



Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature¹

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

1.1 These test methods cover the apparatus, specimens, and procedure for axial-load 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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** Practice for Conditioning and Testing Flexible Barrier Packaging

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.

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

3. Terminology

3.1 **Definitions:** The definitions of terms relating to compression testing and room temperature in Terminology **E6** and Specification **E171**, respectively, shall apply to these test methods.

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*.

3.2.2 **column**—a compression member that is axially loaded and that may fail by buckling.

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:

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

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.

3.2.5 *buckling equations*—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:

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

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

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

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

3.2.6 *end-fixity coefficient*—There are certain ideal specimen end-fixity conditions for which theory will define the value of the constant C (see Fig. 1). These values are:

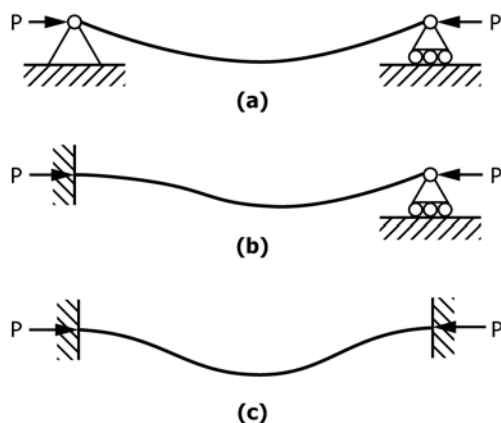


FIG. 1 Diagrams Showing Fixity Conditions and Resulting Buckling of Deformation

Freely rotating ends (pinned or hinged)
One end fixed, the other free to rotate
Both ends fixed

$C = 1$ (a)
 $C = 2$ (b)
 $C = 4$ (c)

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.

3.2.7 *barreling*—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 in Fig. 2. Additional theoretical and experimental information on barreling as illustrated in Fig. 2 is given in Ref (2).

4. Summary of Test Methods

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

5. Significance and Use

5.1 *Significance*—The data obtained from a compression test may include the yield strength, the yield point, 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 on total strain and specimen geometry.

5.2 *Use*—Compressive properties are of interest in the analyses of structures subject to compressive or bending loads 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) 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 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 of the type described in 6.3 is used.

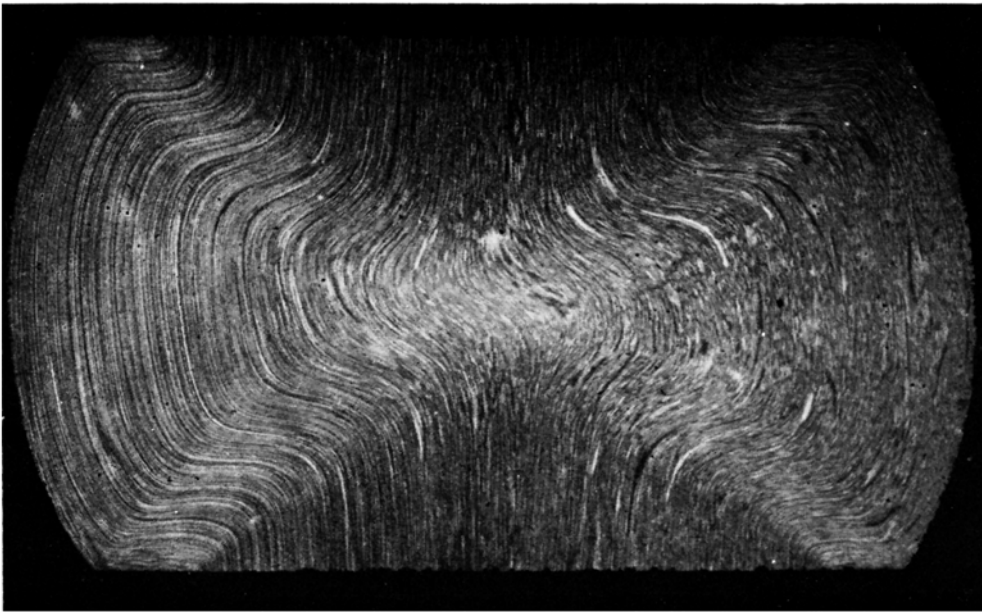
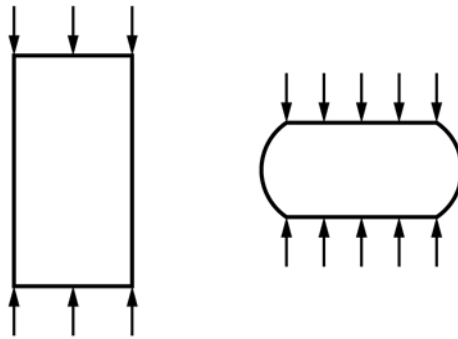
6.2 Bearing Blocks:

6.2.1 Both ends of the compression specimen shall bear on blocks with surfaces flat and parallel within 0.0002 in./in. (m/m). Lack of initial parallelism can be overcome by the use of 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 be carefully centered with respect to the testing machine heads or the subpress if used (see 6.3, Alignment Device/Subpress).

NOTE 3—The purpose of an adjustable bearing block is to give the specimen as even a distribution of initial load as possible. An adjustable bearing block cannot be relied on to compensate for any tilting of the heads that may occur during the test.

6.2.2 The bearing faces of adjustable bearing blocks that contact the specimen shall be made parallel before the load is applied to the specimen. One type of adjustable bearing block that has proven satisfactory is illustrated in 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 Fig. 4.

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



NOTE 1—A cylindrical specimen of AISI 4340 steel (HRC = 40) was compressed 57 % (see upper diagram). The photo macrograph was made of a polished and etched cross section of the tested specimen. The highly distorted flow lines are the result of friction between the specimen ends and the loading fixture. Note the triangular regions of restricted deformation at the ends and the cross-shaped zone of severe shear.

FIG. 2 Illustration of Barreling

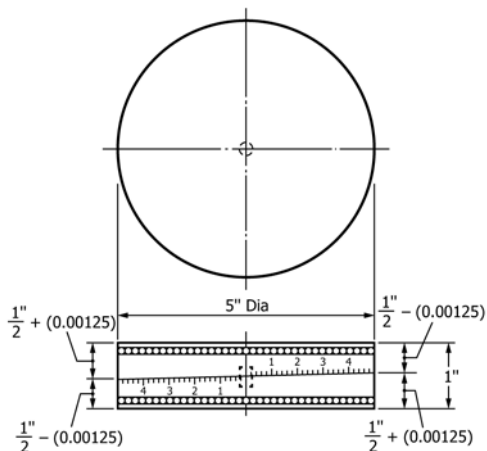


FIG. 3 Adjustable Bearing Block for Compression Testing

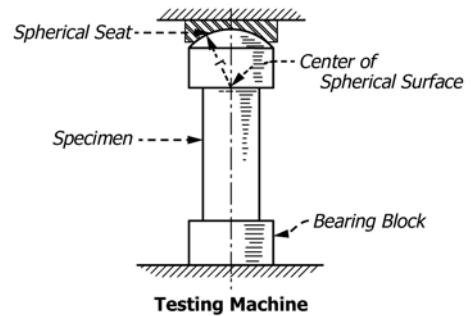


FIG. 4 Spherical-Seated Bearing Block

spherical-seated bearing block be at the upper end of the test specimen (for specimens tested with the load axis vertical). 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:

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 to suppress effects