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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 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.

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 1.2.1–1.2.3 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 1.2.1, 1.2.2, or 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

[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.

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

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 *force-measuring instrument, n*—system consisting of an elastic member combined with an appropriate device for indicating the magnitude (or a quantity proportional to the magnitude) of deformation 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*—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] 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.

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 *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 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 of forces, Ep, shall be calculated from these data as follows:

$$E = A - B \quad (1)$$

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

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 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.

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 fluctuates by more than twice the resolution, as described in 3.3.10, the resolution, expressed as a force, shall be equal to one-half the range of the fluctuation.

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. Force-Measuring Instruments

5.1 When verifying testing machines, use 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 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 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 1.4 and 1.6) in place and operating as in actual use.

7.1.1 If this is not technically possible, refer to Annex A1, Verifying the Force Measuring System out of the Test Machine. Out of the test machine verifications shall be in accordance with the main body of Practices E4 and its Annex A1

7.2 System verification is invalid if the devices are removed and checked independently of the testing machine unless verification is performed according to Annex A1.

7.3 Many testing machines utilize more than one force measuring device in order to obtain more accurate force indication at lower applied forces. These devices are routinely installed and uninstalled in the testing machine. For such devices, interchangeability shall be established during the original verification and shall be reestablished after an adjustment is performed. This is accomplished by performing a normal verification with the device in place as during normal use. It is advisable that orientation be kept consistent, such as by noting the direction of the cable connector so that when reinstalling the device, the orientation will be repeated. Remove and reinstall the device between the two verification runs to demonstrate interchangeability. Repeat the procedure for each interchangeable force measuring device used in the testing machine.

7.3.1 Introduction of the new force measuring devices shall require that interchangeability be established per 7.3.

7.4 A Practices E4 Verification consists of at least two verification runs of the forces contained in the force range(s) selected. See 10.1 and 10.3.

7.4.1 If the initial verification run produces values within the Practices E4 requirements of Section 14, the data may be used "as found" for run one of the two required for the new verification report.

7.4.2 If the initial verification run produces any values which are outside of the Practices E4 requirements, the "as found" data may be reported and may be used in accordance with applicable quality control programs. Calibration adjustments shall be made to the force indicator system(s), after which the two required verification runs shall be conducted and reported in the new verification report and certificate.

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

8. Gravity and Air Buoyancy Corrections

8.1 In the verification of testing machines, where standard weights are used for applying forces directly or through lever or balance-arm systems, correct the force for the local value of gravity and for nominal air buoyancy.

8.1.1 The force exerted by a weight in air is determined by:

$$\text{Force} = Mg\left(1 - \frac{d}{D}\right) \tag{2}$$

where:

F = Force, N
M = true mass of the weight, kg
g = local acceleration due to gravity, m/s^2,
d = air density (1.2 kg/m^3), and
D = density of the weight in the same units as d.

8.1.2 For the purposes of this standard, g can be calculated with a sufficient uncertainty using the following formula.

$$g = 9.7803\left[1 + 0.0053\left(\sin\ \varnothing\right)^2\right] - 0.000001967h \tag{3}$$

where:

where:

$\varnothing$ = latitude
h = elevation above sea level in metres

NOTE 1—Eq 3 corrects for the shape of the earth and the elevation above sea level. The first term, which corrects for the shape of the earth, is a simplification of the World Geodetic System 84 Ellipsoidal Gravity Formula. The results obtained with the simplified formula differ from those in the full version by less than 0.0005%. The second term combines a correction for altitude, the increased distance from the center of the earth, and a correction for the counter-acting Bouguer effect of localized increased mass of the earth. The second term assumes a rock density of 2.67 g/cm^3. If the rock density changed by 0.5 g/cm^3, an error of 0.003 % would result.

8.2 The force in customary units exerted by a weight in air is calculated as follows:

$$F_c = \frac{Mg}{9.80665}\left(1 - \frac{d}{D}\right) \quad (4)$$

where:

where:

F_c = force expressed in customary units, that is, pound force or kilogram-force,
M = true mass of the weight,
g = local acceleration due to gravity, m/s^2,
d = air density (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 customary units of force; this factor is equal to the value for standard gravity, 9.80665 m/s^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 kilogram-force units (kgf). These customary force units are related to the newton (N), the SI unit of force, by the following relationships:

$$1 \text{ lbf} = 4.448222\text{N} \quad (5)$$

$$1 \text{ kgf} = 9.80665 \text{ N (exact)} \quad (6)$$

8.2.1 For use in verifying testing machines, corrections for local values of gravity and air buoyancy to weights calibrated in pounds can be made with sufficient precision using the multiplying factors from Table 1. Alternatively the following formula may be used to find the multiplying factor, MF. Multiply MF times the mass of the weight given in pounds to obtain the value of force in pounds-force, corrected for local gravity and air buoyancy.

