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Standard Practices for Force Verification of Testing Machines[1]

This standard is issued under the fixed designation E 4; 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 Department of Defense.

1. Scope

1.1 These practices cover procedures for the force verification, by means of standard calibration devices, 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 D 76.

1.2 The procedures of 1.1.1-1.1.3 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*.

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

1.4 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, 1.1.2, or 1.1.3, and are within the ±1 % accuracy requirement, comply with Practices E 4.

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:*

D 76 Specification for Tensile Testing Machines for Textiles[2]

[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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E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Force Indication of Testing Machines[3]
E 467 Practice for Verification of Constant Amplitude Dynamic Loads on Displacements in an Axial Load Fatigue Testing System[3]

3. Terminology

3.1 *Definitions:*

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

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

3.1.2 *tension testing machine, CRT (constant-rate-oftraverse)*—a mechanical device for applying a load (force) to a specimen and in which the force is measured by means of a pendulum.

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

3.1.3.1 *Discussion*—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 newton is that force which acting on a 1-kg mass will give to it an acceleration of 1 m/s^2.

3.1.4 *accuracy*—the specified permissible variation from the correct value. A testing machine is said to be accurate if the indicated force is within the specified permissible variation from the actual force.

3.1.4.1 *Discussion*—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.

3.1.5 *error (or the deviation from the correct value)*—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.

3.1.5.1 *Discussion*—The word "error" shall be used with numerical values, for example, "At a force of 30 000 lbf (133 kN), the error of the testing machine was + 15 lbf (67 N)."

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

3.1.6.1 *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, Ep, 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, lbf (or N), and
B = correct value of the applied force, lbf (or N), as determined by the calibration device.

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

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

3.1.8.1 *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.

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

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

3.1.10.1 *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.

3.1.10.2 *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.

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

3.1.12 *resolution of the force indicator*—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.

[2] *Annual Book of ASTM Standards*, Vol 07.01.
[3] *Annual Book of ASTM Standards*, Vol 03.01.

3.1.12.1 *resolution of analog type force indicators (scales, dials, recorders, etc.)*—the resolution is the smallest change in force indicated by a displacement of a pointer, or pen line. 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 0.10 in. (2.5 mm) or greater is recommended for the ratio of 1:10. A ratio less than 1:10 should not be used.

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

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

(*1*) *Discussion* —A single digit or a combination of digits may be the smallest change in force that can be indicated.

3.1.13 If the force indication, for either type of force indicator, fluctuates by more than twice the resolution, as described in 3.1.12.1 or 3.1.12.2, the resolution, expressed as a force, shall be equal to one-half the range of the fluctuation.

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 the amount of force that is applied and indicated, and that the accuracy of the force is traceable to the National Institute of Standards and Technology (NIST), formerly NBS. Practices E 4 provides a procedure to verify these machines, in order that the indicated forces may be traceable. A key element to this NIST traceability is that the devices used in the verification have known force characteristics, and have been calibrated in accordance with Practice E 74.

4.2 The procedures in Practices E 4 may be used by those using, manufacturing, and providing calibration service for testing machines and related instrumentation.

5. Calibration Devices

5.1 When verifying testing machines, use calibration devices only over their Class A force ranges as determined by Practice E 74.

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*—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 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 and 1.4) in place and operating as in actual use.

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

7.3 A Practices E 4 Verification consists of at least two verification runs of the forces contained in the force range(s) selected. See 10.1 and 10.3.

7.3.1 If the initial verification run produces values within the Practices E 4 requirements of Section 18, the data may be used "as found" for run one of the two required for the new verification report.

7.3.2 If the initial verification run produces any values which are outside of the Practices E 4 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.

7.3.3 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 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 air buoyancy.

8.2 Calculate the force exerted by a weight in air as follows:

$$\text{Force} = \frac{Mg}{9.80665}\left(1 - \frac{d}{D}\right) \tag{2}$$

where:

M = mass of the weight,
g = local acceleration due to gravity, m/s^2,
d = air density (0.0012 Mg/m^3), and
D = density of the weight in the same units as d.

For use in verifying testing machines, corrections for local values of gravity and air buoyancy can be made with sufficient accuracy using the multiplying factors from Table 1.

NOTE 2—If M, the mass of the weight is in pounds, the force will be in pounds-force units. If M is in kilograms, the force will be in kilogram-force units. These customary force units are related to the newton, the SI unit of force, by the following relationships:

$$1 \text{ lbf} = 4.448222 \text{ N} 1 \text{ kgf} = 9.80665 \text{ N (exact)} \tag{3}$$

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.

