



Designation: E2428 – 08

Standard Practice for Calibration of Torque-Measuring Instruments for Verifying the Torque Indication of Torque Testing Machines¹

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1. Scope

1.1 This practice is to specify procedure for the calibration of elastic torque-measuring instruments.

NOTE 1—Verification by deadweight and a lever arm is an acceptable method of verifying the torque indication of a torque testing machine. Tolerances for weights used are tabulated in Practice E2624; methods for calibration of the weights are given in NIST Technical Note 577, Methods of Calibrating Weights for Piston Gages.²

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 This practice is intended for the calibration of static or quasi-static torque measuring instruments. The practice is not applicable for high speed torque calibrations or measurements.

1.4 *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:³

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

E2624 Practice for Torque Calibration of Testing Machines and Devices

2.2 American National Standard:

B46.1 Surface Texture⁴

ELASTIC TORQUE-MEASURING INSTRUMENTS

3. Terminology

3.1 Definitions:

3.1.1 *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.

3.1.2 *primary torque standards*—a deadweight force applied through a lever arm or wheel, with a calibrated length or radius of a known uncertainty, that is traceable to national standards.

3.1.3 *secondary torque standard*—an instrument or mechanism, that has been calibrated by a comparison with a primary torque standard(s).

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

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *calibration equation*—a mathematical relationship between output of the unit under test and the applied standard torque, sometimes referred to as the calibration curve.

3.2.2 *continuous-reading device*—a class of instruments whose characteristics permit interpolation of torque values between calibrated torque values.

3.2.2.1 *Discussion*—Such instruments usually have torque-to-deflection relationships that can be fitted to polynomial equations. Departures from the fitted curve are reflected in the uncertainty (see 8.4).

3.2.3 *deflection*—the difference between the readings of an instrument under applied torque and the reading with no applied torque. The definition of deflection applies to output readings in electrical units as well as readings in units of torque.

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² Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

³ 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.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

3.2.4 *torque range*—a range of torque values within which the uncertainty is less than the limits of error specified for the instrument application.

3.2.5 *reading*—a numerical value indicated on the scale, dial, electrical output or digital display of a torque-measuring instrument for a given torque.

3.2.6 *resolution*—the smallest change in reading or indication appropriate to the scale, dial, or display of the torque measuring instrument.

3.2.7 *specific torque device*—an alternative class of instruments not amenable to the use of a calibration equation.

3.2.7.1 *Discussion*—Such instruments, usually those in which the reading is taken from a dial indicator, are used only at the calibrated torque values.

3.2.8 *uncertainty*—a statistical estimate of the limits of error in torque values computed from the calibration equation of a torque-measuring instrument when the instrument is calibrated in accordance with this practice.

4. Significance and Use

4.1 Testing machines that apply and indicate torque are in general use in many industries. Practice E2624 has been written to provide a practice for the torque verification of these machines. A necessary element in Practice E2624 is the use of devices whose torque characteristics are known to be traceable to national standards. Practice E2428 describes how these devices are to be calibrated. The procedures are useful to users of torque testing machines, manufacturers and providers of torque measuring instruments, calibration laboratories that provide calibration services and documents, and service organizations using devices to verify torque testing machines.

5. Reference Standards

5.1 Torque-measuring instruments used for the verification of the torque indication systems of torque testing machines may be calibrated by either primary or secondary standards.

5.2 Torque-measuring instruments used as secondary standards for the calibration of other torque-measuring instruments shall be calibrated by primary standards.

6. Requirements for Torque Standards

6.1 *Primary Standard*—Torque, with traceability derived from national standards of length and mass, and of specific measurement uncertainty, that can be applied to torque measuring devices. Weights used as primary mass standards shall be made of rolled, forged, or cast metal. Adjustment cavities shall be closed by threaded plugs or suitable seals. External surfaces of weights shall have a finish of 3.2μm (Ra) or less as specified in ANSI B46.1.