$$MF = \frac{9.7803\left[1 + 0.0053\left(\sin \varnothing\right)^2\right] - 0.000001967h}{9.80665} \times 0.99985 \quad (7)$$

where:

$\varnothing$ = latitude
h = elevation above sea level in metres

NOTE 2—Eq 7 and Table 1 correct for the shape of the earth, elevation above sea level, and air bouyancy. The correction for the shape of the earth is a simplification of the World Geodetic System 84 Ellipsoidal Gravity Formula. The results obtained with the simplified formula differ by less than 0.0005%. The term that corrects for altitude, corrects for an increased distance from the center of the earth and the counter-acting Bouguer effect of localized increased mass of the earth. The formula assumes a rock density of 2.67 g/cc. If the rock density changed by 0.5 g/cc, an error of 0.003 % would result. The largest inaccuracy to be expected, due to extremes in air pressure, temperature, and humidity when using steel weights, is approximately 0.01%. If aluminum weigths are used, errors on the order of 0.03% can result.

8.3 Standard weights are typically denominated in a unit of mass. When a standard weight has been calibrated such that it exerts a specific force under prescribed conditions, the weight will exert that force only under those conditions. When used in locations where the acceleration of gravity differs from the one in the calibration location, it is necessary to correct the calibrated force value by multiplying the force value by the value for local gravity and dividing by the value of gravity for which the weight was calibrated. Any required air buoyancy corrections must also be taken into account.

9. Application of Force

9.1 In the verification of a testing machine, approach the force by increasing the force from a lower force.

NOTE 3—For any testing machine the errors observed at corresponding forces taken first by increasing the force to any given test force and then by decreasing the force to that test force, may not agree. Testing machines are usually used under increasing forces, but if a testing machine is to be used under decreasing forces, it should be calibrated under decreasing forces as well as under increasing forces.

9.2 Testing machines that contain a single test area and possess a bidirectional loading and weighing system must be verified separately in both modes of weighing.

TABLE 1 Multiplying Factor, MF, in Air at Various Latitudes, see Eq 7

Latitude, Ø,°	Elevation Above Sea Level, h, m (ft)					
	0 (0)	500 (1640)	1000 (3280)	1500 (4920)	2000 (6560)	2500 (8200)
0	0.9972	0.9971	0.9970	0.9969	0.9968	0.9967
5	0.9972	0.9971	0.9970	0.9969	0.9968	0.9967
10	0.9973	0.9972	0.9971	0.9970	0.9969	0.9968
15	0.9975	0.9974	0.9973	0.9972	0.9971	0.9970
20	0.9978	0.9977	0.9976	0.9975	0.9974	0.9973
25	0.9981	0.9980	0.9979	0.9978	0.9977	0.9976
30	0.9985	0.9984	0.9983	0.9982	0.9981	0.9980
35	0.9989	0.9988	0.9987	0.9986	0.9985	0.9984
40	0.9993	0.9992	0.9991	0.9990	0.9989	0.9988
45	0.9998	0.9997	0.9996	0.9995	0.9994	0.9993
50	1.0003	1.0002	1.0001	1.0000	0.9999	0.9998
55	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002
60	1.0011	1.0010	1.0009	1.0008	1.0007	1.0006
65	1.0015	1.0014	1.0013	1.0012	1.0011	1.0010
70	1.0018	1.0017	1.0016	1.0015	1.0014	1.0013

9.3 High-speed machines used for static testing must be verified in accordance with Practices E4. **Warning—** Practices E4 verification values are not to be assumed valid for high-speed or dynamic testing applications (see Practice E467).

NOTE 4—The error of a testing machine of the hydraulic-ram type, in which the ram hydraulic pressure is measured, may vary significantly with ram position. To the extent possible such machines should be verified at the ram positions used.

10. Selection of Verification Forces

10.1 Determine the upper and lower limits of the verified force range of the testing machine to be verified. In no case shall the verified force range include forces below 200 times the resolution of the force indicator.

10.2 If the lower limit of the verified force range is greater than or equal to one-tenth of the upper limit, five or more different verification forces shall be selected such that the difference between two adjacent verification forces is greater than or equal to one twentieth and less than or equal to one-third the difference between the upper and lower limits of the verified force range. One verified force shall be the lower limit of the verified force range and another verified force shall be the upper limit. (Fewer verification forces are required for testing machines designed to measure only a small number of discrete forces, such as certain hardness testers, creep testers, etc.)