9.3 High-speed machines used for static testing must be verified in accordance with Practices E 4.

NOTE 4—**Caution:** Practices E 4 verification values are not to be assumed valid for high-speed or dynamic testing applications (see Practice E 467).

NOTE 5—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.

TABLE 1 Unit Force Exerted by a Unit Mass in Air at Various Latitudes

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

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 6—Example: A testing machine has a full-scale range of 5000 lbf and the resolution of the force indicator is 0.0472 lbf. The lowest possible verified force is 9.44 lbf (0.0472 × 200). Instead of decades starting at 9.44, 94.4 and 944 lbf, three decades, starting at 10, 100, and 1000 lbf 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 lbf. Note that the uppermost decade is not a complete decade and is terminated with the upper limit of the verified force range. The 3000 lbf 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 7—The effect of eccentric force on the accuracy of a testing machine may be determined by verification readings taken with calibration devices 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.

A. VERIFICATION BY STANDARD WEIGHTS

12. Procedure

12.1 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 correct within a limit of error of 0.1 %. Apply the weights in increments and remove in the reverse order. Arrange the weights symmetrically with respect to the weighing platform, so that the center of gravity of the force lies in the vertical line through the center of the platform. Record the applied force and the indicated force for each test load applied, and the error and the percent error calculated from these data.

NOTE 8—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. Fifty-pound (22.7-kg) weights are usually convenient to use. This method of verification is confined to small testing machines and is rarely used above 1000 or 2000 lb.

NOTE 9—In connection with the required limit of error of 0.1 % it may be noted that, in addition to the National Institute for Standards and Technology, many of the states, some counties, and some universities have departments or offices of weights and measures equipped and staffed to certify weights to tolerances closer than the requirement of a limit of error of 0.1 %.

B. VERIFICATION OF HARDNESS TESTING MACHINES BY EQUAL-ARM BALANCE AND STANDARD WEIGHTS

13. Procedure

13.1 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 10—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.

13.2 Since the permissible travel of the indenter of a hardness-testing machine is usually very small, do not allow the balance to oscillate or swing. Instead, maintain the balance in its equilibrium position through the use of an indicator such as an electric contact, which shall be arranged to indicate when the reaction of the indenter force is sufficient to lift the pan containing the standard weights.

13.3 Using combinations of fractional weights, determine both the maximum value of the dead-weight force that can be lifted by the testing machine indenter force during each of ten successive trials, and the minimum value that cannot be lifted during any one of ten successive trials. Take the correct value of the indenting force as the average of these two values. The difference between the two values shall not exceed 0.5 % of the average value.

C. VERIFICATION BY ELASTIC-CALIBRATION DEVICE

14. Temperature Equalization

14.1 When using an elastic calibration device to verify the readings of a testing machine, place the device near to, or preferably in, the testing machine a sufficient length of time before the test to assure that the response of device is stable.

14.2 During the verification, measure the temperature of the elastic device within ±2°F or ±1°C by placing a calibrated thermometer as close to the device as possible.

14.3 Elastic calibration devices not having an inherent temperature-compensating feature must be corrected mathematically for the difference between ambient temperature and the temperature to which its calibration is referenced. Temperature-correction coefficients should be furnished (if applicable) by the manufacturer of the calibration device. Refer to Practice E 74 for further information.

15. Procedure

15.1 Place the elastic device in the testing machine so that its center line coincides with the center line of the heads of the testing machine. Record the Practice E 74 Class A verification value which establishes the lowest limit, or force level, allowable for the calibration device's loading range (see Practice E 74). Each elastic calibration device is to be used only within its Class A force range and identified with the verification readings for which it is used.

15.2 To ensure a stable zero, flex the elastic device from no force to the maximum force at which the device will be used. Repeat as necessary, allowing sufficient time for stability.

15.3 There are two methods for using elastic calibration devices:

15.3.1 *Follow-the-Force Method*—The force on the elastic calibration device is followed until the force reaches a nominal graduation on the force-readout scale of the testing machine. Record the force on the elastic calibration device.

15.3.2 *Set-the-Force Method*—The nominal force is preset on the elastic calibration device, and the testing machine force readout is read when the nominal force on the elastic calibration device is achieved.

