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Standard Practices for Force Verification of Testing Machines[1]

This standard is issued under the fixed designation E4; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These practices cover procedures for the force verification, by means of ~~standard calibration devices,~~force measurement standards, of tension or compression, or both, static or quasi-static testing machines (which may, or may not, have force-indicating systems). These practices are not intended to be complete purchase specifications for testing machines. ~~Testing machines may be verified by one of the three following methods or combination thereof:~~

~~1.1.1 Use of standard weights,~~

~~1.1.2 Use of equal-arm balances and standard weights, or~~

~~1.1.3 Use of elastic calibration devices.~~

~~NOTE 1—These practices do not cover the verification of all types of testing machines designed to measure forces, for example, the constant-rate-of-loading type which operates on the inclined-plane principle. This type of machine may be verified as directed in the applicable appendix of Specification D76/D76M.~~

1.2 Testing machines may be verified by one of the three following methods or combination thereof. Each of the methods require a specific uncertainty of measurement, displaying metrological traceability to The International System of Units (SI).

1.2.1 Use of standard weights,

1.2.2 Use of equal-arm balances and standard weights, or

1.2.3 Use of force-measuring instruments.

1.3 The term 'metrological traceability' is used as defined in the JCGM 200: International vocabulary of metrology-Basic and general concepts and associated terms (VIM).

1.4 The procedures of ~~1.1.1 – 1.1.3~~1.2.1–1.2.3 apply to the verification of the force-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 force-indicating system(s) to be verified and included in the report.*

1.5 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5.1 Other customary force units may be used with this standard such as the kilogram-force (kgf) which is often used with hardness testing machines

1.6 Forces indicated on displays/printouts of testing machine data systems—be they instantaneous, delayed, stored, or retransmitted—which are verified with provisions of ~~1.1.1~~1.2.1, ~~1.1.2~~1.2.2, or ~~1.1.3~~1.2.3, and are within the ±1 % measurement accuracy requirement, comply with Practices E4.

1.7 The requirements of these practices limit the major components of measurement uncertainty when verifying testing machines. These Standard Practices do not require the allowable error to be reduced by the amount of the measurement uncertainty encountered during a verification. As a result, a testing machine verified using these practices may produce a deviation from the true force greater than ±1.0 % when the error is combined with the measurement uncertainty

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

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

1.9 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]

D76/D76M Specification for Tensile Testing Machines for Textiles

E6 Terminology Relating to Methods of Mechanical Testing

E74 Practices for Calibration and Verification for Force-Measuring Instruments

E467 Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System

2.2 *BIPM Standard:*[3]

JCGM 200 : International vocabulary of metrology — Basic and general concepts and associated terms (VIM).

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology E6.

3.2 *Definitions:*

3.2.1 *calibration, n*—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.

3.2.1.1 *Discussion—*

A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

3.2.1.2 *Discussion—*

Calibration should not be confused with adjustment of a measuring system, often mistakenly called "self-calibration", nor with verification of calibration.

3.2.1.3 *Discussion—*

Often, the first step alone in the above definition is perceived as being calibration. **JCGM 200:2012** [4]

3.2.2 *exercise, v*—apply the maximum force to be used in the verification to either a force-measuring instrument or the force-sensing device of a testing machine or to both, to reestablish the hysteresis pattern that tends to disappear during periods of disuse, or with the change of mode of force application, as from compression to tension.

3.2.3 ~~*elastic calibration device,*~~ *force-measuring instrument, n*—~~a device for use in verifying the force readings of a testing machine~~ system consisting of an elastic ~~member(s) to which forces may be applied, combined with a mechanism or~~ member combined with an appropriate device for indicating the magnitude (or a quantity proportional to the magnitude) of deformation ~~under~~ of the member under an applied force.

3.2.4 *measurement accuracy, n*—closeness of agreement between a measured quantity value and a true quantity value of a measurand

3.2.4.1 *Discussion—*

The concept 'measurement accuracy' is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

3.2.4.2 *Discussion—*

[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 BIPM - Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE. this document is available free-of-charge at https://www.bipm.org/en/publications/guides/vim.html

[4] This definition is reproduced here from JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms (VIM) with permission from the Director of BIPM. The text has been put in ASTM International's form and style.

The term "measurement accuracy" should not be used for measurement trueness and the term "measurement precision" should not be used for 'measurement accuracy', which, however, is related to both these concepts.

3.2.4.3 *Discussion—*

'Measurement accuracy' is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand. **JCGM 200:2012** [4]

3.2.5 *metrological traceability, n*—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.

