Designation: E2309 – 05

Standard Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines[1]

This standard is issued under the fixed designation E2309; 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 These practices cover procedures and requirements for the calibration and verification of displacement measuring systems by means of standard calibration devices for static and quasi-static testing machines. This practice is not intended to be complete purchase specifications for testing machines or displacement measuring systems. Displacement measuring systems are not intended to be used for the determination of strain. See Practice E83.

1.2 These procedures apply to the verification of the displacement measuring 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 displacement-measuring system(s) to be verified.*

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

1.4 Displacement values indicated on displays/printouts of testing machine data systems—be they instantaneous, delayed, stored, or retransmitted—which are within the Classification criteria listed in Table 1, comply with Practices E2309.

1.5 *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]

E83 Practice for Verification and Classification of Extensometer Systems

3. Terminology

3.1 *Definitions:*

3.1.1 *accuracy*, *n*—degree of conformity of a measure to a standard.

3.1.2 *error*, *n*—the amount of deviation from a standard.

3.1.2.1 *Discussion*—The word "error" shall be used with numerical values, for example, "At a displacement of +1.00 in., the error of the displacement measuring system was +0.001 in."

3.1.3 *tolerance*, *n*—the allowable deviation from a standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration*, *n*—in the case of displacement measuring systems used with testing machines, the process of comparing the displacement indication of the machine or system under test to that of a standard, making adjustments as needed to meet error requirements.

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

3.2.3 *correction*, *n*—in the case of a testing machine, the difference obtained by subtracting the measured displacement from the correct value of the applied displacement.

3.2.4 *displacement*, *n*—a movement or measurement of length expressed in terms of millimeters, inches, etc.

3.2.5 *displacement measuring system*, *n*—a device or set of devices comprised of a displacement transducer and associated instrumentation.

3.2.6 *lower limit of verification range*, *n*—the lowest value of displacement at which a displacement measuring system can be verified.

3.2.7 *percent error*, *n*—in the case of a displacement measuring system, the ratio, expressed as a percent, of the error to the correct value of the applied displacement.

3.2.7.1 *Discussion*—The measured displacement, as measured by the testing machine, and the applied displacement, as computed from the readings of the verification device, shall be recorded at each verification displacement data point. The error, and the percent error, shall be calculated from this data as follows:

$$\text{Error} = A - B$$

$$\text{Percent Error} = [(A - B)/B] \times 100$$

[1] These practices are 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.

TABLE 1 Classification of Displacement Measuring Systems

Classification	Resolution not to Exceed the Greater of:		Error not to Exceed the Greater of:	
	Fixed Error, mm (in.)	% of Reading	Fixed Error, mm (in.)	Relative Error (% of Displacement)
Class A	0.013 (0.0005)	±0.25	±0.025 (0.001)	±0.5
Class B	0.038 (0.0015)	±0.5	±0.075 (0.003)	±1.0
Class C	0.064 (0.0025)	±1.0	±0.125 (0.005)	±2.0
Class D	0.13 (0.005)	±1.5	±0.25 (0.010)	±3.0

where:

A = displacement measured by the machine being verified, mm (in.), and

B = correct value of the applied displacement, mm (in.), as determined by the calibration device.

3.2.8 *reference standard*, *n*—a standard used to measure displacement applied by the testing machine and measured by the displacement measuring system to be verified.

3.2.9 *resolution of the displacement indicator*, *n*—smallest change of displacement that can be estimated or ascertained on the displacement measuring apparatus of the testing machine or system, at any applied displacement. Appendix X1 describes a method for determining resolution.

3.2.10 *resolution of analog type displacement indicators (scales, dials, recorders, etc.)*, *n*—the resolution is the smallest change in displacement indicated by a displacement of a pointer, or pen line. The resolution is calculated by multiplying the displacement 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.

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

3.2.11.1 *Discussion*—If the displacement indication, for either type of displacement indicator, fluctuates by more than twice the resolution, as described in 3.2.9 or 3.2.10, the resolution, expressed as displacement, shall be equal to one-half the range of the fluctuation.

3.2.12 *relative repeatability*, *n*—the closeness of the agreement between the results of successive measurements from the same applied displacement, carried out under the same conditions of measurement. It is expressed as percentage of the mean indicated output for the same applied displacement on two successive calibrations for the given displacement.

3.2.13 *relative reversibility*, *n*—the difference between the mean measured displacement obtained for a given applied displacement applied in an increasing mode and the mean indicated displacement obtained for the same given displacement applied in a decreasing mode.

3.2.14 *testing machine*, *n*—a mechanical device for applying force and displacement to a specimen.

3.2.14.1 *Discussion*—The instrumentation may be either an electrical or a mechanical device, that is, a scale or pointer system.

3.2.15 *verification*, *n*—in the case of displacement measuring systems used with testing machines, the process of comparing the displacement indication of the machine or system under test to that of a standard and reporting results, without making adjustments.

3.2.16 *verification displacement*, *n*—a displacement with traceability derived from national standards of length with a specific uncertainty of measurement, which can be applied to displacement measuring systems.

3.2.17 *verified range of displacement*, *n*—in the case of testing machines, the range of measured displacement for which the testing machine gives results within the permissible variations specified.