15.4 After selecting suitable test force increments, obtain zero readings for both machine and elastic device, and apply forces slowly and smoothly during all verification measurements.

15.5 The calibration procedure must ensure that use of the maximum force indicator, recorder, or other accessory force devices does not cause testing machine errors to exceed the acceptable tolerances of 18.1.

15.6 Record the indicated force of the testing machine and the applied force from the elastic calibration device (temperature corrected as necessary), as well as the error and percentage of error calculated from the readings.

15.7 Under certain conditions, multi-device setups may be used in compression loading. All devices to be loaded in parallel should be the same height (shims may be used) and the machine's load axis should be coincidental with the force axis of the device setup. This is necessary so that a net moment is not applied to the testing machine loading member. Multi-device setups are not recommended unless the use of a single calibration device is not practical.

16. Constant-Rate-of-Traverse CRT-Type Testing Machines

16.1 In the verification of pendulum-type testing machines having capacities of 2000 lbf or 10 kN or less, special procedures must be followed in order to properly account for the effects of friction, inertia, etc. These machines are usually of the vertical type and usually can be verified by standard weights. For pendulum-type tension-testing machines in which the forces act in a horizontal direction or when verification by standard weights is not practical, other methods of verification may be used. In such cases, devices similar to the equal-arm balances, or the elastic calibrating devices may be used, provided precautions as set forth herein are taken.

16.2 Either or both of two alternative procedures (see 16.5 and 16.6) may be used, depending on the requirements of specifications of materials to be tested, recommendations of the testing machine manufacturer, or other pertinent consideration.

16.3 For any range of forces, verify the tension-testing machine with at least five test forces. Each successive test load shall differ from the previous test force by not more than one third of the difference between the maximum and minimum test forces.

16.3.1 For CRT machines, the verified range of force shall in no case include forces below 15 % of the capacity range.

16.4 Except as set forth in Section 16, other requirements of Practices E 4 shall be applicable.

16.5 *Procedure 1 (Pawls Inoperative)* :

16.5.1 Verify the machine in the condition under which it is to be used, with all attachments and recording mechanisms in operation as they are to be used in actual testing, except that any pawls or other detents in the weighing mechanism shall have been rendered inoperative. In verification, apply the test force and minimize the effect of friction by gently oscillating the pendulum to ensure that the force of the applied test force is in equilibrium with the force exerted by the pendulum.

16.5.2 Examine the machine to detect any friction or slack in the weighing, indicating, or recording mechanisms and estimate the actual effect in terms of units in which the machine is calibrated.

16.5.3 Follow 16.6 to determine the effects described in 16.5.2.

16.6 *Procedure 2 (Pawls Operating)* :

16.6.1 Verify the machine in the condition under which it is to be used with all attachments and recording mechanisms in operation as they are to be used in actual testing. In verification, apply the test force with the pawls or other detents in the normal operating position. After the pendulum has come to rest, disengage the pawls or detents, if any, and depress the pendulum slightly as if the force were decreased (approximately 5 % of the capacity range). Next, with the pawls or detents engaged, release the pendulum smoothly and at a rate approximately the rate of movement of the pendulum during an actual test. The point at which the system comes to rest under these conditions shall be taken as the indicated force on the machine.

17. Lever-Type Creep-Rupture Testing Machines

17.1 Lever-type creep-rupture machines, which do not have a force-indicating device, may be verified using standard weights or elastic calibration device(s), or both. Weights used for verification should conform to the requirements of 12.1. In using an elastic calibration device, the requirements of Sections 14 and 15 must be met as applicable.

17.2 *Procedure*:

17.2.1 Place the calibration device in the testing machine and adjust the counterbalance (if the machine is so equipped) to compensate for the weight of the calibration device.

17.2.2 Connect the lower crosshead of the machine to the calibration device, and apply forces using standard weights in increments conforming to the provisions of 10.1.

17.2.3 Since many lever-type creep-rupture machines do not have a provision for adjustment of the lever ratio or tare, or both, it may be necessary to determine the "best fit" straight line through the calibration data, using the least squares method. By doing this, the actual lever ratio and tare of each machine can be determined, and thus reduce force errors due to small variations of lever ratios. Maximum errors should not exceed the requirements stated in 18.1.

CALCULATION AND REPORT

18. Basis of Verification

18.1 The percent error for forces within the range of forces of the testing machine shall not exceed ±1.0 %. The algebraic difference between errors of two applications of same force (repeatability) shall not exceed 1.0 % (see 10.1 and 10.3).

