unit of mass, with the possible exception of test loads used for measurements of a comparative nature—for example, measurement of eccentric loading or repeatability.

5.1.2 *Standard Weight Traceability*—The traceability of weights to be used as standards shall be demonstrated by calibration consisting of:

5.1.2.1 Determination of the conventional value of mass m_c or the correction δm_c to its nominal value $m_N{:}\delta m_c = m_c - m_N$, or both, together with the expanded uncertainty of the calibration U, or

5.1.2.2 Confirmation that m_c is within specified maximum permissible errors $mpe{:}m_N-(mpe-U)\leq m_c\leq m_N+(mpe-U)$.

5.1.2.3 The standards should further satisfy the following requirements to an extent appropriate to their accuracy:

(1) Density ρ_s sufficiently close to $\rho_c = 8000\,\frac{kg}{m^3}$,

(2) Surface finish suitable to prevent a change in mass through contamination by dirt or adhesion layers, and

(3) Magnetic properties such that interaction with the instrument to be calibrated is minimized.

5.1.2.4 Weights that comply with the relevant specifications of OIML R111-1 or Specification E617 should satisfy all these requirements.

5.1.3 *Recommendation for the Selection of Weight Classes*—It is recommended selecting the weights in order to minimize their uncertainty contribution to the balance uncertainty as far as reasonably possible so that user tolerance requirements are met. The following selection criteria for weight classes could be considered:

5.1.3.1 *1 000 000 < Max/d:* Select an OIML E_2 or ASTM Class 1 weight, or a weight with uncertainty not worse than the permitted OIML E_2 or ASTM Class 1 uncertainty, which is one-third or less of the maximum permissible error; it is recommended to always use the conventional mass value as the reference value;

5.1.3.2 *150 000 < Max/d ≤ 1 000 000:* For a weight where the nominal value is used as the reference value, select an OIML F_1 or ASTM Class 2 weight or better; for a weight where the conventional mass value is used as the reference value, select an OIML F_2 or ASTM Class 4 weight or better;

5.1.3.3 *15 000 < Max/d ≤ 150 000:* For a weight where the nominal value is used as the reference value, select an OIML F_2 or ASTM Class 4 weight or better; for a weight where the conventional mass value is used as the reference value, select an OIML M_1 or ASTM Class 5 weight or better; and

5.1.3.4 *Max/d ≤ 15 000:* For a weight where the nominal value is used as the reference value, select an OIML M_1 or ASTM Class 5 weight or better; for a weight where the conventional mass value is used as the reference value, select an OIML M_2 or ASTM Class 6 weight or better.

5.1.3.5 For multi-interval and multiple range balances, *Max* and *d* refer to the interval/range with the smallest scale interval, abbreviated as Max_1 and d_1, respectively.

5.2 *Substitution Loads*

5.2.1 Calibration requiring substitution loads is not within the scope of this practice. Substitution is discussed elsewhere (see EURAMET cg-18).

5.3 *Other Measuring Instruments Used for Calibration*

5.3.1 Thermometer for monitoring air temperature with a resolution of 0.5 °C or better.

5.3.2 Hygrometer for monitoring ambient relative humidity with a resolution of 5 % RH or better.

5.4 *Calibration Environmental Conditions*

5.4.1 Environmental temperature and relative humidity shall be recorded and reported.

5.4.2 Calibration shall be carried out under stable environmental conditions, where possible. Calibration shall be carried out within the normal working environmental conditions of the installation site.

5.4.3 The test loads should be acclimatized to the environmental conditions in the vicinity of the balance before calibration. Non-acclimatized weights trigger a convection effect of the surrounding air that may impact the indication of the balance. Information on acclimatization times may be found, for example, in EURAMET cg-18, Specification E617, or OIML R111-1.

6. Calibration Practice

6.1 *Measurement Parameters General*—This practice includes the following measurement parameters:

Repeatability;

Eccentric loading; and

Error of indication.