4. Significance and Use

4.1 Testing machines that apply and measure displacement are used in many industries. They may be used in research laboratories to determine material properties, and in production lines to qualify products for shipment. The displacement measuring devices integral to the testing machines may be used for measurement of crosshead or actuator displacement over a defined range of operation. The accuracy of the displacement value shall be traceable to the National Institute of Standards and Technology (NIST) or another recognized National Laboratory. Practices E2309 provides a procedure to verify these machines and systems, in order that the measured displacement values may be traceable. A key element to having traceability is that the devices used in the verification produce known displacement characteristics, and have been calibrated in accordance with adequate calibration standards.

5. Calibration Devices

5.1 Reference standards used for calibration and or verification of displacement measuring systems shall have estimated measurement uncertainties. The reported uncertainty of reference standards must be equal to or less than ⅓ the allowable error for the measuring system Classification as shown in Table 1. The estimated measurement uncertainty of the reference standard should have a confidence level of 95 % (k = 2).

6. System Verification

6.1 Displacement measuring systems shall be verified as a system with the displacement sensing and measuring devices (see 1.2 and 1.4) in place and operating as in actual use.

6.2 System verification is invalid if the displacement sensing devices are removed and checked independently of the testing machine.

6.3 A Practices E2309 verification consists of at least two verification runs of displacement contained in the displacement range(s) selected. See 8.1 and 8.2.

6.3.1 If the initial verification run produces values within the Practices E2309 requirements of Section 15, the data may be used "as found" for run one of the two required for the new verification report.

6.3.2 If the initial verification run produces any values which are outside of the Practices E2309 requirements, the "as found" data may be reported and may be used in accordance with applicable quality control programs.

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

7. Application of Displacement

7.1 In the verification of the displacement measuring system, approach the displacement test value by applying the test displacement from a lower value of displacement. To reduce the error in displacement measurement due to internal backlash of the testing machine, associated fixtures and or apparatus, make sure to approach the starting zero position of the testing machine from a point less than zero and in the direction for which the resultant verification data will be acquired. This procedure shall be followed when acquiring descending verification data as well. When acquiring descending verification data apply a displacement greater than the starting point and adjust the testing machine to re-establish a starting zero position in the direction for which verification data is to be acquired.

7.2 Displacement measuring systems that are used to acquire test data in both ascending and descending directions, shall be verified in both directions.

8. Selection of Verification Displacement Values

8.1 For any displacement range, verify the displacement measuring system by applying at least five test displacement values, at least two times, with the difference between any two successive displacement value applications being no larger than one-third the difference between the selected maximum and minimum test displacement values. Applied displacement values on the second run are to be approximately the same as those on the first run. Report all values.

8.2 The low limit of displacement measurement must be equal to or greater than:

400 times the resolution for Class A
200 times the resolution for Class B
100 times the resolution for Class C
67 times the resolution for Class D

8.2.1 Where the resolution of the displacement measuring system is sufficient to allow for verification below 10 % of displacement capacity or range, verify the displacement range by applying at least two successive series of displacement values, arranged in overlapping decade groups, such that the maximum displacement value in one decade is the minimum displacement value in the next higher decade. Starting with the selected minimal displacement value in each decade, there are to be at least five displacement applications, in an approximate ratio of 1:1, 2.5:1, 5:1, 7.5:1, and 10:1, unless the maximum displacement value is reached prior to completing all displacement application ratios. Report all displacement values and their percent errors.

NOTE 1—Example: If full scale is 200 mm and the minimal resolution is 0.025 mm, the minimum verified displacement would be 5 mm (0.025 × 200). Two decades of 20 and 200 mm could be selected to cover the displacement application range. Suitable verification test displacement values would then be approximately 5, 10, 15, 20, 50, 100, 150, 200 mm. The largest reported error of the two sets of the test runs is the maximum error for the displacement range.

9. Preliminary Procedure

9.1 *Alignment*:

9.1.1 When fixturing the calibration device, it is important to minimize any misalignment. Significant errors can be induced due to misalignment. Gauge blocks or a square may be used to ensure that the calibration device operates parallel to the actuator in hydraulic testing machines or perpendicular to the crosshead in electro-mechanical testing machines.

9.2 *Temperature Considerations*:

9.2.1 Where the displacement measuring systems are electrical, connect the displacement 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 min for the components to be energized.

9.2.2 Position a temperature measuring device in close proximity to the machine being verified. Allow the displacement measuring device and all relevant parts of the verification equipment to reach thermal stability.

9.2.3 Include any bias due to temperature effects in the expanded uncertainty statement associated with the verification displacement values if required.

10. Procedure

10.1 *General*:

10.1.1 After completing the preliminary procedure given in Section 9 and before commencing with the verification procedure, adjust the testing machine to the maximum verification displacement to ensure that the maximum displacement can be achieved, and the machine has adequate space for the calibration device.

NOTE 2—Care should be given to the way a testing machine is used in determining the appropriate procedure for verifying a given machine. If a testing machine used to measure both positive and negative displacement values during normal testing, the system must be verified through zero, and both positive and negative verification values must be obtained.

10.1.2 During the verification, measure the ambient temperature by placing a calibrated thermometer as close to the calibration device as possible. The calibrated thermometer should have an accuracy of ±1°C or better.

10.2 *Procedure*:

10.2.1 Place the calibration device in the testing machine so that its center line coincides as closely as feasible with the center line of the testing machine's application of force.

10.2.2 There are two methods for using displacement calibration devices: