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Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature[1]

This standard is issued under the fixed designation E9; 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~~ Scope*

1.1 These test methods cover the apparatus, specimens, and procedure for ~~axial-load~~axial-force compression testing of metallic materials at room temperature (Note 1). For additional requirements pertaining to cemented carbides, see Annex A1.

NOTE 1—For compression tests at elevated temperatures, see Practice E209.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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 health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E83 Practice for Verification and Classification of Extensometer Systems
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
~~E171/E171M Practice for Conditioning and Testing Flexible Barrier Packaging~~
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E209 Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates
E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E2658 Practices for Verification of Speed for Material Testing Machines

3. Terminology

3.1 *Definitions:* The definitions of terms ~~relating to compression testing and room temperature~~ in Terminology E6 ~~and Practice E171/E171M, respectively,~~ shall apply to these test methods. These terms include compressive strength, extensometer system, modulus of elasticity, necking, proportional limit, stress-strain curve, stress-strain diagram, tangent modulus, testing machine, upper yield strength, yield strength, and Young's modulus. The terms precision, bias, coefficient of variation, repeatability, reproducibility, and accuracy are used as defined in Practice E177.

[1] These test methods are under the jurisdiction of ASTM Committee E28 on Mechanical Testing and are the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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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**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *buckling*—In addition to compressive failure by crushing of the material, compressive failure may occur by (*1*) elastic instability over the length of a column specimen due to nonaxiality of loading, (*2*) inelastic instability over the length of a column specimen, (*3*) a local instability, either elastic or inelastic, over a small portion of the gage length, or (*4*) a twisting or torsional failure in which cross sections rotate over each other about the longitudinal specimen axis. These types of failures are all termed *buckling*.

3.2.1 *column—alignment device—*a compression member that is axially loaded and that may fail by buckling.fixture for compression testing in a testing machine that is an integral part of the load train and that aids in achieving and maintaining axial forces.

3.2.3 *radius of gyration*—the square root of the ratio of the moment of inertia of the cross section about the centroidal axis to the cross-sectional area:

$$\rho = (I/A)^{1/2} \tag{1}$$

where:

ρ = radius of gyration,
I = moment of inertia of the cross section about centroidal axis (for specimens without lateral support, the smaller value of I is the critical value), and
A = cross-sectional area.

3.2.4 *critical stress*—the axial uniform stress that causes a column to be on the verge of buckling. The critical load is calculated by multiplying the critical stress by the cross-section area.

3.2.2 *buckling equations—anti-buckling fixture, n—*If the buckling stress is less than or equal to the proportional limit of the material its value may be calculated using the Euler equation: a device that applies lateral support to a thin-sheet specimen to prevent it from buckling, but does not interfere with axial deformation.

$$S_{cr} = C\pi^2 E/(L/\rho)^2 \tag{2}$$

If the buckling stress is greater than the proportional limit of the material its value may be calculated from the modified Euler equation:

$$S_{cr} = C\pi^2 E_t/(L/\rho)^2 \tag{3}$$

where:

S_{cr} = critical buckling stress,
E = Young's modulus,
E_t = tangent modulus at the buckling stress,
L = column length, and
C = end-fixity coefficient.

Methods of calculating the critical stress using Eq 3 are given in Ref (**1**).[3]

3.2.3 *end-fixity coefficient—solid cylindrical specimen, n—*There are certain ideal specimen end-fixity conditions for which theory will define the value of the constanta specimen with solid cylindrical cross section that does not require lateral support to Cprevent (seebuckling, Fig. 1). These values are:but can require testing

—Freely rotating ends (pinned or hinged)	$C = 1$ (*a*)
—One end fixed, the other free to rotate	$C = 2$ (*b*)
—Both ends fixed	$C = 4$ (*c*)

with an alignment device or subpress to ensure that compressive forces are axial.

NOTE 2—For flat-end specimens tested between flat rigid anvils, it was shown in Ref (**1**) that a value of $C = 3.75$ is appropriate.

3.2.4 *barreling—subpress, n—*restricted deformation of the end regions of a test specimen under compressive load due to friction at the specimen end sections and the resulting nonuniform transverse deformation as shown schematically and in the photograph ina fixture for compression testing in a testing machine Fig. 2. Additional theoretical and experimental information on barreling as illustrated that is designed to be easily inserted into and removed from the load train and that aids in Fig. 2 is given in Ref achieving and maintaining axial forces.(**2**).

3.2.5 *thin-sheet specimen, n—*a specimen that requires lateral support from an anti-buckling fixture to prevent buckling during a compression test.

4. Summary of Test Methods

4.1 The specimen is subjected to an increasing axial compressive load;force; both loadforce and strain may be monitored either continuously or in finite increments, and the mechanical properties in compression determined.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

5. Significance and Use

5.1 *Significance*—The data obtained from a compression test may include the yield strength, the upper yield ~~point,~~ strength, the Young's modulus, the stress-strain curve, and the compressive strength (see Terminology E6). In the case of a material that does not fail in compression by a shattering fracture, compressive strength is a value that ~~is dependent~~ depends on total strain and specimen geometry.

5.2 *Use*—Compressive properties are of interest in the analyses of structures subject to compressive forces or bending ~~loads~~moments or both and in the analyses of metal working and fabrication processes that involve large compressive deformation such as forging and rolling. For brittle or nonductile metals that fracture in tension at stresses below the yield strength, compression tests offer the possibility of extending the strain range of the stress-strain data. While the compression test is not complicated by necking as is the tension test for certain metallic materials, buckling and barreling (see ~~Section 3~~Appendix X1) can complicate results and should be minimized.

6. Apparatus

6.1 *Testing Machines*—Machines used for compression testing shall conform to the requirements of Practices E4~~. For universal machines with a common test space, calibration shall be performed~~ and shall be calibrated in compression.

6.1.1 The bearing surfaces of the heads of the testing machine shall be parallel at all times with 0.0002 in./in. (m/m) unless an alignment device or subpress of the type described in 6.3 is used.

6.1.2 The dynamic response of the force-measuring system shall be sufficient to accurately measure the rate of force change on the specimen.

NOTE 2—This requirement is of particular importance when testing short specimens of materials with high modulus of elasticity.

6.1.3 Where verification of the testing machine speed is required, unless otherwise specified, Practices E2658 shall be used, and the testing machine shall meet Class E.

6.2 *Bearing Blocks:*

6.2.1 ~~Both~~ If the axial force is transmitted through the ends of the ~~compression specimen~~ solid cylindrical or thin-sheet specimen, they shall bear on blocks with surfaces flat and parallel within 0.0002 in./in. (m/m). Lack of initial parallelism ~~can~~may be overcome by ~~the use of~~ using adjustable bearing blocks (Note 3). The blocks shall be made of, or faced with, hard material. ~~Current laboratory practice suggests the use of tungsten carbide when testing steel and hardened steel blocks (55 HRC or greater) and when testing nonferrous materials such as aluminum, copper, etc. The specimen must~~The specimen shall be carefully centered with respect to the testing machine ~~heads or the~~ heads, alignment device, or subpress if used (see 6.3, Alignment ~~Device/Subpress).~~Device or Subpress).

NOTE 3—The purpose of an adjustable bearing block is to give the specimen as even a distribution of initial ~~load~~force as possible. An adjustable bearing block cannot be relied on to compensate for any tilting of the heads that ~~may~~can occur during the test. Tungsten carbide bearing blocks are suitable for testing steel. Hardened steel bearing blocks (55 HRC or greater) are suitable for testing nonferrous materials such as aluminum and copper.

NOTE 4—Appendix X2 describes some bearing blocks that have been used successfully.

6.2.2 The bearing faces of adjustable bearing blocks that contact the specimen shall be made parallel before the ~~load~~force is applied to the specimen. ~~One type of adjustable bearing block that has proven satisfactory is illustrated in~~ If ~~Fig. 3. Another arrangement involving the use of a spherical-seated bearing block that has been found satisfactory for testing material other than in sheet form is shown in~~ a bearing block ~~Fig. 4. It is desirable that the spherical-seated bearing block be at the upper end of the test specimen (for specimens tested with the load axis vertical). The~~ with a spherical seat is used, the spherical surface of the block shall be defined by a radius having its point of origin in the flat surface that bears on the specimen.

6.3 *Alignment ~~Device/Subpress:~~ Device or Subpress:*

6.3.1 ~~It is usually necessary to use an alignment device, unless the testing machine has been designed specifically for axial alignment. The design of the device or subpress depends on the size and strength of the specimen. It must be designed so that the ram (or other moving parts) does not jam or tilt the device or the frame of the machine as a result of loading. The bearing blocks of the device shall have the same requirements for parallelism and flatness as given in~~ Alignment devices and subpresses shall apply the force axially, uniformly, and with negligible "slip-stick" friction.~~6.2.1.~~

NOTE 5— It is usually necessary to use an alignment device or subpress, unless the testing machine has been designed specifically for axial alignment. Appendix X2 shows some examples of alignment devices and subpresses that have been used successfully

6.3.2 The ~~primary requirements of all alignment devices are that the load is applied axially, uniformly, and with negligible "slip-stick" friction. An alignment device that has been found suitable is shown in~~bearing blocks of the alignment device or subpress shall have the same requirements for ~~Fig. 5 and described in Ref.~~parallelism and flatness as given in 6.2.1~~(3). Other devices of the subpress type have also been used successfully.~~

6.4 ~~*Compression Testing Jigs*—In testing thin specimens, such as sheet material, some means should be adopted to prevent the specimen from buckling during loading. This may be accomplished by using a jig containing side-support plates that bear against the wide sides of the specimen. The jig must afford a suitable combination of lateral-support pressure and spring constant to prevent~~

~~buckling, but without interfering with axial deformation of the specimen. Although suitable combinations vary somewhat with variations in specimen material and thickness, testing temperatures, and accuracy of alignment, acceptable results can be obtained with rather wide ranges of lateral-support pressure and spring constant. Generally, the higher the spring constant of the jig, the lower the lateral-support pressure that is required. Proper adjustments of these variables should be established during the qualification of the equipment (see~~ An anti-buckling fixture may be used to prevent thin-sheet specimens from buckling.~~6.6).~~

~~6.4.1 It is not the intent of these methods to designate specific jigs for testing sheet materials, but merely to provide a few illustrations and references to jigs that have been used successfully, some of which are cited in Table 1. Other jigs are acceptable provided they prevent buckling and pass the qualification test set forth in 6.6. Compression jigs generally require that the specimen be lubricated on the supported sides to prevent extraneous friction forces from occurring at the support points.~~

NOTE 6—Appendix X2 describes some anti-buckling fixtures and thin-sheet specimens that have been used successfully.

6.5 *Strain Measurements:*

6.5.1 ~~Mechanical or electromechanical devices used for measuring strain~~ Extensometer systems shall comply with the requirements for the applicable class described in Practice E83~~. The device~~ and shall be verified in compression.

NOTE 7—In using these methods, a Class B-2 extensometer, as described in Practice E83, is sufficiently sensitive for most materials.

6.5.2 Automatic devices that determine offset yield strength without plotting a stress-strain curve may be used if their accuracy has been demonstrated to be satisfactory.

6.5.3 Electrical-resistance strain gages (or other single-use devices) may be used provided the measuring system has been verified and found to be accurate to the degree specified in Practice E83. ~~The characteristics of electrical~~ Electrical resistance strain gages ~~have been determined from~~ shall have performance characteristics established by the manufacturer in accordance with Test Methods E251.

6.6 *Qualification of Test Apparatus*—The complete compression-test apparatus, which consists of the testing machine and when applicable, ~~one or more of the following; the alignment device, the jig and the strain-measurement~~the alignment device or subpress, the anti-buckling fixture and the extensometer system, shall be qualified ~~as follows:~~by the procedure in 6.6.1-6.6.2.

6.6.1 Conduct tests to establish the elastic modulus of five replicate thin-sheet specimens of 2024-T3 aluminum alloy sheet or five replicate solid cylindrical specimens of 2024-T4 aluminum alloy bar in accordance with Test Method E111. These qualification specimens shall be machined from sheet or bar in the location specified in Test Methods B557. The thickness of the sheet or diameter of the bar may be machined to the desired thickness or diameter. ~~It is essential that the extensometer~~ The extensometer shall be properly seated on the ~~specimens~~specimen when this test is performed. When the qualification specimens each provide a modulus value of 10.7×10^6 psi (73.8 GPa) ±5 %, the apparatus qualifies.

6.6.2 The qualification procedure shall be performed using the thinnest ~~rectangular~~thin-sheet specimen or smallest diameter ~~round~~ solid cylindrical specimen to be tested in the apparatus.