6.1.1 These three measurements may be performed in any order to accommodate efficient usage of weights and detect potential defects of the weighing instrument at an early stage.

6.2 *Calibration*

6.2.1 *Calibration Range*—The calibration range is typically from the zero point of the balance to maximum capacity, or the weighing range specified by the customer.

6.2.2 *Calibration Location*—Calibration shall be performed at the location of use of the balance. If calibration at the location of use is not possible, then this exception shall be noted in the calibration certificate. If the balance is moved to another location after calibration, the following situations may occur:

(1) Difference in local gravitational acceleration;

(2) Changes in environmental conditions; and

(3) Impact (damage) during transport.

NOTE 1—Each of the above may cause the performance of the balance to change and can invalidate the calibration. Therefore, moving the balance after calibration should be avoided. Recalibration of the balance is recommended after it has been moved if evidence of altered performance cannot be excluded.

6.2.3 *Preparation Before Calibration*—Check the balance nameplate or product identification. Identify the model, scale interval, maximum capacity, serial number, manufacturer, and other applicable information. The balance shall be energized at an appropriate time prior to calibration, such as the warm-up time specified in the balance instructions or the time set by the user.

6.2.3.1 If there is no such rule, the balance warm-up time should be no less than 30 min.

6.2.3.2 If as-found data is to be collected, do not level prior to as-found calibration. The balance should be levelled before as-left calibration.

6.2.3.3 If the balance is equipped with an auto-zero function, this function should be turned off before calibration, if possible.

6.2.4 *Measurement of Repeatability*—Under repeatability conditions, the same load is placed on the balance pan several times in a practical and consistent manner in a short time period. This provides an indication of the balance ability to produce consistent results, expressed as a standard deviation. Repeatability conditions include:

(1) The same measurement procedure;

(2) The same operator;

(3) The same measurement system; and

(4) The same operating conditions and the same location.

6.2.5 The test load should consist of a single weight whenever possible.

6.2.6 For balances with only a single scale interval, the test load is usually chosen between approximately 50 % of the maximum capacity and approximately 100 % of the maximum capacity. If the customer requires a special measurement point, the test load value can be adjusted. A typical application for which the repeatability test load may be adjusted is weighing quantities on the balance with mass values significantly smaller than maximum capacity.

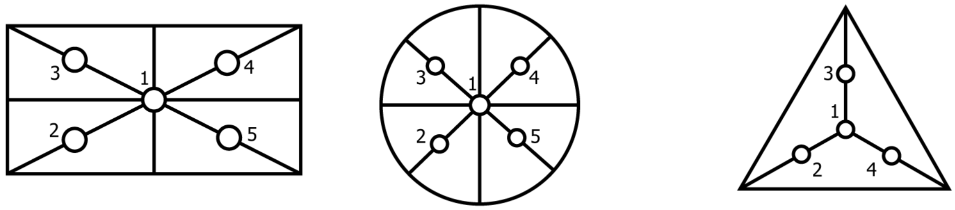
6.2.7 For multi-interval/multiple range balances, the test loads are usually chosen between approximately 50 % to approximately 100 % of the upper limit of each interval/range. If the customer requires a special measurement point, the test load value can be adjusted. A typical application for which the repeatability test load may be adjusted is weighing quantities on the balance with mass values significantly smaller than maximum capacity.

6.2.8 Before each measurement, set the balance to zero, load the test load in the middle of the balance weighing pan, and record the indication after stabilization. For all balances with a scale interval of 0.1 mg and finer, complete a minimum of 10 measurements. For all balances with a scale interval larger than 0.1 mg, complete a minimum of 5 measurements. For multi-interval/multiple range balances, the number of measurements shall be the same in all intervals/ranges. The smallest scale interval shall be taken as reference for defining the minimum number of measurements.

