Designation: D 3410/D 3410M – 03

Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading[1]

This standard is issued under the fixed designation D 3410/D 3410M; 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 This test method determines the in-plane compressive properties of polymer matrix composite materials reinforced by high-modulus fibers. The composite material forms are limited to continuous-fiber or discontinuous-fiber reinforced composites for which the elastic properties are specially orthotropic with respect to the test direction. This test procedure introduces the compressive force into the specimen through shear at wedge grip interfaces. This type of force transfer differs from the procedure in Test Method D 695 where compressive force is transmitted into the specimen by end-loading, Test Method D 6641/D 6641M where compressive force is transmitted by combined shear and end loading, and Test Method D 5467/D 5467M where compressive force is transmitted by subjecting a honeycomb core sandwich beam with thin skins to four-point bending.

1.2 This test method is applicable to composites made from unidirectional tape, wet-tow placement, textile (for example, fabric), short fibers, or similar product forms. Some product forms may require deviations from the test method.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text the inch-pounds units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

NOTE 1—Additional procedures for determining compressive properties of resin-matrix composites may be found in Test Methods D 695, D 5467/D 5467M, and D 6641/D 6641M.

1.4 *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 695 Test Method for Compressive Properties of Rigid Plastics[2]

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[2]

D 883 Terminology Relating to Plastics[2]

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins[3]

D 2734 Test Methods for Void Content of Reinforced Plastics[3]

D 3171 Test Method for Constituent Content of Composite Materials[4]

D 3878 Terminology for Composite Materials[4]

D 5229/D 5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials[4]

D 5379/D 5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method[4]

D 5467/D 5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composites Using a Sandwich Beam[4]

D 6641/D 6641M Test Method for Determining the Compressive Properties of Polymer Matrix Composite Laminates Using a Combined Loading Compression (CLC) Test Fixture[4]

E 4 Practices for Force Verification of Testing Machines[5]

E 6 Terminology Relating to Methods of Mechanical Testing[5]

E 83 Practice for Verification and Classification of Extensometers[5]

E 111 Test Method for Young's Modulus, Tangent Modulus,

[1] This specification is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.04 on Lamina and Laminate Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.02.

[4] *Annual Book of ASTM Standards*, Vol 15.03.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

and Chord Modulus[5]
E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for Characteristic of a Lot or Process[6]
E 132 Test Method for Poisson's Ratio at Room Temperature[5]
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[6]
E 251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages[5]
E 456 Terminology Relating to Quality and Statistics[6]
E 1237 Guide for Installing Bonded Resistance Strain Gages[5]
E 1309 Guide for the Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases[4]
E 1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases[4]
E 1471 Guide for the Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases[4]

2.2 *ASTM Adjunct:*
Compression Fixture, D3410 Method B[7]

2.3 *Other Documents:*
ANSI Y14.5M-1982[8]
ANSI/ASME B46.1-1985[8]

3. Terminology

3.1 Terminology D 3878 defines terms relating to high-modulus fibers and their composites. Terminology D 883 defines terms relating to plastics. Terminology E 6 defines terms relating to mechanical testing. Terminology E 456 and Practice E 177 define terms relating to statistics. In the event of a conflict between terms, Terminology D 3878 shall have precedence over the other Terminology standards.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *nominal value*, *n*—a value, existing in name only, assigned to a measurable property for the purpose of convenient designation. Tolerances may be applied to a nominal value to define an acceptable range for the property.

3.2.2 *orthotropic material*, *n*—a material with a property of interest that, at a given point, possesses three mutually perpendicular planes of symmetry defining the principal material coordinate system for that property.

3.2.3 *principal material coordinate system*, *n*—a coordinate system with axes that are normal to the planes of symmetry that exist within the material.

3.2.4 *reference coordinate system*, *n*—a coordinate system for laminated composites used to define ply orientations. One of the reference coordinate system axes (normally the Cartesian *x*-axis) is designated the reference axis, assigned a position, and the ply principal axis of each ply in the laminate is referenced relative to the reference axis to define the ply orientation for that ply.

3.2.5 *specially orthotropic*, *adj*—a description of an orthotropic material as viewed in its principal material coordinate system. In laminated composites, a specially orthotropic laminate is a balanced and symmetric laminate of the $[0_i/90_j]_{ns}$ family as viewed from the reference coordinate system, such that the membrane-bending coupling terms of the stress-strain relation are zero.

3.2.6 *transition strain, $\epsilon^{transition}$*, *n*—the strain value at the mid-range of the transition region between the two essentially linear portions of a bilinear stress-strain or strain-strain curve (a transverse strain-longitudinal strain curve as used for determining Poisson's ratio).

3.3 *Symbols:*

3.3.1 A—cross-sectional area of specimen.

3.3.2 B_y—percent bending in specimen.

3.3.3 CV—sample coefficient of variation, in percent.

3.3.4 E—modulus of elasticity in the test direction.

3.3.5 F^{cu}—ultimate compressive stress (compressive strength).

3.3.6 G_{xz}—through-thickness shear modulus of elasticity.

3.3.7 h—specimen thickness.

3.3.8 i, j, n—as used in a layup code, the number of repeats for a ply or group of plies of a material.

3.3.9 l_g—specimen gage length.

3.3.10 n—number of specimens.

3.3.11 P—force applied to test specimen.

3.3.12 P^f—force applied to test specimen at failure.

3.3.13 P^{max}—maximum force before failure.

3.3.14 s—as used in a layup code, denotes that the preceding ply description for the laminate is repeated symetrically about its midplane.

3.3.15 s_{n-1}—sample standard deviation.

3.3.16 w—specimen width.

3.3.17 x_i—measured or derived property.

3.3.18 $\bar{x}$—sample mean (average).

3.3.19 ϵ—indicated normal strain from strain transducer.

3.3.20 ν^c—compressive Poisson's ratio.

3.3.21 σ_c—compressive normal stress.

4. Summary of Test Method

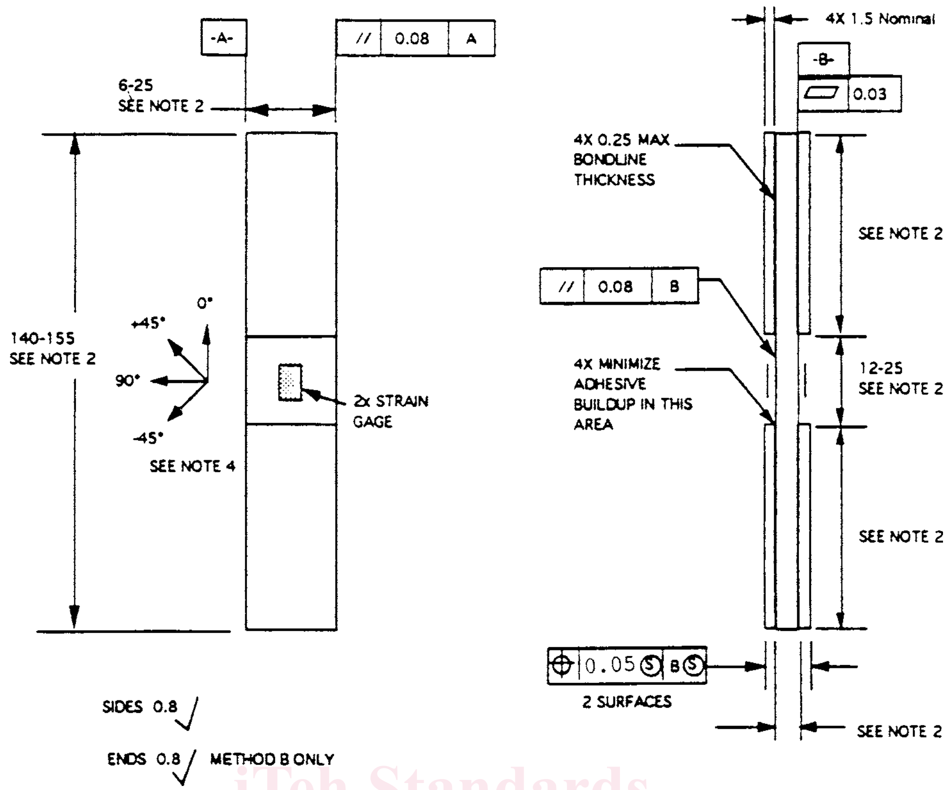
4.1 A flat strip of material having a constant rectangular cross section, as shown in the specimen drawings of Figs. 1-4, is loaded in compression by a shear force acting along the grips. The shear force is applied via wedge grips in a specially-designed fixture shown in Figs. 5-7. The influence of this wedge grip design on fixture characteristics is discussed in 6.1.

4.2 To obtain compression test results, the specimen is inserted into the test fixture which is placed between the platens of the testing machine and loaded in compression. The ultimate compressive stress of the material, as obtained with this test fixture and specimen, can be obtained from the maximum force carried before failure. Strain is monitored with strain or displacement transducers so the stress-strain response of the material can be determined, from which the ultimate

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] A blueprint of the detailed drawing for the construction of the fixture shown in Fig. 4 is available at a nominal cost from ASTM International Headquarters, 100 Barr Harbor Dr., PO Box C700, West Conshohocken, PA 19428–2959. Order Adjunct ADJD3410.

[8] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.



Notes:
1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985.
2. See Section 8 and Table 2 and Table 3 of the test standard for values of required or recommended width, thickness, gage length, tab length and overall length.
3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle, and tab adhesive.
4. Ply orientation tolerance relative to -A- ±0.5°.

FIG. 1 Compression Test Specimen Drawing, (SI with Tabs)

compressive strain, the compressive modulus of elasticity, Poisson's ratio in compression, and transition strain can be derived.

5. Significance and Use

5.1 This test method is designed to produce compressive property data for material specifications, research and development, quality assurance, and structural design and analysis. Factors that influence the compressive response and should therefore be reported include the following: material, methods of material preparation and layup, specimen stacking sequence, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement. Properties, in the test direction, that may be obtained from this test method include:

5.1.1 Ultimate compressive strength,

5.1.2 Ultimate compressive strain,

5.1.3 Compressive (linear or chord) modulus of elasticity,

5.1.4 Poisson's ratio in compression, and

5.1.5 Transition strain.

6. Interferences

6.1 *Test Fixture Characteristics*—This test method transmits force to the specimen via tapered rectangular wedge grips. The rectangular wedge grip design is used to eliminate the wedge seating problems induced by the conical wedges of the so-called Celanese compression test fixture previously utilized in this test method (**1**).[9] Earlier versions of this test method containing full details of the Celanese test method, including Test Method D 3410/D 3410M-95, are available.[8] Another fixture characteristic that can have a significant effect on test results is the surface finish of the mating surfaces of the wedge grip assembly. Since these surfaces undergo sliding contact they must be polished, lubricated, and nick-free (11.5.1).

NOTE 2—An acceptable level of polish for the surface finish of wedge grip mating surfaces has been found to be one that ranges from 2 to 12 micro in. rms with a mean finish of 7 micro in. rms.

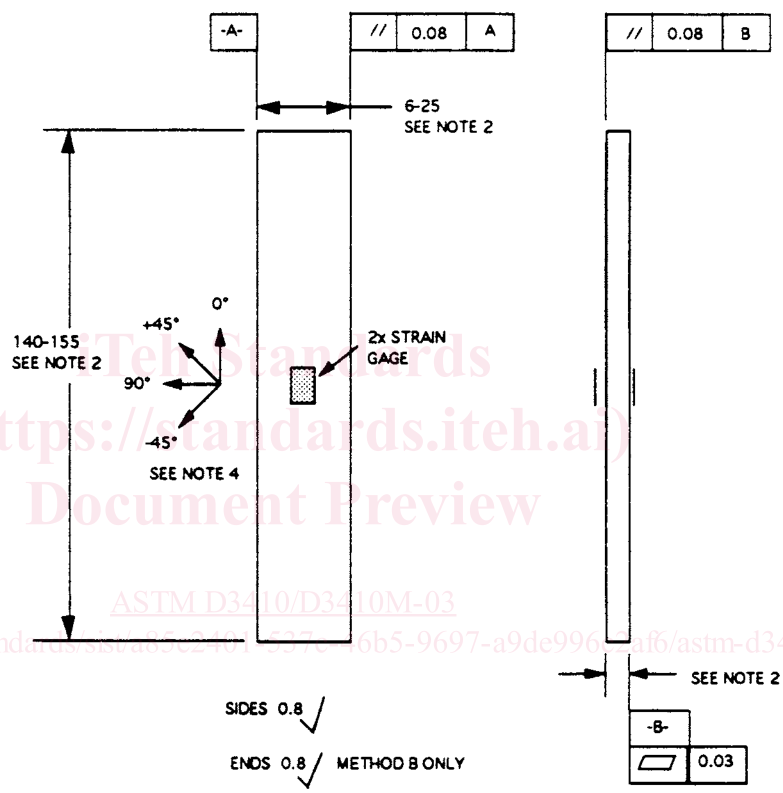
6.1.1 The specimen gripping faces of the wedge grips are typically roughened in some manner, as required for the particular application. Examples include serrated (7 to 8 serrations/cm) or thermal-sprayed tungsten carbide particle (100 grit) grip faces (see also 8.3.3).

6.2 *Test Method Sensitivity*—Compression strength for a single material system has been shown to differ when determined by different test methods. Such differences can be attributed to specimen alignment effects, specimen geometry effects, and fixture effects even though efforts have been made

[9] Boldface numbers in parentheses refer to the list of references at the end of this test method.

Notes:

1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985
2. See Section 8 and Tables 2 and 3 of the test standard for values of required or recommended width, thickness, gage length, tab length and overall length.
3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- ±0.5°



COMPRESSION TEST SPECIMEN WITHOUT TABS
SI VERSION

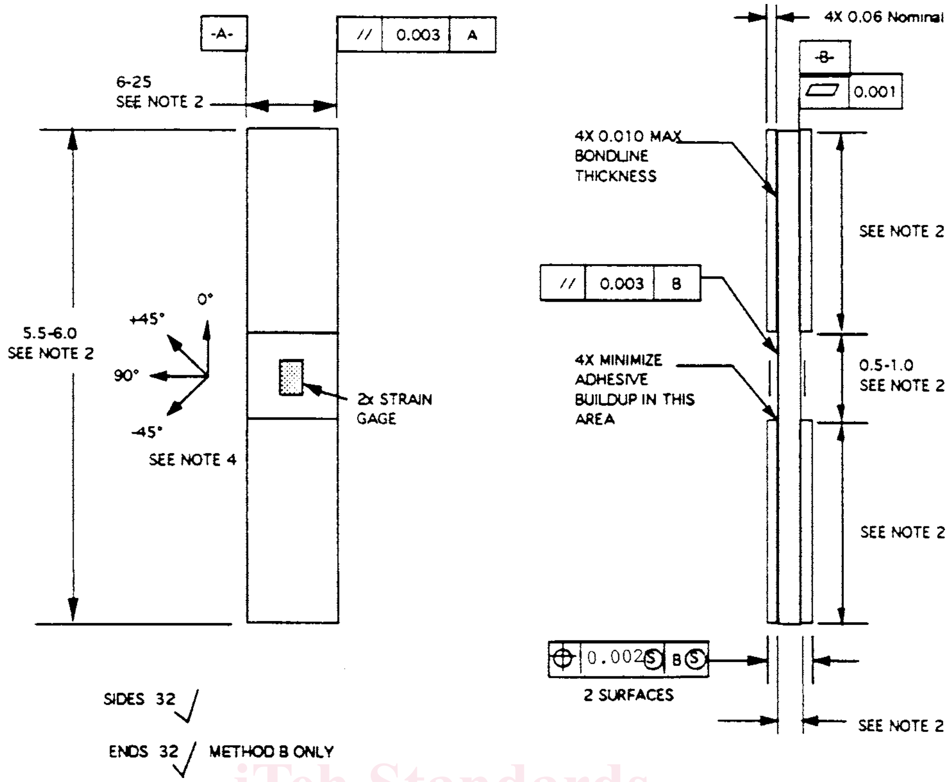
All Dimensions in mm

FIG. 2 Compression Test Specimen Drawing, (SI without Tabs)

to minimize these effects. Examples of differences in test results between various test methods can be found in Refs **(1,2)**.

6.3 *Material and Specimen Preparation*—Compression modulus, and especially ultimate compressive stress, are sensitive to poor material fabrication practices, damage induced by improper specimen machining, and lack of control of fiber alignment. Fiber alignment relative to the specimen coordinate axis should be maintained as carefully as possible, although no standard procedure to ensure this alignment exists. Procedures found satisfactory include the following: fracturing a cured unidirectional laminate near one edge parallel to the fiber direction to establish the 0° direction, or laying in small filament count tows of contrasting color fiber (aramid in carbon laminates and carbon in aramid or glass laminates) parallel to the 0° direction either as part of the prepreg production or as part of panel fabrication.

6.4 *Tabbing and Tolerances*—The data resulting from this test method has been shown to be sensitive to the flatness and parallelism of the tabs, so care should be taken to ensure that



Notes:
1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985.
2. See Section 8 and Table 2 and Table 3 of the test standard for values of required or recommended width, thickness, gage length, tab length, and overall length.
3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- ±0.5°.

FIG. 3 Compression Test Specimen Drawing, (Inch-Pound with Tabs)

the specimen tolerance requirements are met. This usually requires precision grinding of the tab surfaces after bonding them to the specimen.

