



Designation: E9 – 19

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-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

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.

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
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 in Terminology **E6** 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**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 **alignment device**—a 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.

3.2.2 **anti-buckling fixture, n**—a device that applies lateral support to a thin-sheet specimen to prevent it from buckling, but does not interfere with axial deformation.

3.2.3 **solid cylindrical specimen, n**—a specimen with solid cylindrical cross section that does not require lateral support to

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

prevent buckling, but can require testing with an alignment device or subpress to ensure that compressive forces are axial.

3.2.4 *subpress, n*—a fixture for compression testing in a testing machine that is designed to be easily inserted into and removed from the load train and that aids in achieving and maintaining axial forces.

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 force; both force 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 upper yield 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 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 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 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 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 If the axial force is transmitted through the ends of the 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 may be overcome by using adjustable bearing blocks (Note 3). The blocks shall be made of, or faced with, hard material. The specimen shall be carefully centered with respect to the testing machine heads, alignment device, or subpress if used (see 6.3, Alignment Device or Subpress).

NOTE 3—The purpose of an adjustable bearing block is to give the specimen as even a distribution of initial force as possible. An adjustable bearing block cannot be relied on to compensate for any tilting of the heads that 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 force is applied to the specimen. If a bearing block 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 or Subpress:

6.3.1 Alignment devices and subpresses shall apply the force axially, uniformly, and with negligible “slip-stick” friction.

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 bearing blocks of the alignment device or subpress shall have the same requirements for parallelism and flatness as given in 6.2.1

6.4 An anti-buckling fixture may be used to prevent thin-sheet specimens from buckling.

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 Extensometer systems shall comply with the requirements for the applicable class described in Practice E83 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. Electrical resistance strain gages 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, the alignment device or subpress, the anti-buckling fixture and the extensometer system, shall be qualified 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. The extensometer shall be properly seated on the specimen when this test is performed. When the qualification specimens each provide a modulus value of 10.7×10^6 psi (73.8 GPa) $\pm 5\%$, the apparatus qualifies.

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

7. Test Specimens

7.1 *Specimens in Solid Cylindrical Form*—Where feasible, compression test specimens should be in the form of solid circular cylinders. Three forms of solid cylindrical specimens for metallic materials are recognized, and designated as short, medium, and long (Note 8). Suggested dimensions for solid cylindrical specimens for general use are given in Table 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 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 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 *Thin-sheet Specimens*—Test specimens shall be flat and should be the full thickness of the material. The length shall be sufficient to allow the specimen to shorten the amount required to define the yield strength, or upper yield strength, but not long enough to permit buckling in the unsupported portion.

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

TABLE 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 <i>L/D</i> Ratio
	in.	mm	in.	mm	
Short	1.12 \pm 0.01	30.0 \pm 0.2	1.00 \pm 0.05	25 \pm 1	0.8
	0.50 \pm 0.01	13.0 \pm 0.2	1.00 \pm 0.05	25 \pm 1	2.0
Medium	0.50 \pm 0.01	13.0 \pm 0.2	1.50 \pm 0.05	38 \pm 1	3.0
	0.80 \pm 0.01	20.0 \pm 0.2	2.38 \pm 0.12	60 \pm 3	3.0
	1.00 \pm 0.01	25.0 \pm 0.2	3.00 \pm 0.12	75 \pm 3	3.0
	1.12 \pm 0.01	30.0 \pm 0.2	3.38 \pm 0.12	85 \pm 3	3.0
Long	0.80 \pm 0.01	20.0 \pm 0.2	6.38 \pm 0.12	160 \pm 3	8.0
	1.25 \pm 0.01	32.0 \pm 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.

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 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 a reduced section is used, this requirement applies only to the surface of the reduced section. The centerlines of all lateral surfaces of the specimens shall be coaxial within 0.01 in. (0.25 mm).

7.3.1 *Surface Roughness*—Machined surfaces of solid cylindrical and thin-sheet specimens shall have a surface roughness of 63 μ in. (1.6 μ m) Ra or better. Machined lateral surfaces to which lateral support is applied shall have a surface roughness of 40 μ in. (1.0 μ m) Ra or better.

7.3.2 *Flatness and Parallelism*—The ends of 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.

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 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 with potentially altered properties. If a reduced section is used, this requirement applies only to the edges of the reduced section. Thin-sheet specimens shall be finished so that the surfaces are free of nicks, grooves, and burrs.

7.4 *Gauge Length Location*—The ends of the gauge length shall not be closer to the ends of the solid cylindrical or thin-sheet specimen or the ends of the reduced section, than one half of the diameter or 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 along the 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 measured to the nearest 1 % of the dimension being measured. Calculate the average cross-sectional area of the specimen 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 surfaces, including the ends of solid cylindrical specimens and the ends and faces of thin-sheet 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 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

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