6.2.9 *Measurement of Eccentric Loading*—The error of indication of the same load at different positions on the weighing pan is expressed by the maximum difference between the indication of the different positions and the indication of the center position. A single weight should be used when possible. For multi-interval/multiple range as well as single range balances, the test load is preferably approximately one-third of the maximum capacity. Measurements include placing the test load at different locations on the pan in such a way as to ensure that the center of gravity of the applied load is at the positions shown in Fig. 1, or as close as possible. The number and location of measurement points can vary depending on the shape of the pan.

6.2.10 Depending on the mechanical construction of the balance, the eccentricity test might not be possible or required, for example, for balances with a hanging weighing pan or hopper scales. Care must be taken when performing this test on balances with leveling pans to position weights so that they do not tip off the tilted pan surface.

6.2.11 The measurement can be performed with the following methods:



1. Center
2. Lower left
3. Upper left
4. Top right
5. Bottom right

FIG. 1 Load Positions

6.2.11.1 *Method 1 (Recommended for Single Range Balances)*—Set the value to zero before measuring. Place the test load at position 1 and then move to the other positions in sequence. The indication is recorded for each position.

6.2.11.2 *Method 2 (Recommended for Multi-interval/Multiple Range Balances)*—First place the test load in position 1 and perform a tare operation on the balance. The test load is then moved sequentially to the other positions. The indication is recorded for each position.

6.2.11.3 *Method 3 (Recommended for Single Range Balances that Might Easily Show Drift)*—Set the value to zero before measuring. First place the test load in position 1, remove it, then place it in the next position, remove it, and so on, until it is removed from the last position. For each position, record the indication. The indication is set to zero each time the load is removed.

6.2.11.4 *Method 4 (Recommended for Multi-interval/Multiple Range Balances that Might Easily Show Drift)*—First place the test load in position 1 and perform a tare operation on the balance. Move the test load to the first off-center position and then move back to position 1. Record the indication for the off-center position. When the load is back at position 1 and if the display is not zero, then the indication is set to zero before continuing. Move the test load to the next off-center position, and back to position 1. Continue until the test load has been removed from the last off-center and center positions.

NOTE 2—If the weighing system auto-zero is activated, the eccentric loading test results can be affected, resulting in a falsely small error. The calibration technician must be observant of such effects and disable the auto-zero, if necessary, to obtain correct results (see 6.2.3).

6.2.12 *Measurement of Error of Indication*—The measuring points should be uniformly selected within the weighing range to be calibrated, as far as reasonably possible. At least 5 different test loads shall be required, including zero and maximum capacity or close to the maximum capacity (for example, 0, 25, 50, 75, and 100 % of maximum capacity). Measurement points may be added according to customer needs. Ideally, each test load should consist of a single weight; however, multiple weights may be used when necessary to achieve the appropriate test load. Before each measurement, the indication value is set to zero. The measurement can be selected according to the following methods:

6.2.12.1 *Method 1*—Increase from zero load to maximum capacity. Unload the weights at each step of the measurement process. After unloading, check the zero point. If the zero point is not zero, set the value to zero.

6.2.12.2 *Method 2*—Increase from zero load to maximum capacity; no need to unload the weights during the measurement. This method may produce creep effects in the results.

6.2.12.3 *Method 3*—If the customer requests, the measurement can also be performed from maximum capacity to zero load, without unloading weights after each measurement. As in Method 2, this may produce creep effects in the results.

7. Calibration Results

7.1 *Error of Indication Measurement Results*—For each test load, the error of indication (E) is calculated as follows:

$$E = I - m_{ref} \tag{1}$$

7.1.1 For the value of the reference mass, the nominal mass of the test load can be taken:

$$m_{ref} = m_N \tag{2}$$

7.1.2 Alternatively, the conventional mass value of the test load can be taken:

$$m_{ref} = m_c = m_N + \delta m_c \tag{3}$$

7.2 *Repeatability Measurement Results*—The standard deviation, s, is calculated from the load indications of the repeatability test.