7. Test Specimens

7.1 *Specimens in Solid Cylindrical Form*—~~It is recommended that, where~~ Where feasible, compression test specimens should be in the form of solid circular cylinders. Three forms of solid cylindrical ~~test~~ specimens for metallic materials are recognized, and designated as short, ~~medium-length,~~medium, and long (Note ~~4~~8). Suggested dimensions for solid ~~compression test~~ cylindrical specimens for general use are given in Table ~~2~~1.

NOTE 8—Short specimens typically are used for compression tests of such materials as bearing metals, which in service are used in the form of thin plates to carry load perpendicular to the surface. Medium-length specimens typically are used for determining the general compressive strength properties

TABLE ~~2~~1 Suggested Solid Cylindrical Specimens[A]

NOTE 1—Metric units represent converted specimen dimensions close to, but not the exact conversion from inch-pound units.

Specimens	Diameter		Length		Approx L/D Ratio
	in.	mm	in.	mm	
Short	1.12 ± 0.01	30.0 ± 0.2	1.00 ± 0.05	25 ± 1	0.8
	0.50 ± 0.01	13.0 ± 0.2	1.00 ± 0.05	25 ± 1	2.0
Medium	0.50 ± 0.01	13.0 ± 0.2	1.50 ± 0.05	38 ± 1	3.0
	0.80 ± 0.01	20.0 ± 0.2	2.38 ± 0.12	60 ± 3	3.0
	1.00 ± 0.01	25.0 ± 0.2	3.00 ± 0.12	75 ± 3	3.0
	1.12 ± 0.01	30.0 ± 0.2	3.38 ± 0.12	85 ± 3	3.0
Long	0.80 ± 0.01	20.0 ± 0.2	6.38 ± 0.12	160 ± 3	8.0
	1.25 ± 0.01	32.0 ± 0.2	12.50 min	320 min	10.0

[A] Other length-to-diameter ratios may be used when the test is for compressive yield strength.

of metallic materials. Long specimens are best adapted for determining the modulus of elasticity in compression of metallic materials. The specimen dimensions given in Table ~~2~~1 have been used successfully. Specimens with a *L/D* (length/diameter ratio) of 1.5 or 2.0 are best adapted for determining the compressive strength of high-strength materials.

7.2 ~~*Rectangular or Sheet-Type*~~ *Thin-sheet Specimens*—Test specimens shall be flat and ~~preferably of~~should be the full thickness of the material. ~~Where lateral support is necessary, the width and length are dependent upon the dimensions of the jig used to support the specimen.~~ The length shall be sufficient to allow the specimen to shorten the amount required to define the yield strength, or upper yield ~~point,~~strength, but not long enough to permit buckling in the unsupported portion. ~~Specimen dimensions and the various types of jigs are given in Table 1.~~

NOTE 9—Where lateral support is necessary, the width and length depend upon the dimensions of the anti-buckling fixture used to support the specimen.

NOTE 10—Appendix X2 describes dimensions of thin-sheet specimen dimensions and examples of anti-buckling fixtures that have been used successfully.

7.3 *Preparation of Solid Cylindrical and Thin-Sheet Specimens*—Lateral surfaces in the ~~gage~~gauge length shall not vary in diameter, width, or thickness by more than 1 % or 0.002 in. (0.05 mm), whichever is less. ~~(If~~If a reduced section is used, this requirement applies only to the surface of the reduced ~~section.) Also, the centerline~~ section. The centerlines of all lateral surfaces of the specimens shall be coaxial within 0.01 in. (0.25 mm).

7.3.1 *Surface ~~Finish—~~Roughness*—Machined surfaces of solid cylindrical and thin-sheet specimens shall have a surface ~~finish~~roughness of 63 µin. (1.6 µm) Ra or better. Machined lateral surfaces to which lateral support is ~~to be~~ applied shall ~~be finished to at least 40 microinches (1.0 µm) arithmetic average.~~have a surface roughness of 40 µin. (1.0 µm) Ra or better

7.3.2 *Flatness and Parallelism*—The ends of ~~a~~ solid cylindrical specimens from Table 2 and of thin-sheet specimens where the force is applied through the ends of the specimen shall be flat and parallel within 0.0005 in./in. (mm/mm) and perpendicular to the lateral surfaces to within 3' of arc. ~~In most cases this requirement necessitates the machining or grinding of the ends of the specimen.~~

NOTE 11—In most cases meeting this requirement can only be achieved by machining or grinding of the ends of the specimen.

