Designation: E2624 – 17

Standard Practice for Torque Calibration of Testing Machines[1]

This standard is issued under the fixed designation E2624; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers procedures and requirements for the calibration of torque for static and quasi-static torque capable testing machines. These may, or may not, have torque indicating systems and include those devices used for the calibration of hand torque tools. Testing machines may be calibrated by one of the three following methods or combination thereof:

1.1.1 Use of standard weights and lever arms.

1.1.2 Use of elastic torque measuring devices.

1.1.3 Use of elastic force measuring devices and lever arms.

1.1.4 Any of the methods require a specific uncertainty of measurement, displaying metrological traceability to The International System of Units (SI).

NOTE 1—— for further definition of the term metrological traceability, refer to the latest revision of JCGM 200: International vocabulary of metrology — Basic and general concepts and associated terms (VIM).

1.2 The procedures of 1.1.1, 1.1.2, and 1.1.3 apply to the calibration of the torque-indicating systems associated with the testing machine, such as a scale, dial, marked or unmarked recorder chart, digital display, etc. In all cases the buyer/owner/user must designate the torque-indicating system(s) to be calibrated and included in the report.

1.3 Since conversion factors are not required in this practice, either english units, metric units, or SI units can be used as the standard.

1.4 Torque values indicated on displays/printouts of testing machine data systems—be they instantaneous, delayed, stored, or retransmitted—which are calibrated with provisions of 1.1.1, 1.1.2 or 1.1.3 or a combination thereof, and are within the ±1 % of reading accuracy requirement, comply with this practice.

1.5 The following applies to all specified limits in this standard: For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of Practice E29, for Using Significant Digits in Test Data to Determine Conformance with Specifications.

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]

E6 Terminology Relating to Methods of Mechanical Testing

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

E2428 Practice for Calibration and Verification of Torque Transducers

2.2 *NIST Technical Notes:*

NIST Technical Note 1297 Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results[3]

2.3 *BIPM Standard:*[4]

JCGM 200 : International vocabulary of metrology — Basic and general concepts and associated terms (VIM)

3. Terminology

3.1 *Definitions:* In addition to the terms listed, see Terminology E6.

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[1] This practice is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus.

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[2] 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* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

[4] Available from BIPM (Bureau International des Poids et Mesures)- Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE http://www.bipm.org

***A Summary of Changes section appears at the end of this standard**

3.1.1 *accuracy*—the permissible variation from the correct value.

3.1.1.1 *Discussion*—A testing machine is said to be accurate if the indicated torque is within the specified permissible variation from the actual torque. In this practice the word "accurate" applied to a testing machine is used without numerical values. For example, "An accurate testing machine was used for the investigation." The accuracy of a testing machine should not be confused with sensitivity. For example, a testing machine might be very sensitive; that is, it might indicate quickly and definitely small changes in torque, but nevertheless, be very inaccurate. On the other hand, the accuracy of the results is in general limited by the sensitivity.

3.1.2 *error, n*—for a measurement or reading, the amount it deviates from a known or reference value represented by a measurement standard. Mathematically, the error is calculated by subtracting the accepted value from the measurement or reading.

3.1.2.1 *Discussion*—The word "error" shall be used with numerical values, for example, "At a torque of 3000 lbf·in., the error of the testing machine was +10 lbf·in."

3.1.3 *percent error, n*—in the case of a testing machine or device, the ratio, expressed as a percent, of an error to the known accepted value represented by a measurement standard.

3.1.4 *reference standard, n*—an item, typically a material or an instrument, that has been characterized by recognized standards or testing laboratories, for some of its physical or mechanical properties, and that is generally used for calibration or verification, or both, of a measurement system or for evaluating a test method.

3.1.4.1 *Discussion*—Torque may be generated by a length calibrated arm and calibrated masses used to produce known torque. Alternatively, torque applied to a torque measuring device to be calibrated may be measured by the use of a reference torque measurement device, that is, an elastic torque calibration device, or a length calibrated arm and an elastic force measuring device.

3.1.5 *resolution, n*—for a particular measurement device, the smallest change in the quantity being measured that causes a perceptible change in the corresponding indication.

3.1.5.1 *Discussion*—Resolution may depend on the value (magnitude) of the quantity being measured.

3.1.5.2 *Discussion*—For paper charts or analog indicators, the resolution should not be assumed to be better (smaller) than 1⁄10 of the spacing between graduations. For digital devices, the best resolution potentially achievable is the smallest difference between two different readings given by the display.