10.3 If the lower limit of the verified force range is less than one-tenth the upper limit, verification forces shall be selected as follows:

10.3.1 Starting with the lower limit of the verified force range, establish overlapping force decades such that the maximum force in each decade is ten times the lowest force in the decade. The lowest force in the next higher decade is the same as the highest force in the previous decade. The highest decade might not be a complete decade.

10.3.2 Five or more different verification forces shall be selected per decade such that the difference between two adjacent verification forces is greater than or equal to one-twentieth and less than or equal to one-third the difference between the maximum and the minimum force in that decade. It is recommended that starting with the lowest force in each decade, the ratio of the verification forces to the lowest force in the decade are 1:1, 2:1, 4:1, 7:1, 10:1 or 1:1, 2.5:1, 5:1, 7.5:1, 10:1.

10.3.3 If the highest decade is not a complete decade, choose verification forces at the possible ratios and include the upper limit of the verified force range. If the difference between two adjacent verification forces is greater than one-third of the upper limit, add an additional verification force.

NOTE 5—Example: A testing machine has a full-scale range of 5000 N and the resolution of the force indicator is 0.0472 N. The lowest possible verified force is 9.44 N (0.0472 × 200). Instead of decades starting at 9.44, 94.4 and 944 N, three decades, starting at 10, 100, and 1000 N are selected to cover the verified range of forces. Suitable verification forces are 10, 20, 40, 70, 100, 200, 400, 700, 1000, 2000, 3000, 4000, 5,000. Note that the uppermost decade is not a complete decade and is terminated with the upper limit of the verified force range. The 3000 N reading was added because the difference between 2000 and 4000 was greater than one-third of 5000. If the alternative distribution of forces is used, the verification forces selected would be 10, 25, 50, 75, 100, 250, 500, 750, 1000, 2500, 3750, 5000.

10.4 All selected verification forces shall be applied twice during the verification procedure. Applied forces on the second run are to be approximately the same as those on the first run.

10.5 Approximately 30 s after removing the maximum force in a range, record the return to zero indicator reading. This reading shall be 0.0 ± either the resolution, 0.1 % of the maximum force just applied, or 1 % of the lowest verified force in the range, whichever is greater.

11. Eccentricity of Force

11.1 For the purpose of determining the verified force range of a testing machine, apply all calibration forces so that the resultant force is as nearly along the axis of a testing machine as is possible.

NOTE 6—The effect of eccentric force on the measurement accuracy of a testing machine may be determined by verification readings taken with force measurement standards placed so that the resultant force is applied at definite distances from the axis of the machine, and the verified force range determined for a series of eccentricities.

12. Methods of Verification

12.1 *Method A, Verification by Standard Weights:*

12.1.1 *Procedure:*

12.1.1.1 Place standard metal weights of suitable design, finish, and adjustment on the weighing platform of the testing machine or on trays or other supports suspended from the force measuring mechanism in place of the specimen. Use weights certified within five years to be accurate within 0.1%. Apply the weights in ascending increments. If data is to be taken in both ascending and descending directions, remove the weights in reverse order. Record the forces, corrected for gravity and air buoyancy in accordance with Section 8.

NOTE 7—The method of verification by direct application of standard weights can be used only on vertical testing machines in which the force on the weighing table, hydraulic support, or other weighing device is downward. The total force is limited by the size of the platform and the number of weights available. Twenty-five kg or [fifty lb] weights are usually convenient to use. This method of verification is confined to small testing machines and is rarely used above 5000 N [1000 lbf].

12.2 *Method B. Verification Of Hardness Testing Machines by Equal-Arm Balance and Standard Weights:*

12.2.1 *Procedure:*

12.2.1.1 Position the balance so that the indenter of the testing machine being calibrated bears against a block centered on one pan of the equal-arm balance, the balance being in its equilibrium position when the indenter is in that portion of its travel normally occupied when making an impression. Place standard weights complying with the requirements of Section 12 on the opposite pan to balance the load exerted by the indenter.

NOTE 8—This method may be used for the verification of testing machines other than hardness-testing machines by positioning the force-applying member of the testing machine in the same way that the indenter of a hardness-testing machine is positioned. For other methods of verifying hardness testing machines see the applicable ASTM test method.

12.2.1.2 Since the permissible travel of the indenter of a hardness-testing machine is usually very small, do not allow