NOTE 11—This means that the report of the verification of a testing machine will state within what verified range of forces it may be used, rather than reporting a blanket acceptance or rejection of the machine. In machines that possess multiple-capacity ranges, the verified range of forces of each must be stated.

18.2 In no case shall the verified range of forces be stated as including forces outside the range of forces applied during the verification test.

18.3 Testing machines may be more or less accurate than the allowable ±1.0 % error, or more or less repeatable than 1.0 %, which are the Practices E 4 verification basis. Buyers/owners/users or product specification groups might require or allow larger or smaller error systems. Systems with accuracy errors larger than ±1.0 % or repeatability errors larger than 1.0 % do not comply with Practices E 4.

19. Corrections

19.1 The indicated force of a testing machine that exceeds the permissible variation shall not be corrected either by calculation or by the use of a calibration diagram in order to obtain values within the required permissible variation.

20. Time Interval Between Verifications

20.1 It is recommended that testing machines be verified annually or more frequently if required. In no case shall the time interval between verifications exceed 18 months (except for machines in which a long-time test runs beyond the 18-month period). In such cases, the machine shall be verified after completion of the test.

20.2 Testing machines shall be verified immediately after repairs (this includes new or replacement parts, or mechanical or electrical adjustments) that may in any way affect the operation of the weighing system or the values displayed.

20.2.1 Examples of new or replacement parts which may not effect the operation of the weighing system are: printers, computer monitors, keyboards, and modems.

20.3 Verification is required immediately after a testing machine is relocated (except for machines designed to be moved from place to place in normal use), and whenever there is a reason to doubt the accuracy of the force indicating system, regardless of the time interval since the last verification.

21. Accuracy Assurance Between Verifications

21.1 Some product-testing procedures may require daily, weekly, or monthly spot checks to ascertain that a testing machine is capable of producing accurate force values between the testing machine verifications specified in Section 20.

21.2 Spot checks may be performed on ranges of interest or at force levels of interest utilizing a calibration device that complies with Methods A, B, and C as applicable. Elastic calibration devices must meet Class A requirements of Practice E 74 for the force level(s) at which the spot checks are made.

21.3 Make spot checks at approximately 20 % and 80 % of a range unless otherwise agreed upon or stipulated by the material supplier/user.

21.4 Testing machine error shall not exceed ±1.0 % of the spot check applied forces. Should errors be greater than ±1.0 % at any of the spot check force levels, verify the testing machine immediately (see 20.3).

21.5 Maintain a record of the spot check tests which shall include the name, serial number, verification date, verification agency, and the minimum Class A, Practice E 74 value of the calibrating device(s) used to make spot checks; also include the name of person making the spot checks.

21.6 The testing machine shall be considered verified up to the date of the last successful spot check verification (see 21.4), provided that the testing machine is verified in accordance with Section 20 on a regular schedule. Otherwise spot checks are not permitted.

21.7 When spot checks are made, a clear, concise record must be maintained as agreed upon between the supplier and the user. The record must also contain documentation of the regular verification data and schedule.

22. Report

22.1 Prepare a clear and complete report of each verification of a testing machine which shall include the following:

22.1.1 Name of the calibrating agency,

22.1.2 Date of verification,

22.1.3 Testing machine description, serial number, and location,

22.1.4 Method of verification used,

22.1.5 Serial number and manufacturer of all devices used for verification,

22.1.6 Statement of how, by whom, and when the calibration of the apparatus used in verifying the testing machine was made,

22.1.7 Class A range of forces, in accordance with Practice E 74, for each calibration device,

22.1.8 Temperature of the calibration device and a statement that computed forces have been temperature corrected as necessary,

22.1.9 Statement identifying the force-indicating systems that were verified (for testing machines having more than one type of indicating system),

22.1.10 Indicated force of the testing machine and applied force indicated by the calibration device for each run at each verification force for each force-indicating system verified,

22.1.11 Testing machine error, percent error, and alegebraic error difference (repeatability) for each force-indicating system at each force point,

22.1.12 Verified range of forces of each force-indicating system of the testing machine and associated resolutions(s),

22.1.13 Return to zero reading for each range (see 10.5),

22.1.14 Statement that verification has been performed in accordance with Practice E 4 – XX. It is recommended that verification be performed in accordance with the latest published issue of Practice E 4, and

22.1.15 Names of calibration personnel and witnesses (if required).

23. Certificate

23.1 A certificate shall be prepared and signed by the person in responsible charge of the verification which shall include the following:

