Designation: E2510 – 07 (Reapproved 2013)

Standard Test Method for Torque Calibration or Conformance of Rheometers[1]

This standard is issued under the fixed designation E2510; 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 test method describes the calibration or performance conformance for the torque signal generated by commercial or custom-built rheometers. The specific range of the test depends upon the torque range of the rheometer.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 There is no ISO standard equivalent to this test method.

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:*[2]

E4 Practices for Force Verification of Testing Machines

E473 Terminology Relating to Thermal Analysis and Rheology

E617 Specification for Laboratory Weights and Precision Mass Standards

E1142 Terminology Relating to Thermophysical Properties

3. Terminology

3.1 Specific technical terms used in this test method are defined in Terminologies E473 and E1142. These terms include angular frequency, frequency, loss modulus, rheometer, storage modulus, strain, stress, viscoelasticity, viscometer, viscometry, and viscosity.

3.2 *Definitions:*

3.2.1 *torque, n*—force applied through a moment arm that produces or tends to produce rotation (N · m).

4. Summary of Test Method

4.1 A known force is applied to a rheometer coupling shaft through a moment arm to produce a torque. The torque thus applied is measured and compared to the measured torque. The ratio between indicated and applied torque is used to create a calibration coefficient that may be used in future determinations.

4.2 The known force generated by suspended precision mass or masses is transmitted to the rheometer coupling shaft by a line and an appropriate series of pulleys.

4.3 Torque is mathematically defined by Eq 1:

$$\tau = d\, F \sin\Phi \qquad (1)$$

where:

τ = torque
d = the length of the moment arm (m)
F = the applied force (N)
Φ = the angle to the moment arm over which the force is applied (°)

4.3.1 If the force is applied tangentially at right angles (that is, $\Phi = 90°$) to the moment arm, then $\sin\Phi = 1$ and Eq 1 reduces to Eq 2:

$$\tau = d\, F \qquad (2)$$

4.4 The moment arm in this test method is created by attaching a fixture of known radius to the rheometer coupling shaft in lieu of a geometry, tool or plate. The radius of the fixture is the value of d in Eq 2.

4.5 A force is applied to the fixture at a tangent by a suspended mass through a thin wire and a suitable pulley arrangement (see, for example, Fig. 1).

4.6 For a mass or masses of known value, the applied force is given by Eq 3:

$$F = M\, g\, f \qquad (3)$$

where:

M = the suspended mass (kg)
g = standard acceleration due to gravity (= 9.8065 m s^{-2})
f = correction factor for local gravity and air buoyancy taken from Table 1 (dimensionless)

[1] This test method is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.08 on Rheology.

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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.

