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Standard Practice for ~~Calibrating~~ Calibration/Verification of Linear Displacement Transducers for Geotechnical Purposes¹

This standard is issued under the fixed designation D6027/D6027M; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope*

1.1 This practice outlines the procedure for ~~calibrating~~ calibration/verification of displacement transducers and their readout systems for geotechnical purposes. It covers any transducer used to measure displacement, which gives an electrical output that is linearly proportional to displacement. This includes linear variable displacement transducers (LVDTs), linear displacement transducers (LDTs) and linear strain transducers (LSTs).

1.2 This ~~calibration~~ calibration/verification procedure is used to determine the relationship between output of the transducer and its readout system and change in length. This relationship is used to convert readings from the transducer readout system into engineering units.

1.3 This ~~calibration~~ calibration/verification procedure also is used to determine the accuracy of the transducer and its readout system over the range of its use to compare with the manufacturer's specifications for the instrument and the suitability of the instrument for a specific application.

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

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 unless superseded by this standard.

1.5.1 The procedures used to specify how data are collected, recorded or calculated in this standard are regarded as the industry standard. In addition they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any consideration for the user's objectives; it is common practice to increase or reduce significant digits of reported data to be commensurate with these ~~consideration~~ considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design.

1.6 This practice offers a set of instructions for performing one or more specific operations. This standard cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a

¹ This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.95 on Information Retrieval and Data Automation.

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

given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.7 *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, safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *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

[D653 Terminology Relating to Soil, Rock, and Contained Fluids](#)

[D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction](#)

[D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data](#)

[E2309/E2309M Practices for Verification of Displacement Measuring Systems and Devices Used in Material Testing Machines³](#)

3. Terminology

3.1 ~~Definitions~~—Definitions of terms used in this practice are in accordance with Terminology [D653](#).

3.1 ~~Definitions of Terms Specific to This Standard: Definitions:~~

3.1.1 Definitions of common technical terms used in this practice refer to Terminology [D653](#). For definitions of common metrology terms used in this standard, refer to the International Vocabulary of Metrology.⁴

3.1.2 calibrated range, n—distance ~~for~~over which the ~~transducer~~linear displacement sensor system is calibrated.

3.1.3 core calibration, n—~~central rod that moves in and out of the transducer body;~~operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.

3.1.4 displacement measurement standard, n—system consisting of micrometer or Precision Gauge Blocks combined with an appropriate device for indicating the magnitude (or a quantity proportional to the magnitude) of deformation of the member under an applied displacement

3.1.5 displacement transducer, n—an electrical transducer which converts linear displacement to electrical output.

3.1.6 null position; metrological traceability, n—~~the core position within the sensor body at which the transducer voltage output is zero (some transducers may not have a null position);~~property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

3.1.7 power supply, n—a voltage source with output equal to that required by the sensor.

3.1.8 readout system, n—electronic equipment that accepts output from the signal conditioner for the transducer and provides a visual display or digital record of the transducer output.

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 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.

⁴ International vocabulary of metrology—Basic and general concepts and associated terms (VIM), 3rd Edition. Joint Committee for Guides in Metrology, 2012. https://www.bipm.org/utis/common/documents/jcgm/JCGM_200_2012.pdf



3.1.9 *signal conditioner, n*—electronic equipment that makes the output of the transducer compatible with the readout system. The signal conditioner may also filter the transducer output to remove noise.

3.1.10 *total linear range (TLR), n*—total distance that the core may move from the position of maximum voltage output to the position of minimum voltage output with a linear relationship between displacement and voltage.

3.1.11 *traceability certificate, transducer, n*—a certificate of inspection certifying that the transducer meets indicated specifications for its particular grade or model and whose accuracy is traceable to the National Institute of Standards and Technology or to another international standard device, used in measurement, that provides an output quantity having a specified relation to the input quantity.

3.1.12 *verification, n*—provision of objective evidence that a given item fulfils specified requirements.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *core, n*—central rod that moves in and out of the transducer body.