23.1.1 Name of calibrating agency,

23.1.2 Testing machine description and serial number,

23.1.3 Date of certification,

23.1.4 Identification of verified force-indicating systems,

23.1.5 Verified range(s) of force for each force-indicating system of the testing machine,

23.1.6 Maximum verified range tolerance in percent, and

23.1.7 Serial number, verified range of force, and calibration date of testing devices used for verification.

23.2 The certificate shall be error-free, and contain no alteration of data, dates, etc.

23.2.1 The certificate shall clearly reference associated report(s), when supplied.

24. Keywords

24.1 calibration; force range; resolution; verification

APPENDIXES

(Nonmandatory Information)

X1. DETERMINING RESOLUTION OF THE FORCE INDICATOR

X1.1 The resolution of a testing machine in general is a complex function of many variables including applied force, force range, electrical and mechanical components, electrical and mechanical noise, and software employed, to name a few.

X1.2 A variety of methods may be used to check the resolution of the system. Some suggested procedures are as follows.

X1.3 *Procedure for Analog Type Force Indicators:*

X1.3.1 Typically these devices are not auto-ranging. The resolution should be checked at the lowest verified force in each force range (typically 10 % of the force range).

X1.3.2 Divide the pointer width by the distance between two adjacent graduation marks at the force where the resolution is to be ascertained to determine the pointer to graduation ratio. If the distance between the two adjacent graduation marks is less than 0.10 in. (2.5 mm) and the ratio is less than 1:5, use 1:5 for the ratio. If the distance between the two adjacent graduation marks is greater than or equal to 0.10 in. (2.5 mm) and the ratio is less than 1:10, use 1:10 for the ratio. If the ratio is greater than those given in these exceptions, use the ratio determined. Typical ratios in common usage are 1:1, 1:2, 1:5, and 1:10.

X1.3.3 Multiply the ratio determined above by the force represented by one graduation to determine the resolution.

X1.3.4 Apply as constant a force as possible where the resolution is to be ascertained to minimize the fluctuation of the force indicator. It is recommended that the fluctuation be no more than twice the resolution determined in the previous step.

X1.4 *Procedure for Non-Auto-Ranging Digital Type Force Indicators:*

X1.4.1 The resolution should be checked at the lowest verified force in each force range (typically 10% of the force range).

X1.4.2 Apply a tension or compression force to a specimen approximately equal to that at which the resolution is to be ascertained, and slowly change the applied force. Record the smallest change in force that can be ascertained as the resolution. Applying the force to a flexible element such as a spring or an elastomer makes it easier to change the force slowly.

X1.4.3 Next apply as constant a force as possible at the force where the resolution is to be ascertained to ensure that the force indicator does not fluctuate by more than twice the resolution determined in the previous step. If the indicator fluctuates by more than twice the resolution, the resolution shall be equal to one-half the range of the fluctuation.

X1.5 *Procedure for Auto-Ranging Digital Type Force Indicators:*

X1.5.1 This procedure is the same as that for non-auto-ranging digital force indicators except that the resolution is checked at the lowest verified force in each decade or at other forces to ensure that the indicator resolution is 200 times smaller than the forces. Some examples are as follows.

X1.5.1.1 A 60 000 lbf capacity machine is to be verified from 240 lbf up to 60 000 lbf. The resolution should be determined at 240, 2400, and 24 000 lbf.

X1.5.1.2 A 150 000 N capacity machine is to be verified from 300 N up to 150 000 N. The resolution should be determined at 300, 3000, and 30 000 N.

X1.5.1.3 A 1000 lbf. capacity machine is to be verified from 5 lbf. up to 1000 lbf. The resolution should be determined at 5, 50, and 500 lbf.

X1.6 *Procedure for Machines with Discrete Forces Such as Certain Hardness Testers and Creep Testers:*

X1.6.1 These machines generally incorporate fixed lever ratios to apply force. The force applied is determined by the poise applied on the lever multiplied by the lever ratio. They do not have a resolution as described in the standard. This procedure ensures that the sensitivity of the machine is sufficient to apply accurate forces at the lowest verified force and may be substituted for reporting resolution.

X1.6.2 With an elastic calibration device mounted in the machine, apply the appropriate poise for the lowest verified force.

X1.6.3 Gently add weight to the poise approximately equal to 1/200 of the weight of the poise.