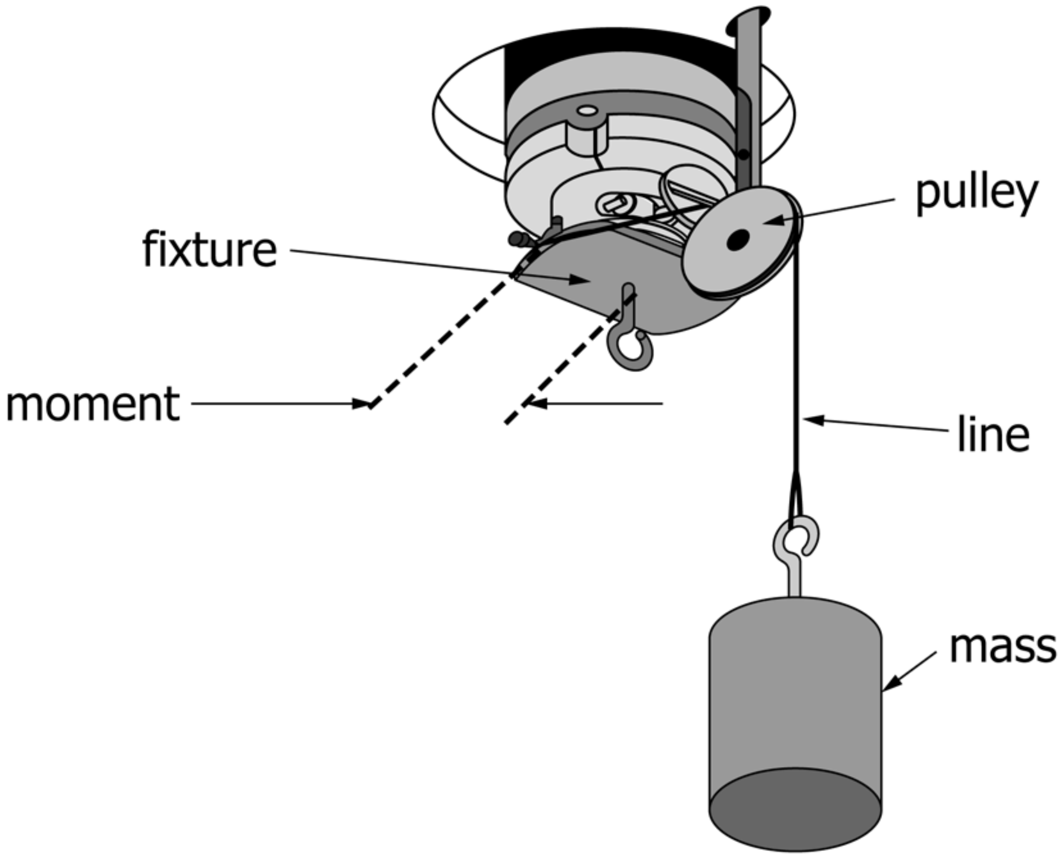

FIG. 1 Example of Suspended Mass

TABLE 1 Unit Force Exerted by a Unit Mass in Air at Various Latitudes and Elevations[A]

	Elevation Above Sea Level, m (ft)					
Latitude, °	–30.5 to 152 (–100 to 500)	152 to 457 (500 to 1500)	457 to 762 (1500 to 2500)	762 to 1067 (2500 to 3500)	1067 to 1372 (3500 to 4500)	1372 to 1676 (4500 to 5500)
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

[A] Taken from Practice E4.

5. Significance and Use

5.1 The test method calibrates or demonstrates conformity of the torque signal of a rheometer at ambient temperature.

5.2 A calibration factor thus determined may be used to obtain correct torque values.

5.3 This test method may be used in research, development, specification acceptance, and quality control or assurance.

6. Apparatus

6.1 *Rheometer*—The essential instrumentation required providing the minimum rheological analytical capabilities include:

6.1.1 *Drive Actuator,* to apply torque or angular displacement to the specimen in a periodic manner capable of frequencies of oscillation from 0.001 to 100 rad/s. This actuator may also be capable of providing static torque or displacement on the specimen.

6.1.2 *Coupling Shaft,* or other means to transmit the torque or displacement from the motor to the specimen.

6.1.3 *Geometry* or *Tool,* to fix the specimen between the drive shaft and a stationary position.

6.1.4 *Sensor,* to measure the torque developed by the specimen, a position sensor to measure the angular displacement of 50 nanoradians of the test specimen, or both.

6.1.5 *Temperature Sensor,* to provide an indication of the specimen temperature to within ±0.1°C.

6.1.6 *Furnace,* or *Heating/Cooling Element,* to provide controlled heating or cooling of a specimen at a constant temperature or at a constant rate within the temperature range of interest.

6.1.7 *Temperature Controller,* capable of executing a specific temperature program by operating the furnace or heating/cooling element between selected temperature limits constant to within ±0.1°C.

6.1.8 *Recording Device,* capable of recording and displaying on the Y-axis any fraction of the measured signal (here applied torque) or calculated signal (such as viscosity, storage and loss modulus, etc.) including signal noise using a linear or logarithmic scale as a function of any fraction of the independent experimental parameter (such as temperature, time) or calculated signals (such as stress or strain) on the X-axis including signal noise.

6.1.9 Auxiliary instrumentation considered necessary or useful in conducting this method includes:

6.1.9.1 *Cooling Capability,* to hasten cool down from elevated temperatures, to provide constant cooling rates, or to sustain an isothermal sub-ambient temperature.

6.1.9.2 *Data Analysis Capability,* to provide viscosity, storage and loss modulus, stress, strain, etc. or other useful parameters derived from the measured signals.

6.1.10 A test fixture of known radius to attach a tangentially applied load to the coupling shaft in lieu of the geometry, tool, or plate.

NOTE 1—Test fixtures of appropriate design may be obtained from the manufacture of the rheometry apparatus.

6.1.11 *Mass* or *Masses,* with a suspending hook, the mass value for which are known to within ±0.1 % (see E617). The value of the required mass or masses depends upon the nominal torque range of the rheometer and is given by Eq 4:

$$M = 80 \textit{ to } 90\,\% \textit{ of } \frac{\tau_a}{(d_n\, g)} \tag{4}$$

where:

τ_a = maximum measuring torque of the rheometer
d_n = nominal radius of the test fixture (m)

6.1.12 *Line* or *Lines,* composed of a non-elastic material such as monofilament line of suitable length to connect the calibration mass or masses to the test fixture at its tangent.

6.1.13 An arrangement of pulleys over which the line may be strung so that the force of the suspended mass is transmitted tangentially to the test fixture.

NOTE 2—The friction of the pulley(s) shall be sufficiently small that it will not significantly contribute to the torque measurement.