3.2.5.1 *Discussion—*

For this definition, a 'reference' can be a definition of a measurement unit through its practical realization, or a measurement procedure including the measurement unit for a non-ordinal quantity, or a measurement standard.

3.2.5.2 *Discussion—*

Metrological traceability requires an established calibration hierarchy.

3.2.5.3 *Discussion—*

Specification of the reference must include the time at which this reference was used in establishing the calibration hierarchy, along with any other relevant metrological information about the reference, such as when the first calibration in the calibration hierarchy was performed.

3.2.5.4 *Discussion—*

For measurements with more than one input quantity in the measurement model, each of the input quantity values should itself be metrologically traceable and the calibration hierarchy involved may form a branched structure or a network. The effort involved in establishing metrological traceability for each input quantity value should be commensurate with its relative contribution to the measurement result.

3.2.5.5 *Discussion—*

Metrological traceability of a measurement result does not ensure that the measurement uncertainty is adequate for a given purpose or that there is an absence of mistakes.

3.2.5.6 *Discussion—*

A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards. **JCGM 200:2012** [4]

3.2.6 *portable testing machine (force-measuring type), n*—a device specifically designed to be moved from place to place and for applying a force (load) to a specimen.

3.2.7 *testing machine (force-measuring type), n*—a mechanical device for applying a force to a specimen.

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

3.2.8.1 *Discussion—*

EXAMPLE 1 Confirmation that a given reference material as claimed is homogeneous for the quantity value and measurement procedure concerned, down to a measurement portion having a mass of 10 mg.

3.2.8.2 *Discussion—*

EXAMPLE 2 Confirmation that performance properties or legal requirements of a measuring system are achieved.

3.2.8.3 *Discussion—*

EXAMPLE 3 Confirmation that a target measurement uncertainty can be met.

3.2.8.4 *Discussion—*

When applicable, measurement uncertainty should be taken into consideration.

3.2.8.5 *Discussion—*

The item may be, for example, a process, measurement procedure, material, compound, or measuring system.

3.2.8.6 *Discussion—*

The specified requirements may be, for example, that a manufacturer's specifications are met.

3.2.8.7 *Discussion—*

Verification in legal metrology, as defined in VIML[53], and in conformity assessment in general, pertains to the examination and marking and/or issuing of a verification certificate for a measuring system.

3.2.8.8 *Discussion—*

Verification should not be confused with calibration. Not every verification is a validation.

3.2.8.9 *Discussion—*

In chemistry, verification of the identity of the entity involved, or of activity, requires a description of the structure or properties of that entity or activity. **JCGM 200:2012** [4]

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *accuracy, n*—the specified permissible variation from the reference value.

3.3.1.1 *Discussion—*

A testing machine is said to be accurate if the indicated force is within the specified permissible variation from the actual force. 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 force, but nevertheless, be very inaccurate. On the other hand, the accuracy of the results is in general limited by the sensitivity.

3.3.2 *calibration, n— in the case of force testing machines*, the process of comparing the force indication of the machine under test to that of a standard, making adjustments as needed to meet error requirements.

3.3.1 *capacity range, n*—in the case of testing machines, the range of forces for which it is designed.

3.3.1.1 *Discussion—*

Some testing machines have more than one capacity range, that is, multiple ranges.

3.3.2 *correction, n*—in the case of a testing machine, the difference obtained by subtracting the indicated force from the correct value of the applied force.

3.3.3 *error (or the deviation from the correct value), n*—in the case of a testing machine, the difference obtained by subtracting the force indicated by the calibration device from the force indicated by the testing machine.

3.3.3.1 *Discussion—*

The word "error" shall be used with numerical values, for example, "At a force of 300 kN [60 000 lbf], the error of the testing machine was + 67 N [+ 15 lbf]."

3.3.4 *force, n*—in the case of testing machines, a force measured in units such as pound-force, newton, or kilogram-force.

3.3.4.1 *Discussion—*

The newton is that force which acting on a 1-kg mass will give to it an acceleration of 1 m/s^2. The pound-force is that force which acting on a [1-lb] mass will give to it an acceleration of 9.80665 m/s^2 [32.1740 ft/s^2]. The kilogram-force is that force which acting on a 1-kg mass will give to it an acceleration of 9.80665 m/s^2[32.1740 ft/s^2].

3.3.5 *force measurement standard, n*—a standard weight, an equal-arm balance and a standard weight, or a force-measuring instrument used as a reference, with associated measurement uncertainty, in compliance with these practices and Preactices E74.