X1.6.4 Ensure that at least one-half of the appropriate change in force is detected by the elastic calibration device when the weight is added and when it is gently removed.

X2. IDENTIFYING AND DETERMINING MEASUREMENT UNCERTAINTY COMPONENTS DURING AN ASTM E 4 VERIFICATION

X2.1 The measurement uncertainty determined using this appendix is the measurement uncertainty of the errors reported during verification of a testing machine. It is not the measurement uncertainty of the testing machine or the measurement uncertainty of test results determined using the testing machine.

X2.2 Under normal conditions, the measurement uncertainty of the reported errors of a testing machine determined during an Practices E 4 verification is a combination of three major components: the measurement uncertainty of the calibration laboratory performing the verification, the uncertainty component of the resolution of the force indicator of the testing machine at the force the error is being determined, and the uncertainty component of the resolution of the force indicator of the testing machine at zero force.

X2.2.1 The measurement uncertainty of the calibration laboratory performing the verification is a combination of factors such as, but not limited to:

X2.2.1.1 The measurement uncertainty of the laboratory's force standards per Practice E 74,

X2.2.1.2 Environmental effects such as temperature variations,

X2.2.1.3 Uncertainty in the value used for the local acceleration of gravity at the site where the verification is performed when using standard weights,

X2.2.1.4 Drift in the force standard,

X2.2.1.5 Measurement uncertainty of the verification of the force standard, and

X2.2.1.6 Repeatability of the force standard in actual use.

NOTE X2.1—A laboratory's measurement uncertainty should be based on the maximum uncertainty of the force standards used and the worst environmental conditions allowed. It may be advantageous to evaluate the measurement uncertainty of the actual force standard used at the actual force for which the measurement uncertainty of the error of the testing machine is being determined.

NOTE X2.2—If there are circumstances in which verification is performed under conditions outside of the laboratory's normal operating parameters, additional components may need to be considered. For example, a laboratory may permit a 5°C temperature variation to occur during verification and has factored this into their measurement uncertainty. When greater temperature variations occur, the uncertainty due to this increased temperature variation shall be included in the determination of measurement uncertainty.

NOTE X2.3—A calibration laboratory's measurement uncertainty is usually expressed as an expanded uncertainty using a coverage factor of two. If this is the case, prior to combining it with the other uncertainty components, divide it by two.

X2.2.2 The uncertainty component due to the resolution of the force indicator of the testing machine being verified can be determined by dividing the resolution of the force indicator at the force where uncertainty is being evaluated by the quantity of two times the square root of three.

X2.2.3 The uncertainty component due to the resolution of the force indicator of the testing machine at zero force can be determined by dividing the resolution of the force indicator at zero force by the quantity of two times the square root of three.

X2.3 The three major components can be combined by squaring each component, adding them together, and then taking the square root of the sum to determine the combined measurement uncertainty of the error determined for the testing machine.

X2.4 The expanded measurement uncertainty may then be determined by multiplying the combined uncertainty by two, for a confidence level of approximately 95 %.

NOTE X2.4—Example: The measurement uncertainty of the error of a testing machine determined at 2000 N is to be determined. The calibration laboratory's measurement uncertainty expanded using a factor of 2 is 0.3 % of applied force. The testing machine's resolution at 2000 N is 5 N. The resolution of the testing machine at 0 force is 5 N. The component due to the calibration laboratory's measurement uncertainty, u_{CL} is:

$$u_{CL} = \frac{0.003 \times 2000}{2} = 3\text{ N} \tag{X2.1}$$

The component due to the testing machine's resolution at 2000 N, u_{R2000} is:

$$u_{R2000} = \frac{5}{2\sqrt{3}} = 1.4\text{ N} \tag{X2.2}$$

The component due to the testing machine's resolution at zero force, u_Z is:

$$u_Z = \frac{5}{2\sqrt{3}} = 1.4\text{ N} \tag{X2.3}$$

The combined measurement uncertainty of the error determined at 2000 N, u is:

$$u = \sqrt{3^2 + 1.4^2 + 1.4^2} = 3.6\text{ N} \tag{X2.4}$$

The expanded measurement uncertainty of the error determined at 2000 N, U using a coverage factor of two is:

$$U = 2 \times 3.6 = 7.2\text{ N} \tag{X2.5}$$

NOTE X2.5—For additional resources relating to Measurement Uncertainty, refer to the Guide to the Expression of Uncertainty in Measurement–1995.