6.1.14 *Calipers,* or other length-measuring device with a range of up to 10 cm to determine length to within ±0.1 µm.

7. Preparation of Apparatus

7.1 Mount the test fixture to the coupling shaft in such a way that a line or lines connected to a mass or masses transmits the force of the suspended mass or masses tangentially to the test fixture and coupling shaft. An illustrative example is shown in Fig. 1.

8. Calibration and Standardization

8.1 Prepare the apparatus for testing according to the manufacturers recommendation as described in the operations manual.

9. Procedure

9.1 Measure the distance from the center of the connecting shaft to the edge of the test fixture to within ±0.1 mm and record this value as *d*.

NOTE 3—The value of *d* is commonly 2.5 cm (= 0.025 m).

9.2 With no torque applied to the test fixture, observe the torque signal and ensure that it is less than 0.1 % of the full scale torque value.

9.3 Select a precision mass the value for which is within the maximum range of the apparatus as defined by Eq 4.

9.4 Apply the calibrating torque to the rheometer by connecting one end of the line to the calibration fixture, over any needed pulleys to the suspended mass or masses. Ensure that the mass(es) is (are) free hanging without obstruction and that the mass is steady (without swinging from side-to-side).

NOTE 4—The friction of the pulley(s) shall be sufficiently small that it will not significantly contribute to the torque measurement.

9.5 Measure the applied torque and record this value as τ_i.

9.6 Calculate the calibration constant (*S*) using Eq 5.

9.7 Calculate the percent conformance (*C*) using Eq 6.

10. Calculation or Interpretation of Results

10.1 For the purposes of this test method, it is assumed that the relationship between the indicated and applied reference torque is linear and governed by the slope (*S*) of Eq 5:

$$S = \frac{M\, g\, d\, f}{\tau_i} \tag{5}$$

where:

S = slope of the torque calibration curve (dimensionless)
τ_i = the indicated torque (N · m)

10.2 The percent conformity (*C*) (that is, the percent difference between the experimental slope and unity) of the instrument's torque measurement is calculated using the value of *S* from 10.1 and Eq 6:

$$C = (S - 1.0000) \times 100\,\% \tag{6}$$

11. Report

11.1 The report shall include the following information:

11.1.1 Details and description of the rheometer including the manufacturer and model number.

11.1.2 The value of calibration constant (*S*) determined in section 9.6 reported to within ±0.0001.

11.1.3 The conformity value (*C*) as described in section 9.7 reported to at least two significant figures.

11.1.4 The specific dated version of this method used.

12. Precision and Bias

12.1 Precision of the torque measurement depends upon the precision of the moment arm, the mass and the acceleration due to gravity. Maximum imprecision in the determination of the torque may be estimated from the imprecisions in the individual measurements by the following equation:

$$\delta\tau/\tau = \left[(\delta d/d)^2 + (\delta M/M)^2 + (\delta g/g)^2\right]^{1/2} \quad (7)$$

where:

$\delta\tau$ = imprecision in the value for torque
τ = torque
δd = imprecision in the measurement of the moment arm, mm
d = moment arm, mm
δg = imprecision in the value for acceleration due to gravity, m s^{-2}
g = acceleration due to gravity, m s^{-2}
δM = imprecision in mass value, g
M = mass, g

12.1.1 *Example:*
if:

$\delta d = \pm 0.5$ mm
$d = 25$ mm
$\delta g = \pm\ 0.0026$ m s^{-2}
$g = 9.8$ m s^{-2}
$\delta M = \pm\ 0.5$ g
$M = 500$ g
then:

$$\delta\tau/\tau = \left[(0.5\text{ mm}/25\text{ mm})^2 + (0.5\text{ g}/500\text{ g})^2 + (0.0026\text{ m s}^{-2}/9.8\text{ m s}^{-2})^2\right]^{1/2}$$

or expressed as percent:

$$\delta\tau/\tau = \left[(2.0\,\%)^2 + (0.1\,\%)^2 + (0.27\,\%)^2\right]^{1/2} = \pm 2.0\,\%$$

12.2 An interlaboratory study is planned for 2007–2008 to generate precision and bias information for this test method. Anyone wishing to participate in this study may contact the E37 Staff Manager at ASTM International Headquarters.

12.3 *Precision:*

12.3.1 The intralaboratory repeatability standard deviation for *S* for a single instrument was found to be ±0.05.

12.4 *Bias:*

12.4.1 The measurement of conformance in this test method is a comparison of the calibration constant *S* with the theoretical value of 1.000 and is an indicator of bias.

12.4.2 Interlaboratory results indicate that the value for *C* is anticipated to be ±5 %.

13. Keywords

13.1 rheometer; calibration; torque