3.1.5.3 *Discussion*—For both analog and digital devices, the actual resolution can be significantly poorer than described above, due to factors such as noise, friction, etc.

3.1.6 *torque, n*—a moment (of forces) that produces or tends to produce rotation or torsion.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibrated range of torque—in the case of testing machines*, the range of indicated torque for which the testing machine gives results within the permissible variations specified.

3.2.2 *calibration torque*—a torque with metrological traceability derived from standards of mass and length and of specific uncertainty of measurement, which can be applied to torque measuring devices.

3.2.3 *capacity range—in the case of testing machines*, the range of torque for which it is designed.

3.2.3.1 *Discussion*—Some testing machines have more than one capacity range, that is, multiple ranges.

3.2.4 *correction—in the case of testing machines*, the difference obtained by subtracting the indicated torque from the reference value of the applied torque.

3.2.5 *elastic torque-measuring device*—a device or system consisting of an elastic member combined with a device for indicating the measured values (or a quantity proportional to the measured value) of deformation of the member under an applied torque.

3.2.5.1 *Discussion*—The instrumentation for the elastic devices may be either an electrical or a mechanical device, that is, a scale or pointer system.

3.2.6 *expanded uncertainty*—a statistical measurement of the probable limits of error of a measurement, NIST Technical Note 1297 treats the statistical approach including the expanded uncertainty.

3.2.7 *lower torque limit of calibration range*—the lowest value of torque at which a torque measuring system can be calibrated.

3.2.8 *parasitic torque*—Forces that bypass the torque axis and can cause errors in determining the value of the torque.

3.2.8.1 *Discussion*—Usually the result of off axis loading (bending moments) caused by cables, conduit, or hydraulic lines attached to objects that are in the torque path and cause subsequent errors in the measured torque.

3.2.9 *permissible variation (or tolerance)— in the case of testing machines*, the maximum allowable error in the value of the quantity indicated.

3.2.9.1 *Discussion*—It is convenient to express permissible variation in terms of percentage of error. The numerical value of the permissible variation for a testing machine is so stated hereafter in these practices.

3.2.10 *torque-capable testing machine*—a testing machine or device that has provision for applying a torque to a specimen.

4. Significance and Use

4.1 Testing machines that apply and indicate torque are used in many industries, in many ways. They may be used in a research laboratory to measure material properties, and in a production line to qualify a product for shipment. No matter what the end use of the machine may be, it is necessary for users to know the amount of torque that is applied, and that the accuracy of the torque value is traceable to the SI. This standard provides a procedure to verify these machines and devices, in order that the indicated torque values may be traceable. A key element to having metrological traceability is that the devices used in the calibration produce known torque characteristics, and have been calibrated in accordance with Practice E2428.

4.2 This standard may be used by those using, those manufacturing, and those providing calibration service for torque capable testing machines or devices and related instrumentation.

5. Calibration Devices

5.1 *Calibration by Standard Weights and Lever Arms*—Calibration by the application of standard weights using a lever arm to the torque sensing mechanism of the testing machine, where practicable, is the most accurate method. Its limitations are: *(1)* the small range of torque that can be calibrated, *(2)* the non-portability of any high capacity standard weights and *(3)* analysis of all parasitic torque components.

5.2 *Calibration by Elastic Calibration Devices*—The second method of calibration of testing machines involves measurement of the elastic strain or rotation under the torque of a torque transducer or a force transducer/lever arm combination. The elastic calibration devices are less constrained than the standards referenced in 5.1. The design of fixtures and interfaces between the calibration device and the machine are critical. When using elastic torque or force measuring devices, use the devices only over their Class A loading ranges as determined by Practice E2428 for elastic torque measuring devices or Practice E74 for elastic force measuring devices.

6. Requirements for Torque Standards

6.1 *Weights and Lever Arms*—Weights and lever arms with traceability derived from standards of mass, force, length and of specific measurement uncertainty may be used to apply torque to testing machines. Weights used as force standards shall be made of rolled, forged, or cast metal. The expanded uncertainty, with a confidence factor of 95% (k=2), for the weight values shall not exceed 0.1 %.

6.1.1 The force exerted by a mass in air is determined by:

$$F = Mg\left(1 - \frac{d}{D}\right) \tag{1}$$

where:

F = force, N
M = true mass of the weight, kg
g = local acceleration due to gravity, m/s^2,
d = air density (1.2 kg/m^3), and
D = density of the weight in the same units as d

NOTE 2—Neglecting air buoyancy can cause errors on the order of 0.01% to 0.05% depending on the metal the weight is fabricated from. If it is neglected, it should be considered in any uncertainty analysis.