7.3.3 *Edges of ~~Rectangular~~thin-sheet Specimens*—A width of material equal to at least the thickness of the thin-sheet specimen shall be machined from all sheared or stamped edges in order to remove material ~~whose properties may have been altered.~~ with potentially altered properties. If a reduced section is used, this requirement applies only to the edges of the reduced section. ~~Specimens~~ Thin-sheet specimens shall be finished so that the surfaces are free of nicks, grooves, and burrs.

7.4 *~~Gage~~Gauge Length Location*—The ends of the ~~gage~~gauge length shall not be closer to the ends of the solid cylindrical or thinsheet specimen or the ends of the reduced section, than one half of the ~~width~~diameter or ~~diameter~~ one half of the width of the specimen.

8. Procedure

8.1 *Specimen Measurement*—Measure the width and thickness, or the diameter of the specimen ~~with a micrometer~~ along the ~~gage~~gauge section. Specimen dimensions greater than or equal to 0.10 in. (2.5 mm) should be measured to the nearest 0.001 in. (0.02 mm), and those less than 0.10 in. (2.5 mm) should be ~~determined~~measured to the nearest 1 % of the dimension being measured. Calculate the average cross-sectional area of the specimen ~~gage~~gauge section.

8.2 *Cleaning*—Clean the ends of the specimen and fixture bearing blocks with acetone or another suitable solvent to remove all traces of grease and oil.

8.3 *Lubrication*—Bearing ~~surface friction can affect test results (see section~~ surfaces, including ~~5.2 and Fig. 2). Friction has been successfully reduced by lubricating the bearing surfaces with TFE-fluorocarbon sheet, molybdenum disulfide, and other materials summarized in Ref.~~the ends of solid cylindrical specimens and the ends and faces of ~~(~~thin-sheet~~3).~~ specimens may be lubricated.

NOTE 12—Bearing surface friction can affect test results (see Fig. X1.2). Friction has been successfully reduced by lubricating the bearing surfaces

TABLE ~~3~~2 Precision

Material	*YS*(0.02% offset)	Repeatability standard deviation	Reproducibility standard deviation	95 % Repeatability limit (within a laboratory)	95 % Reproducibility limit (between laboratories)
	$\bar{x}$ MPa	s_r MPa	s_R MPa	*r* MPa	*R* MPa
AA2024–T351	346.2	3.8	6.8	10.7	19.1
		Repeatability coefficient of variation $CV_r = \frac{s_r}{\bar{x}}$	Reproducibility coefficient of variation $CV_R = \frac{s_R}{\bar{x}}$	r %	R %
AA2024–T351		1.1 %	2.0 %	3.1 %	5.5 %

The table was calculated using the relationship limit = 2.8 × standard deviation. The quantity $1.96\sqrt{2}$ rounds to 2.77 or 2.8.

with TFE-fluorocarbon sheet, molybdenum disulfide, and other materials summarized in (**1**).[3]

8.4 *Specimen Installation*—Place the specimen in the test fixture and carefully align the specimen to the fixture to ensure ~~concentric~~coaxial loading. ~~Also, check~~ Check that the specimen loading/reaction surfaces mate with the respective surfaces of the fixture. If the fixture has ~~side~~lateral supports, the ~~specimen sides~~ sides of thin-sheet specimens should contact the ~~support mechanism~~ supports with the clamping pressure recommended by the anti-buckling fixture manufacturer, or as determined during the ~~fixture verification~~ fixture-qualification tests. If screws are used to adjust ~~side~~lateral support pressure, ~~it is recommended that~~ a torque wrench should be ~~utilized~~used to ensure consistent pressure.

8.4.1 *Transducer Attachment*—If required, attach the extensometer or other transducers, or both, to the specimen ~~gage~~gauge section. The ~~gage length must~~ gauge length of solid cylindrical specimens shall be at least one half ~~or preferably one~~ diameter away from the ends of the ~~specimen (see~~ specimen, and should be a full diameter away from the ends of the specimen. The gauge length of the thin-sheet specimen shall be at least one half the width away from the ends of the specimen or ends of the reduced section, and should be at least full width away. See 7.4~~)~~..