3.2.2 *null position, n*—the core position within the sensor body at which the transducer voltage output is zero (some transducers may not have a null position).

3.2.3 *percent error of displacement, E_p , n*—the ratio of the displacement measurement error to the applied displacement as measured by the displacement measurement standard, expressed as a percent.

4. Summary of Practice

4.1 A displacement transducer is mounted in such manner to permit it to be subjected to a precise, known displacement.

4.2 Displacement is applied in steps over the full range of the transducer and readings taken from the readout device.

4.3 The slope of the best-fit straight line relating sensor readout data to displacement is determined by linear regression.

4.4 The percent error of the transducer readout system is calculated and compared with the requirements for the specific use of the sensor.

4.5 See [Appendix X1](#) for a flowchart of the calibration/verification process.

4.6 See [Appendix X2](#) for identifying and determination measurement uncertainty component during a displacement transducer system calibration/verification.

5. Significance and Use

5.1 The displacement transducer plays an important role in geotechnical applications to measure change in dimensions of specimens.

5.2 The displacement transducer must be calibrated/calibrated/verified for use in the laboratory to ensure reliable conversions of the sensor's electrical output to engineering units.

5.3 The displacement transducer should be calibrated/calibrated/verified before initial use, at least annually thereafter, after any change in the electronic configuration that employs the sensor, after any significant change in test conditions using the transducer that differ from conditions during the last calibration/calibration/verification, and after any physical action on the transducer that might affect its response.

5.4 Displacement transducer generally has a working range within which voltage output is linearly proportional to displacement

of the transducer. This procedure is applicable to the linear range of the transducer. Recommended practice is to use the displacement transducer only within its linear working range.

NOTE 1—Verification as in Practices E2309/E2309M should not be confused with calibration

6. Apparatus

6.1 *Linear Displacement Transducer*, to be calibrated.

6.2 *Power Supply with Output*, equal to that required by the sensor.

NOTE 2—Some LVDTs use ac voltage while others use dc. The LVDTs and displacement transducer may be damaged if connected to the incorrect power supply.

6.3 *Signal Conditioning, Readout Equipment, and Related Cables and Fittings*.

6.4 *Test Method A—Precision Gauge Block Calibration: Calibration/Verification:*

6.4.1 *Precision Gauge Blocks*, a set of precision reference blocks traceable to the National Institute for Standards and Technology or ~~other~~another recognized standard agency. A gauge block set ~~should~~shall contain sizes necessary to perform satisfactorily the calibration procedures as outlined in Section 9 over the total linear range of the ~~transducer~~transducer (otherwise the test cannot be performed).

6.4.2 *Comparator Stand*, consisting of a base of warp-free stability and ground to a guaranteed flatness, a support column, and an adjustable arm onto which the sensor mounting block can be securely attached. Alternatively, mount the sensor in the configuration it ~~will~~ be used in such a way that gauge blocks can be inserted to displace the core for ~~calibration~~calibration/verification purposes. As shown in Fig. 1.

6.4.3 *Sensor Mounting Block*, a device used to attach the sensor to the comparator stand. Alternatively, mount the sensor to the test equipment in which the transducer is to be used. The mounting holder shall be antiferromagnetic.

6.5 *Test Method B—Micrometer Fixture Calibration: Calibration/Verification:*

6.5.1 *Micrometer Fixture*, a precision instrument for linear measurement capable of obtaining readings over the total linear range



FIG. 1 Comparator Stand Fixture

of the displacement transducer. The spindle must be nonrotating. The micrometer fixture is to be calibrated annually by the manufacturer or other qualified personnel. As shown in Fig. 2.

7. Hazards

7.1 Safety Hazards:

7.1.1 This practice involves electrical equipment. Verify that all electrical wiring is connected properly and that the power supply and signal conditioner are grounded properly to prevent electrical shock to the operator. Take necessary precautions to avoid exposure to power signals.