6.1.2 For the purposes of this standard, g can be calculated with a sufficient uncertainty using the following formula.

$$g = 9.7803[1 + 0.0053 (\sin \varnothing)^2] - 0.000001967h \tag{2}$$

where:

$\varnothing$ = latitude
h = elevation above sea level in meters.

NOTE 3—Formula 2 corrects for the shape of the earth and elevation above sea level. The correction for the shape of the earth is a simplification of the World Geodetic System 84 Ellipsoidal Gravity Formula. The results obtained with the simplified formula differ by less than 0.0005%. The term that corrects for altitude, corrects for an increased distance from the center of the earth and the counter-acting Bouguer effect of localized increased mass of the earth. The formula assumes a rock density of 2.67 g/cc. If the rock density changed by 0.5 g/cc, an error of 0.003 % would result.

6.2 The force in customary units exerted by a weight in air is calculated as follows:

$$F_c = \frac{Mg}{9.80665}\left(1 - \frac{d}{D}\right) \tag{3}$$

where:

F_c = force expressed in customary units, that is, pound force or kilogram force
M = true mass of the weight
g = Local acceleration due to gravity, m/s^2
d = air density (1. 2 kg/m^3)
D = density of the weight in the same units as d, and
9.80665 = The factor converting SI units of force into customary units of force; this factor is equal to the value of standard gravity. 9.80665 m/s^2

NOTE 4—If M, the mass of the weight is in pounds, the force will be in pound-force units (lbf). If M is in kilograms, the force will be in kilogram-force units (kgf). These customary force units are related to the newton (N), the SI unit of force, by the following relationships:

$$1\,\text{lbf} = 4.448222\,\text{N} \tag{4}$$

$$1\,\text{kgf} = 9.80665\,\text{N}(\text{exact}) \tag{5}$$

6.2.1 For use in verifying testing machines, corrections for local values of gravity and air buoyancy to weights calibrated in pounds can be made with sufficient accuracy using the multiplying factors from Table 1. Alternatively the following formula may be used to find the multiplying factor, *MF*. Multiply *MF* times the mass of the weight given in pounds to obtain the value of force in pounds-force, corrected for local gravity and air buoyancy.

$$MF = \frac{9.7803[1 + 0.0053 (\sin \varnothing)^2] - 0.000001967h}{9.80665} \times 0.99985 \tag{6}$$

where:

$\varnothing$ = latitude
h = elevation above sea level in metres.

NOTE 5—Equation 6 and Table 1 correct for the shape of the earth, elevation above sea level, and air buoyancy. The correction for the shape of the earth is a simplification of the World Geodetic System 84 Ellipsoidal Gravity Formula. The results obtained with the simplified formula differ by less than 0.0005%. The term that corrects for altitude, corrects for an increased distance from the center of the earth and the counter-acting Bouguer effect of localized increased mass of the earth. The formula assumes a rock density of 2.67 g/cc. If the rock density changed by 0.5 g/cc, an error of 0.003 % would result. The largest inaccuracy to be expected, due to extremes in air pressure and humidity when using steel weights, is approximately 0.01%. If aluminum weights are used, errors on the order of 0.03% can result.

6.2.2 Standard weights are typically denominated in a unit of mass. When a standard weight has been calibrated such that it exerts a specific force under prescribed conditions, it must be recognized that the weight will exert that force only under those conditions. When used in other fields of gravity, it is necessary to correct the calibrated force value by multiplying the force value by the value for local gravity and dividing by the value of gravity for which the weight was calibrated. Any required air buoyancy corrections must also be taken into account.

TABLE 1 Unit Force Exerted by a Unit Mass in Air at Various Latitudes

Latitiude, ∅, °	Elevation Above Sea Level, h, m (ft)					
	0 (0)	500 (1640)	1000 (3280)	1500 (4920)	2000 (6560)	2500 (8200)
0	0.9972	0.9971	0.9970	0.9969	0.9968	0.9967
5	0.9972	0.9971	0.9970	0.9969	0.9968	0.9967
10	0.9973	0.9972	0.9971	0.9970	0.9969	0.9968
15	0.9975	0.9974	0.9973	0.9972	0.9971	0.9970
20	0.9978	0.9977	0.9976	0.9975	0.9974	0.9973
25	0.9981	0.9980	0.9979	0.9978	0.9977	0.9976
30	0.9985	0.9984	0.9983	0.9982	0.9981	0.9980
35	0.9989	0.9988	0.9987	0.9986	0.9985	0.9984
40	0.9993	0.9992	0.9991	0.9990	0.9989	0.9988
45	0.9998	0.9997	0.9996	0.9995	0.9994	0.9993
50	1.0003	1.0002	1.0001	1.0000	0.9999	0.9998
55	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002
60	1.0011	1.0010	1.0009	1.0008	1.0007	1.0006
65	1.0015	1.0014	1.0013	1.0012	1.0011	1.0010
70	1.0018	1.0017	1.0016	1.0015	1.0014	1.0013

