Designation: E2624 – 09

Standard Practice for Torque Calibration of Testing Machines and Devices[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 or devices. 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 and a traceability derived from national standards of mass and length.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

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 of Torque-Measuring Instruments for Verifying the Torque Indication of Torque Testing Machines

2.2 *NIST Technical Notes:*

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

3. Terminology

3.1 *Definitions:*

3.1.1 *accuracy*—accuracy is defined in Terminology E6.

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 these methods 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.

[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.

Current edition approved April 1, 2009. Published May 2009. DOI: 10.1520/E2624-09.

[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.

3.1.2 *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.

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

3.1.4 *capacity range—in the case of testing machines*, the range of torque for which it is designed. Some testing machines have more than one capacity range, that is, multiple ranges.

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

3.1.6 *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.

NOTE 1—The instrumentation for the elastic devices may be either an electrical or a mechanical device, i.e., a scale or pointer system.

3.1.7 *error (or the deviation from the reference value)—in the case of a testing machine or device*, the difference obtained by subtracting the torque indicated by the calibration device from the torque indicated by the testing machine or device.

3.1.7.1 *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."

3.1.8 *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.

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

3.1.10 *parasitic torque*—torque that bypasses a desired torque path that can cause errors in determining the value of the torque in that path. It is usually caused by cables, conduit, or hydraulic lines attached to objects that are in the torque path. These attachments absorb torque and cause subsequent errors in the measured torque.

3.1.11 *percent error—in the case of a testing machine or device*, the ratio, expressed as a percent, of the error to the reference value of the applied torque.

3.1.11.1 *Discussion*—The test torque, as indicated by the testing machine, and the applied torque, as computed from the readings of the calibration device, shall be recorded at each test point. The error, E, and the percent error, E_p, shall be calculated from this data as follows:

$$E = A - B \tag{1}$$

$$E_p = ((A - B)/B) \times 100$$

where:

A = torque indicated by the machine being calibrated, N-m (lbf-in.), and
B = reference value of the applied torque, N-m (lbf-in.), as determined by the calibration device.

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

3.1.12.1 *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.

3.1.13 *reference standard*—a standard used to generate or to measure torque applied to the testing machine to be calibrated.

NOTE 2—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, i.e., an elastic torque calibration device, or a length calibrated arm and an elastic force measuring device.

3.1.14 *resolution of analog type torque indicators (scales, dials, recorders, etc.)*—the resolution is the smallest change in torque indicated by a displacement of a pointer, or pen line. The resolution is calculated by multiplying the torque corresponding to one graduation by the ratio of the width of the pointer or pen line to the center to center distance between two adjacent graduation marks.

3.1.15 *resolution of digital type torque indicators (numeric, displays, printouts, etc.)*—the resolution is the smallest change in torque that can be displayed on the digital torque indicator, at any applied torque. Appendix X1 describes a method for determining resolution.

3.1.15.1 *Discussion*—If the torque indication, for either type of torque indicator, fluctuates by more than twice the resolution, as described in 3.1.15 or 3.1.16, the resolution, expressed as torque, shall be equal to one-half the range of the fluctuation.

3.1.16 *resolution of the torque indicator*—smallest change of torque that can be estimated or ascertained on the torque indicating apparatus of the testing machine or device, at any applied torque. Appendix X1 describes a method for determining resolution.

3.1.17 *torque*—vector product of force and length, expressed in terms of N-m, lbf-in., etc.

3.1.18 *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 National Standards. 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 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 national 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 weight in air is calculated as follows:

$$\text{Force} = (Mg/9.80665)\,(1 - (d/D)) \tag{2}$$

where:

M = mass of the weight,
g = local acceleration due to gravity, m/s^2,
d = air density (approximately 0.0012 Mg/m^3),
D = density of the weight in the same units as d (Note 3), and
9.80665 = the factor converting SI units of force into the customary units of force. For SI units, this factor is not used.

6.1.2 The masses of the weights shall be determined by comparison with reference standards traceable to the national standards of mass. Corrections for the local value of the acceleration due to gravity can be made with sufficient accuracy by using the multiplying factors from Table 1.

NOTE 3—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 kgf = 9.80665 N (exact)
1 lbf = 4.44822 N

6.1.3 The lever arm or wheel shall be calibrated to determine the length or radius within a known uncertainty, that is traceable to national standards of length. 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 %.

6.2 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 torque range 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

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

Latitude, °	Elevation Above Sea Level, ft (m)					
	–100 to 500 (–30.5 to 152)	500 to 1500 (152 to 457)	1500 to 2500 (457 to 762)	2500 to 3500 (762 to 1067)	3500 to 4500 (1067 to 1372)	4500 to 5500 (1372 to 1676)
20	0.9978	0.9977	0.9976	0.9975	0.9975	0.9974
25	0.9981	0.9980	0.9979	0.9979	0.9978	0.9977
30	0.9985	0.9984	0.9983	0.9982	0.9982	0.9981
35	0.9989	0.9988	0.9987	0.9987	0.9986	0.9985
40	0.9993	0.9993	0.9992	0.9991	0.9990	0.9989
45	0.9998	0.9997	0.9996	0.9996	0.9995	0.9994
50	1.0003	1.0002	1.0001	1.0000	0.9999	0.9999
55	1.0007	1.0006	1.0005	1.0005	1.0004	1.0003

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 4—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 3.1.16 and Appendix X1, which contains a non-mandatory method for determining resolution.

NOTE 5—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 manner to minimize bending around the centerline of the torque sensing device. The support shall be designed so as to minimize all parasitic forces from being applied to the torque transducer.

8.3 Where a reference torque transducer is to be used for torque calibration of a testing machine, ensure that there is minimum misalignment of the transducers or load train variables that could exert bias within the setup.

8.4 *Temperature Considerations:*

8.4.1 Where the torque measuring device(s) are electrical, connect the force/torque transducer, indicator, interface, etc. using the appropriate cabling used in the actual machine setup. Turn on power and allow the components to warm up for a period of time recommended by the manufacturer. In the absence of any recommendations, allow at least 15 minutes for the components to be energized.

8.4.2 Position a temperature measurement device in close proximity of the machine being calibrated. Allow the force/torque measuring devices and all relevant parts of the measuring system equipment to reach thermal stability.

9. System Calibration

9.1 A testing machine shall be calibrated as a system with the torque sensing and indicating devices (see 1.2 and 1.4) in place and operating as in actual use.

9.2 System calibration is invalid if the torque sensing devices are removed and calibrated independently of the testing machine.

9.3 A calibration consists of at least two runs of torque contained in the torque range(s) selected. See 7.2 and 7.3.

9.3.1 If the initial run produces values within the requirements of Section 10, the data may be used "as found" for run one of the two required for the new calibration certificate.

9.3.2 If the initial run produces any values which are outside of these requirements, the "as found" data may be reported and may be used in accordance with applicable quality control programs. Calibration adjustments shall be made to the torque indicator system(s), after which the two required runs shall be conducted and reported in the new calibration certificate.

9.3.3 Calibration adjustments may be made to improve the accuracy of the system. They shall be followed by the two required runs, and issuance of a new calibration certificate.

9.3.4 The indicated torque of a testing machine that exceeds the permissible variation and that cannot be properly adjusted, shall not be corrected either by calculation or by the use of a calibration diagram in order to obtain torque values within the required permissible variation.

9.4 In the calibration of a testing machine, approach the torque value to be calibrated by increasing the torque from a lower value.

9.4.1 For any testing machine the errors observed at a given torque value taken first by increasing the torque to any given torque value and then by decreasing the torque to that same