7.2 Safety Precautions:

7.2.1 Examine the sensor body for burrs or sharp edges, or both. Remove any protrusions that might cause harm.

7.2.2 The transducer can be permanently damaged if incorrectly connected to the power supply or if connected to a power supply with the wrong excitation level.

7.2.3 Follow the manufacturer's recommendations with regard to safety.

7.3 Technical Precautions:

7.3.1 The core and body of the displacement transducer are a matched set. For best performance, do not interchange cores with other displacement transducer bodies.

7.3.2 Replace the core and body if either shows any signs of dents, bending, or other defects that may affect performance of the device.

7.3.3 Store the body and core in a protective case when not in use.

7.3.4 Do not exceed the allowable input voltage of the sensor as specified by the manufacturer.

7.3.5 Do not connect a voltage source to the output leads of the sensor.

7.3.6 Do not over tighten the sensor within the mounting block.

7.3.7 The behavior of some transducers may be affected by metallic holders. If possible, the working holder should be used during calibration/calibration/verification.



FIG. 2 Micrometer Fixture



8. Calibration/Verification and Standardization

8.1 ~~If using Test Method A, verify that the gauge blocks are of sufficient precision and bias and in a clean, unscratched condition.~~ Calibration of Linear Displacement Transducers for Geotechnical Purposes shall be performed in accordance with D6027/D6027M unscratched condition.

8.1.1 If using Test Method A, verify that the gauge blocks are of sufficient precision and bias and in a clean, unscratched condition.

8.1.2 If using Test Method B, verify that the micrometer fixture is in good working order and of sufficient precision and bias.

8.2 ~~If using Test Method B, verify that the micrometer fixture is in good working order and of sufficient precision and bias.~~ Verification of Linear Displacement Transducers for Geotechnical Purposes shall be performed in accordance with Practices E2309/E2309M and of sufficient precision and bias.

9. Procedure

9.1 Perform this ~~calibration/verification~~ calibration/verification in an environment as close to that in which the sensor will be used as possible. The displacement transducer, ~~calibration/verification~~ calibration/verification gauge blocks, micrometer fixture, and comparator stand ~~should~~ shall be in the environment in which they are to be ~~calibrated for~~ calibrated/verified for a sufficient length of time or for at least 1 ~~hour~~ hour prior to ~~calibration/verification~~ calibration/verification to stabilize temperature effects.

9.2 Verify that the power supply is adjusted to supply the recommended voltage to the sensor.

9.3 With equipment turned off, connect all power supply, signal conditioning, and recording equipment exactly as it will be used in service. Allow all electronics to warm up for a sufficient length of time, or for at least 30 min before beginning any readings.

9.4 Record type and serial number of the sensor to be ~~calibrated~~ calibrated/verified. If it has no serial number, record the model number and other identifying markings.

9.5 Record the maximum allowable input voltage specified by the manufacturer and the input voltage used for this ~~calibration/verification~~ calibration/verification.

9.6 Record the total linear range of the sensor and the range over which the transducer will be calibrated.

9.7 Record the type and serial number of the reference standard used.

9.8 ~~Test Method A—Precision Gauge Block Calibration:~~ Calibration/Verification:

9.8.1 Attach the sensor mounting block to the adjustable arm of the comparator stand as shown in Fig. 1 or mount into test equipment as it will be used in service.

9.8.2 Slide the displacement transducer core and core extension rod assembly into the displacement transducer body.

NOTE 3—Some displacement transducers require the core to be in place before powering the displacement transducer.

NOTE 4—Displacement transducer should be checked use for freedom of movement particularly if the core rod and body of the transducer are manufactured as a single unit with a spring loaded core as part of the ~~calibration/verification~~ calibration/verification procedure.

9.8.3 Place the sensor body into the sensor mounting block and tighten the appropriate screw on the mounting block. Do not over tighten the screw on the mounting block. This can damage the sensor body.

9.8.4 Place a gauge block (or series of blocks) that has a height equal to the total linear range of the sensor under the core.

9.8.5 Adjust the sensor body up or down on the comparator stand support column as necessary to obtain a reading on the readout