6.3 The lever arm or wheel shall be calibrated to determine the length or radius within a known uncertainty, that is traceable to SI. The expanded uncertainty, with a confidence factor of 95% (k=2), for the measured length of the calibration lever arm shall not exceed 0.1 %.

6.4 Elastic torque-measuring instruments may be used as secondary standards and shall be calibrated by primary standards. Practice E2428 defines the calibration of elastic torque-measuring instruments. Practice E74 defines the calibration of elastic force-measuring instruments.

7. Selection of Applied Torques

7.1 Determine the upper and lower limits of the torque range of the testing machine to be calibrated. In no case shall the calibrated range of torque include torques below 200 times the resolution of the torque indicator.

7.2 If the lower limit of the torque range is greater or equal to one-tenth the upper limit, calibrate the testing machine by applying at least five test torque values, at least two times, with the difference between any two successive torque value applications being no larger than one-third the difference between the selected maximum and minimum test torque values. Minimum torque values may be one-tenth the maximum torque values. Applied torque values on the second run are to be approximately the same as those on the first run. Report all values, including the indicator reading, after removal of torques. Include indicator resolution for the minimum torque value.

NOTE 6—When calibration is done using lever arms and weights, the combination of standard weights and lever arms may not exactly correspond to the desired upper and lower torques to be applied to the testing machine. In this case torque values that differ from the desired value by ±2.5 % are acceptable.

7.3 When the lower limit of a calibrated torque range is less than 10 % of the capacity of the range, or where the resolution of the torque indicator changes automatically and extends or selects ranges without the influence of an operator, verify the torque range by applying at least two successive series of torque values, arranged in overlapping decade groups, such that the maximum torque value in one decade is the minimum torque value in the next higher decade. Starting with the selected minimal torque value in each decade, there are to be at least five torque applications, in an approximate ratio of 1:1, 2:1, 4:1, 7:1, 10:1 or 1:1, 2.5:1, 5:1, 7.5:1, 10:1, unless the maximum torque value is reached prior to completing all torque application ratios. The decade's minimum torque must be a torque 200 or more times the resolution of the torque indicator in each decade. Report all torque values and their percent errors. Include the resolution of the torque indicator for each decade. See 3.1.6 and Appendix X1, which contains a non-mandatory method for determining resolution.

NOTE 7—Example: If full scale is 5000 lbf·in. and the minimal torque resolution is 0.04 lbf·in., the minimum calibrated torque would be 8 lbf·in. (0.04 × 200). Instead of decades of 8, 80 and 800 lbf·in., three decades of 10, 100 and 1000 lbf·in. could be selected to cover the torque application range. Suitable calibration test torque values would then be approximately 10, 20, 40, 70, 100, 200, 400, 700, 1000, 2000, 4000, 5000 lbf·in. Note that the uppermost decade would not be a complete decade and would be terminated with the maximum torque value in the range. If the alternate distribution of torques is used, the verification torques selected would be 10, 25, 50, 75, 100, 250, 500, 750, 1000, 2500, 3750, 5000 lbf·in.

7.4 Report the resolution of each decade and the percent error for each test torque value of the two runs. The largest reported error of the two sets of the test runs is the maximum error for the torque range.

7.5 Approximately 30 seconds after removing the maximum torque in a range, record the return to zero indicator reading. This reading shall be 0.0 ± either the resolution, 0.1 % of the maximum torque just applied, or 1 % of the lowest calibrated torque in the range, whichever is greater.

8. Extraneous Factors

8.1 For the purpose of determining the calibrated torque range of a testing machine, apply all torque values such that the resultant torque is as nearly along the axis of the torque sensing device as is possible. Care should be given to minimize any concentricity or angular misalignment.

8.2 Where a lever arm is to be used, ensure that there is minimal angular misalignment to the reaction point of applied torque values and the centerline of the torque sensing device. The lever arm shall be designed so that it will withstand the loading applied during calibration without deflections that will change it's effective length. It shall be supported in such a