8.5 ~~*Load-Strain*~~*Force-Strain Range Selection*—Set the ~~load~~force range of the testing machine so the maximum expected ~~load~~force is at least one third of the range selected. ~~Select~~ If an autographic recorder is used, select the strain or deflection scale so that the elastic portion of the ~~load-versus-strain or load-versus-deflection plot on the autographic record,~~ force-versus-strain or force-versus-deflection, is between 30° and 60° to the ~~load~~force axis.

~~8.6 *Strain Measurements*—Devices used for measuring strain shall comply with the requirements for the applicable class of extensometer described in Practice E83. Electrical strain gages, if used, shall have performance characteristics established by the manufacturer in accordance with Test Methods E251.~~

8.6 *Testing Speed*—For testing machines equipped with strain-rate ~~pacers,~~control, set the machine to strain the specimen at a nominal rate of 0.005 ~~in./in.·min (m/m·min).~~in./in./min (m/m/min). For machine with ~~load~~force control or with crosshead speed control, set the nominal rate so the specimen is tested at a rate equivalent to 0.005 in./in.·min (m/m·min) strain-rate in the elastic portion. A nominal rate of 0.003 ~~in./in.·min (m/m·min) can~~in./in./min (m/m/min) may be used if the material is strain-rate sensitive.

8.6.1 For machines without ~~strain-pacing equipment or~~ automatic feedback control systems, maintain a constant crosshead speed to obtain the desired average strain-rate from the start of loading to the end point of the test. ~~The average strain-rate can be determined from a time-interval-marked load-strain record, a time-strain graph, or from the time of the start of loading to the end point of test as determined from a time-measuring device (for example, stopwatch). It should be recognized that the use of machines with constant rate of crosshead movement does not ensure constant strain rate throughout a test.~~

Note 13—The average strain rate can be determined from a time-interval-marked force-strain record, a time-strain graph, or from the time of the start of loading to the end point of test as determined from a time-measuring device, for example a stopwatch. Constant rate of crosshead movement does not ensure constant strain rate throughout a test. The free-running crosshead speed can differ from the speed under load for the same machine setting. Specimens of different stiffnesses can also result in different rates, depending upon the testing machine and fixturing.

8.6.2 ~~It should also be noted that the free-running crosshead speed may differ from the speed under load for the same machine setting, and that specimens of different stiffnesses may also result in different rates, depending upon the test machine and fixturing.~~ Whatever the method, the specimen should be tested at a uniform rate without reversals or sudden changes. ~~The test rate must also be such that the rate of load change on the specimen being tested will be within the dynamic response of the measuring systems. This requirement is of particular importance when testing short specimens of high-modulus materials.~~

8.7 *Test Conduct*—After the specimen has been installed and aligned, and the strain- or deflection-measuring transducer installed, activate the recording device(s) and initiate the test at the prescribed rate. Continue the test at a uniform rate until the test has been completed as stated below.

8.7.1 *Ductile Materials*—For ductile materials, ~~the~~ if allowed by the material specification, the test may be halted after the strain is large enough to determine the yield strength or ~~yield point, and sometimes~~ upper yield strength, or the strength at a strain greater than the yield ~~strain, can be determined. The conduct of the test to determine either the onset of yielding or the compressive strength or both is the same. Materials without sharp-kneed stress-strain diagrams will require that the strain or deflection at yield be initially estimated, and the specimen tested sufficiently beyond the initial estimation to be sure the yield stress can be determined after the test (see~~ strain. ~~9.3).~~ For materials that exhibit a sharp-kneed stress-strain curve or a distinctive yield point, the test ~~can~~may be terminated either after a sharp knee or after the drop in ~~load~~force is observed.

Note 14—For materials without sharp-kneed stress-strain diagrams, it is useful to estimate the strain or deflection at yield and test the specimen sufficiently beyond this estimate to ensure that the yield strength can be determined after the test (see 9.3).

8.7.2 *Brittle Materials*—Brittle materials that fail by crushing or shattering may be tested to failure.

8.8 *Number of Specimens*—Specimen blanks shall be taken from bulk materials according to applicable specifications. The number of specimens to be tested should be sufficient to meet the requirements as determined by the test purpose, or as agreed upon between the parties involved. ~~The larger the sample, the greater the confidence that the sample represents the total population. In most cases, between five and ten specimens should be sufficient to determine the compressive properties of a sample with reasonable confidence.~~