



Designation: E209 – 18

Standard Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates¹

This standard is issued under the fixed designation E209; 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.

1. Scope

1.1 This practice covers compression test in which the specimen is heated to a constant and uniform temperature and held at temperature while an axial force is applied at a controlled rate of strain.

1.2 In metals with extremely high proportional limit or low modulus of elasticity, 1.5 % total strain under load could be reached before the 0.2 %-offset yield strength is reached. In this event the end point of the test may be reported as the 0.2 percent-offset yield strength unless rupture occurs before that point.

1.3 For acceptable compression tests it is imperative that the specimens not buckle before the end point is reached. For this reason the equipment and procedures shall be designed to maintain uniform loading and axial alignment.

1.4 Preferred conditions of testing are recommended so that data from different sources conducting the tests will be comparable.

1.5 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.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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.*

¹ This practice is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.04 on Uniaxial Testing.

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2. Referenced Documents

2.1 *ASTM Standards:*²

E4 Practices for Force Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature

E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E83 Practice for Verification and Classification of Extensometer Systems

3. Apparatus

3.1 *Testing Machines*—Machines used for compression testing shall conform to the requirements of Practices E4.

3.2 *Bearing Blocks and Loading Adapters*—Load both ends of the compression specimens through bearing blocks or through pin-type adapters that are part of the compression-testing assembly. Bearing blocks may be designed with flat bearing faces for sheet- or bar-type specimens. Sheet specimens may also be loaded through pin-type adapters that are clamped rigidly to the grip sections of specimens designed for these adapters (1).³ The main requirement is that the method of applying the force be consistent with maintaining axial alignment and uniform loading on the specimen throughout the test. When bearing blocks with flat faces are used, the load-bearing surfaces should be smooth and parallel within very close limits. The tolerance for parallelism for these surfaces should be equal to or closer than that specified for the loaded ends of the specimens. The design of the equipment should provide adequate rigidity so that parallelism is maintained during heating and loading. The bearing blocks or pin-type adapters should be made of a material that is sufficiently hard at the testing temperature to resist plastic indentation at maximum force. They should also be of a material or coated with a material that is sufficiently oxidation resistant at the maximum

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.

³ Boldface numbers in parentheses refer to references at the end of this practice.

testing temperature to prevent the formation of an oxide coating that would cause misalignment. In any compression test it is important that the specimen be carefully centered with respect to the bearing blocks, which in turn should be centered with respect to the testing machine heads.

NOTE 1—Bearing blocks with straight cylindrical or threaded holes depending on specimen design may be used for bar-type specimens providing the apparatus qualifies in accordance with Section 10.

NOTE 2—Bearing blocks of an adjustable type to provide parallel loading surfaces are discussed in Test Methods E9. Bearing blocks with a spherical seat for the upper block are also shown.

3.3 *Subpresses*—A subpress or other alignment device is necessary in order to maintain suitable alignment when testing specimens that are not laterally supported, unless the testing machine has been designed specifically for axial alignment and uniform application of force in elevated-temperature compression testing. A subpress for room-temperature testing is shown in Test Methods E9. For elevated-temperature compression testing, the subpress must accommodate the heating and loading devices and the temperature-sensing elements. The design of the subpress is largely dependent on the size and strength of the specimens, the temperatures to be used, the environment, and other factors. It must be designed so the ram does not jam or tilt the frame as a result of heating or application of force. If the bearing faces of the subpress, the opposite faces of both bearing blocks, and the ends of the specimen are respectively plane and parallel within very close limits, it is unnecessary to use adjustable or spherical seats. In any case, the specimen should be properly centered in the subpress.

3.4 *Compression Testing Jigs*—When testing sheet material, buckling of the specimen during application of compressive forces must be prevented. This may be accomplished by using a jig containing side-support plates that bear against the faces of the specimen. The jig must afford a suitable combination of lateral-support pressure and spring constant to prevent buckling without interfering with axial deformation of the specimen (1). Although suitable combinations vary somewhat with variations in specimen material and thickness, testing temperature, and accuracy of alignment, acceptable results can be obtained with rather wide ranges of lateral-support pressure and spring constant for any given test conditions. Generally, the higher the spring constant of the jig, the lower the lateral-support pressure that is required. Proper adjustment of these test variables may be established in preliminary verification tests for the equipment (Section 10).

3.4.1 This practice does not intend to designate specific compression jigs for testing sheet metals, but merely to provide a few illustrations and references to jigs that have been used successfully. Many other jigs are acceptable provided they prevent buckling and pass the qualification tests set forth in Section 10. Satisfactory results have been obtained in room-temperature testing using the jigs illustrated in Test Methods E9. These jigs usually require that the specimen be lubricated to permit normal compression on loading. For elevated-temperature testing, modified jigs that accommodate the heating and strain-measuring equipment as well as the temperature-sensing elements must be used. A number of compression-

testing jigs have been evaluated specifically for performance in elevated-temperature tests (2, 3). The preferred type depends on the material, its thickness, and the temperatures involved. For moderately elevated temperatures, one of the room-temperature designs may be used in an oven in which the air is circulated to provide uniform heating. One design for side-support plates that has been found satisfactory for use at temperatures up to 1000 °F (538 °C) when lubricated with graphite is shown in Fig. 1(a) (4). Longitudinal grooves are cut in each plate with the grooves offset across the thickness of the specimen. These plates are made of titanium carbide. A type of side-support plate that has been used in compression jigs to 1800 °F (982 °C) is shown in Fig. 1(b) (4). This is an assembly of small titanium carbide balls backed up by a titanium carbide plate. The balls protrude through holes in the front retaining plate. The holes for the balls are large enough to allow rotation and translation of each ball while at the same time retaining the balls in the plate assembly. The spacing of the balls, which is normally about 1/8 in. (3.2 mm), determines the minimum specimen thickness that can be tested without buckling between the balls. Rational values of the ball spacing can be obtained from calculations based upon the plastic buckling of simply supported plates where the plate width can be taken as the ball spacing. Another type of jig has a number of leaf-spring supports on each side of the specimen (3, 5). This design is limited to a temperature range in which the metal leaf-spring elements can support the specimen satisfactorily. Jigs for use with specimens that are heated by self resistance are discussed in (1, 6) and (7), which also provide quantitative information on the effects of lubrication, lateral-support pressure, spring constant, and misalignment.