3.3.5.1 *Discussion—*

A force measurement standard is a specific type of "measurement standard" as defined in JCGM 200: International vocabulary of metrology — Basic and general concepts and associated terms (VIM).

3.3.6 *percent ~~error,~~ error of force, n*—in the case of a testing machine, the ratio, expressed as a percent, of the error to the correct value of the applied force.

3.3.6.1 *Discussion—*

The test force, as indicated by the testing machine, and the applied force, as computed from the readings of the verification device, shall be recorded at each test point. The error, *E*, and the percent ~~error,~~ error of forces, *E*p, shall be calculated from these data as follows:

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

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

where:

A = force indicated by machine being verified, N [or lbf], and
~~*B* = correct value of the applied force, N [or lbf], as determined by the calibration device.~~
B = correct value of the applied force, N [or lbf], as determined by the force measurement standard.

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

3.3.7.1 *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.

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

3.3.8.1 *Discussion—*

Appendix X1 describes a method for determining resolution.

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

3.3.9.1 *Discussion—*

The resolution is calculated by multiplying the force 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. The typical ratios used are 1:1, 1:2, 1:5, or 1:10. A spacing of 2.5 mm [0.10 in.] or greater is recommended for the ratio of 1:10. A ratio less than 1:10 should not be used.

3.3.9.2 *Discussion—*

If a force indicating dial has graduations spaced every 2.0 mm [0.080 in.], the width of the pointer is approximately 1.0 mm (0.040 in.), and one graduation represent 25N [5 lbf]. The ratio used would be 1:2 and the resolution would be equal to 12-½ N [2-½ lbf].

3.3.9.3 *Discussion—*

If the force indication fluctuates by more than twice the resolution, as described in 3.3.9, the resolution, expressed as a force, shall be equal to one-half the range of the fluctuation.

3.3.10 *resolution of digital type force indicators (numeric, displays, printouts, etc.), n*—the resolution is the smallest change in force that can be displayed on the force indicator, at any applied force.

3.3.10.1 *Discussion—*

A single digit or a combination of digits may be the smallest change in force that can be indicated.

3.3.10.2 *Discussion—*

If the force ~~indication, for either type of force indicator,~~ indication fluctuates by more than twice the resolution, as described in 3.3.10~~ or 3.3.11~~, the resolution, expressed as a force, shall be equal to one-half the range of the fluctuation.

~~3.3.12 *verification, n— in the case of force testing machines*, the process of comparing the force indication of the machine under test to that of a standard and reporting results, without making adjustments.~~

3.3.11 *verified range of forces, n*—in the case of testing machines, the range of indicated forces for which the testing machine gives results within the permissible variations specified.

4. Significance and Use

4.1 Testing machines that apply and indicate force 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 that the amount of force applied and indicated is traceable to the International System of Units (SI) through a National Metrology Institute (NMI). The procedures in Practices E4 may be used to verify these machines so that the indicated forces are traceable to the SI. A key element of traceability to the SI is that the devices used in the verification have known force characteristics, and have been calibrated in accordance with Practice E74.

4.2 The procedures in Practices E4 may be used by those using, manufacturing, and providing calibration service for testing machines and related instrumentation.

5. ~~Calibration Devices~~Force-Measuring Instruments

5.1 When verifying testing machines, use ~~calibration devices~~force-measuring instruments only over their Class A force ranges as determined by Practice E74.

6. Advantages and Limitations of Methods

6.1 *Verification by Standard Weights*—Verification by the direct application of standard weights to the weighing mechanism of the testing machine, where practicable, is the most accurate method. Its limitations are: (*1*) the small range of forces that can be verified, (*2*) the nonportability of any large amount of standards weights, and (*3*) its nonapplicability to horizontal testing machines or vertical testing machines having weighing mechanisms that are not designed to be actuated by a downward force.

6.2 *Verification by Equal-Arm Balance and Standard Weights—*The second method of verification of testing machines involves measurement of the force by means of an equal-arm balance and standard weights. This method is limited to a still smaller range of forces than the foregoing method, and is generally applicable only to certain types of hardness testing machines in which the force is applied through an internal lever system.

6.3 *Verification by ~~Elastic Calibration Devices—~~Force-measuring Instruments—*The third method of verification of testing machines involves measurement of the elastic strain or deflection under force of a ring, loop, tension or compression bar, or other ~~elastic device. The elastic calibration device~~ force-measuring instrument. The force-measuring instrument is free from the limitations referred to in 6.1 and 6.2.

7. System Verification

7.1 A testing machine shall be verified as a system with the force sensing and indicating devices (see ~~1.2~~1.4 and ~~1.4~~1.6) in place and operating as in actual use.