6.1.1 The force exerted by a weight in air is calculated as follows:

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

where:

M = mass of the weight,
 g = local acceleration due to gravity, m/s^2 ,
 d = air density (approximately 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 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. The local value of the acceleration due to gravity, calculated within 0.0001 m/s^2 (10 milligals), may be obtained from the National Geodetic Information Center, National Oceanic and Atmospheric Administration.⁵

NOTE 2—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 kilo gram-force units (kgf). These customary force units are related to the newton (N), the SI unit of force, by the following relationships:

$$\begin{aligned} 1 \text{ kgf} &= 9.80665 \text{ N (exact)} \\ 1 \text{ lbf} &= 4.44822 \text{ N} \end{aligned}$$

The pound-force (lbf) is defined as that force which, applied to a 1-lb mass, would produce an acceleration of 32.1747 ft/s^2 .

6.1.3 The lever arm or wheel shall be calibrated to determine the length or radius with a known uncertainty, that is traceable to national standards of length. The expanded uncertainty with a confidence factor of 95 % ($K=2$) for the torque calibrator shall not exceed 0.012 %.

6.2 *Secondary Standards*—Secondary torque standards may be either elastic torque-measuring instruments used with a machine for applying torque, or a mechanical or hydraulic mechanism to apply or multiply a deadweight force.

6.2.1 The multiplying ratio of a force multiplying system used as a secondary torque standard shall be measured at not less than ten points over its range with an accuracy of 0.06 % of ratio or better. Some systems may show a systematic change in ratio with increasing force. For these cases the ratio at intermediate points may be obtained by linear interpolation between measured values. Deadweights used with multiplying-type secondary standards shall meet the requirements of 6.1 and 6.1.2. The force exerted on the system shall be calculated from the relationships given in 6.1.1. The force multiplying system shall be checked annually by elastic force measuring instruments used within their class AA loading ranges to verify the forces applied by the system are within acceptable ranges defined by this standard. Changes exceeding 0.06 % of applied force shall be cause for re-verification of the force multiplying system.

6.2.2 Elastic torque-measuring instruments used as secondary standards shall be calibrated by primary standards and used only over the Class AA loading range (see 8.5.2.1).

6.2.3 Other types of torque standards may be used and shall be calibrated. The expanded uncertainty with a confidence factor of 95% ($K=2$) shall not exceed 0.06% of the applied torque.

7. Calibration

7.1 *Basic Principles*—The relationship between the applied torque and the deflection of an elastic torque-measuring

⁵ Available from National Oceanic and Atmospheric Administration (NOAA), 14th St. and Constitution Ave., NW, Room 6217, Washington, DC 20230, <http://www.noaa.gov>.

instrument is, in general, not linear. As the torque is applied, the shape of the elastic element changes, progressively altering its resistance to deformation. The result is that the slope of the torque-deflection curve changes gradually and uniformly over the entire range of the instrument. This characteristic of full-scale non-linearity is a stable property of the instrument that is changed only by a severe overload or other similar cause.

7.1.1 Localized Non-linearities—Superimposed on this curve are localized non-linearities introduced by the imperfections in the torque indicating system of the instrument. Examples of these imperfections include voltage and sensing instabilities. Some of these imperfections are less stable than the full-scale non-linearity and may change from one calibration to another.

7.1.2 Curve Fitting—A second degree polynomial fitted to the observed calibration data using the method of least squares, predicts the deflection values for applied torque throughout the loading range of the elastic torque measuring instrument (see 8.4). Such an equation compensates effectively for the full-scale non-linearity, allowing the localized non-linearities to appear as deviations. A statistical estimate, called the uncertainty, is made of the width of the band of these deviations about the basic curve. The uncertainty is an estimate of the limits of error contributed by the instrument when torque values measured in service are calculated using the calibration equation. Actual errors in service will vary for torque values applied under loading and environmental conditions differing from those of the calibration.

7.1.3 Curve Fitting for High Resolution Devices—Annex A1 recommends a procedure for obtaining the degree of the best-fit calibration curve for these devices.