3.4.2 The side-support plates are assembled in a frame that is part of the jig. A typical frame and jig assembly is shown in Fig. 2. A furnace is placed around the jig after the specimen and extensometer are assembled in the jig. The holes in the support blocks are for auxiliary cartridge-type heaters.

4. Significance and Use

4.1 *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

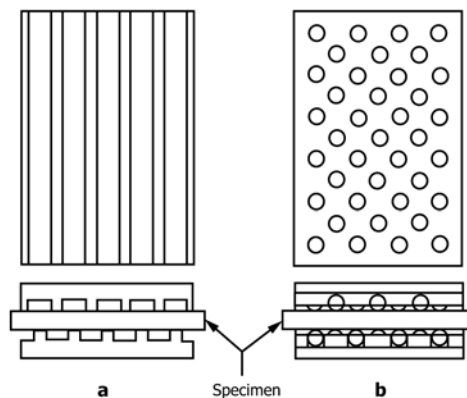


FIG. 1 Specimen Side Support Plates (4)

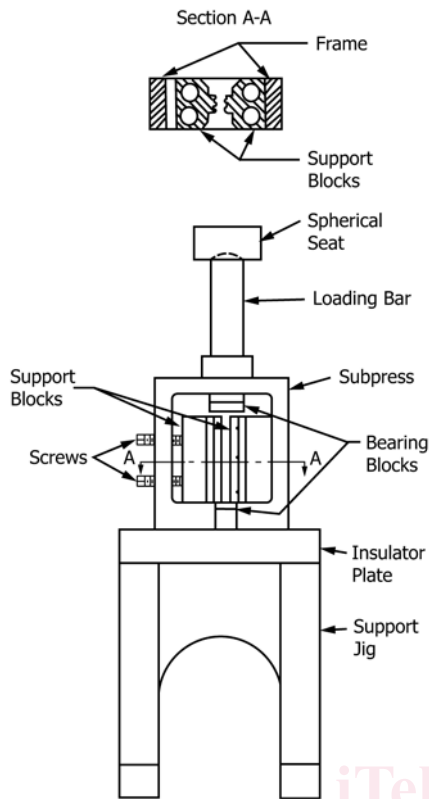


FIG. 2 Typical Compression Testing Jig for Sheet Specimens Mounted on Support Jig (3)

fail in compression by a shattering fracture, compressive strength is a value that is dependent on total strain and specimen geometry.

4.2 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 can complicate results and should be minimized

5. Heating Apparatus

5.1 The apparatus and method for heating the specimens are not specified, but in present practice the following are mainly used.

- 5.1.1 The resistance of the specimen gage length to the passage of an electric current,
- 5.1.2 Resistance heating supplemented by radiant heating,
- 5.1.3 Radiant heating,
- 5.1.4 Induction heating, or
- 5.1.5 Convection heating with circulating-air furnace.

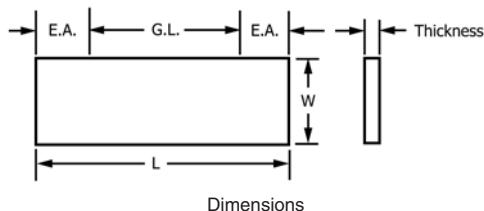
5.2 The apparatus must be suitable for heating the specimen under the conditions specified in Section 6.

6. Test Specimen

6.1 The size and shape of the test specimen should be based on three requirements as follows:

- 6.1.1 The specimen should be representative of the material being investigated and should be taken from the material produced in the form and condition in which it will be used,
- 6.1.2 The specimen should be adapted to meet the requirements on temperature control and rates of heating and straining, and
- 6.1.3 The specimen should be conducive to the maintenance of axial alignment uniform application of force, and freedom from buckling when loaded to the end point in the apparatus used.

6.2 The specimens are divided into two general classifications: those with rectangular cross sections and those with round cross sections. The dimensions of the specimens are optional. The specimen must be long enough to be compressed to the required deformation without interference from a supporting jig but not long enough to permit buckling where it is unsupported. The end allowance (dimension between the gage points and the adjacent end of the uniform section) should be a minimum of one half the width of rectangular specimens or one half the diameter of round specimens. Typical acceptable specimens are illustrated in Fig. 3 and Fig. 4.



	Specimen 1	Specimen 2	Specimen 3
G.L.—Gage Length, in. (mm)	1.000 ± 0.005 (25.4 ± 0.13)	2.000 ± 0.005 (50.8 ± 0.13)	2.000 ± 0.005 (50.8 ± 0.13)
L—Uniform Section, in. (mm)	2.500 ± 0.005 (63.5 ± 0.13)	3.000 ± 0.005 (76.2 ± 0.13)	2.50 min (63.5)
W—Width, in. (mm)	0.625 ± 0.010 (15.9 ± 0.25)	1.000 ± 0.010 (25.4 ± 0.25)	0.500 ± 0.010 (12.7 ± 0.25)
E.A.—End Allowance, in. (mm)	0.75 (19)	0.50 (12.7)	0.25 min (6.35)

FIG. 3 Dimensions of Typical Rectangular Specimens