NOTE 3—Experimental work by several calibration laboratories in fitting higher than second degree polynomials to the observed data indicated that, for some devices, use of a higher degree equation may result in a lower uncertainty than derived from the second degree fit (ASTM RR:E28-1009). Over-fitting should be avoided. Equations of greater than 5th degree should not be used due to the limited number of torque increments in the calibration protocol. Numerical errors may occur if calculations are performed with insufficient precision. A device used to measure torque not subjected to repair, overloading, modifications, or other significant influence factors which alter its elastic properties, or its sensing characteristics, will likely exhibit the same degree of best fit on each succeeding calibration using this procedure. A device not subjected to the influence factors outlined above which exhibits continued change of degree of best fit with several successive calibrations may not have sufficient performance stability to allow application of the curve fitting procedure of Annex A1.

7.2 Selection of Calibration Torque Values—A careful selection of the different torque values to be applied in a calibration is essential to provide an adequate and unbiased sample of the full range of the deviations discussed in 7.1 and 7.1.1. For this reason, the selection of the calibration torque values is made by the standardizing laboratory. An exception to this, and to the recommendations of 7.2.1 and 7.2.4, is made for specific torque measurement devices, where the selection of the torque values is dictated by the needs of the user.

7.2.1 Distribution of Calibration Torque Values—Distribute the calibration torque values over the full range of the instrument, providing, if possible, at least one calibration

torque for every 10 % interval throughout the range. It is not necessary, however that these torque values be equally spaced. Calibration torque values at less than one tenth of capacity are permissible and tend to give added assurance to the fitting of the calibration equation. If the lower limit of the loading range of the device (see 8.5.1) is anticipated to be less than one tenth of the maximum torque applied during calibration, then the torque values should be applied at or below this lower limit. In no case should the smallest torque applied be below the theoretical lower limit of the instrument as defined by the values: $400 \times$ resolution for Class A loading range and $2000 \times$ resolution for Class AA loading range.

7.2.2 Resolution Determination—The resolution of a digital instrument is considered to be one increment of the last active number on the numerical indicator, provided that the reading does not fluctuate by more than plus or minus one increment when no torque is applied to the instrument. If the readings fluctuate by more than plus or minus one increment, the resolution will be equal to half the range of fluctuation.

7.2.3 Number of Calibration Torque Values—A total of at least 30 torque applications per mode, clockwise or counter clockwise, is required for a calibration and, of these, at least 10 must be at different torque values. Apply each torque value at least twice during the calibration in both the clockwise and counter clockwise direction, as applies.

7.2.4 Specific Torque Devices (Limited Torque Devices)—Because these devices are used only at the calibrated torque values, select those torque values which would be most useful in the service function of the instrument. Coordinate the selection of the calibration torque values with the submitting organization. Apply each calibration torque at least three times in order to provide sufficient data for the calculation of the standard deviation of the observed deflections about their average values.

7.3 Temperature Equalization:

7.3.1 Allow the torque measurement system sufficient time to adjust to the ambient temperature in the calibration machine prior to calibration in order to assure stable instrument response.

7.3.2 The recommended value for room temperature calibrations is 23°C (73.4°F) but other temperatures may be used.

7.3.3 During the calibration, monitor and record the temperature as close to the elastic device as possible. It is recommended that the test temperature not change more than $\pm 1^\circ\text{C}$ during calibration, but in no case shall it change more than $\pm 2^\circ\text{C}$.

7.4 Procedural Order in Calibration—Immediately before starting the calibration, pre-load the torque-measuring instrument to the maximum torque to be applied at least two times. Pre-loading is necessary to reestablish a stable minimum torque output value and to condition the transducer for stable performance. This is particularly necessary following a change in the mode of loading, as from clockwise to counter clockwise. Some instruments may require more than two pre-loads to achieve stability in zero- torque indication.

NOTE 4—Overload or proof load tests are not required by this practice. It must be emphasized that an essential part of the manufacturing process for a torque-measuring instrument should be the application of tests of