6.5 *Thickness and Gage Length Selection*—The gage section for this test method is unsupported, resulting in a tradeoff in the selection of specimen gage length and the specimen thickness. The gage length must be short enough to be free from Euler (column) buckling, yet long enough to allow stress decay to uniaxial compression and to minimize Poisson restraint effects as a result of the grips. Minimum thickness requirements are provided in 8.2.3.

6.6 *Gripping*—A high percentage of grip-induced failures, especially when combined with high material data scatter, is an indicator of specimen gripping problems.

6.7 *System Alignment*—Excessive bending will cause premature failure, as well as highly inaccurate modulus of elasticity determination. Every effort should be made to eliminate bending from the test system. Bending may occur for the following reasons: (*1*) misaligned (or out-of tolerance) grips or associated fixturing, (*2*) improper installation of specimen, or (*3*) poor specimen preparation.

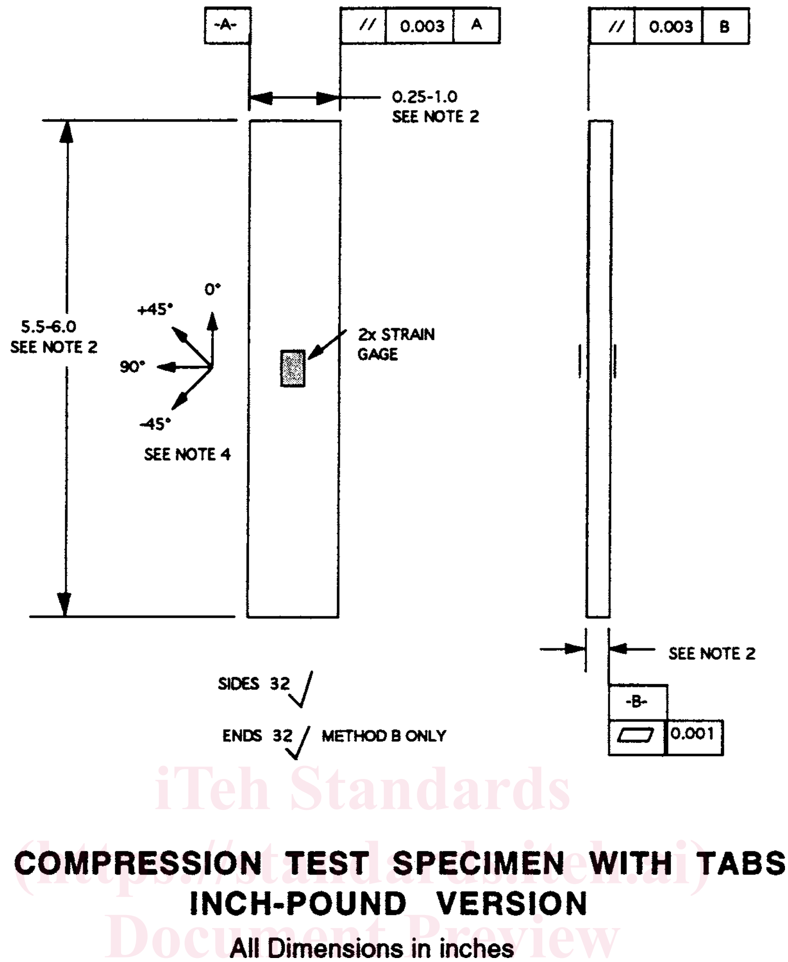
6.8 *Edge Effects in Angle-Ply Laminates*—Premature failures and lower stiffnesses are observed due to edge softening in laminates containing off-axis plies. Because of this, the strength and modulus for angle-ply laminates can be underestimated. For quasi-isotropic laminates and those containing even higher percentages of 0° plies, the effect is less.

7. Apparatus

7.1 *Micrometers*—The micrometer(s) shall use a suitable size diameter ball interface on irregular surfaces such as the bag side of a laminate and a flat anvil interface on machined edges or very smooth tooled surfaces. The accuracy of the instruments shall be suitable for reading to within 1 % of the sample width and thickness. For typical specimen geometries, an instrument with an accuracy of ±2.5 μm [±0.0001 in.] is desirable for thickness measurement, while an instrument with an accuracy of ±25 μm [±0.001 in.] is desirable for width measurement.

7.2 *Compression Fixture*:

7.2.1 *Fixture*—The fixture uses rectangular wedges and allows for variable width and thickness specimens. A sectional schematic and photographs of the fixture are shown in Figs. 5-7. Each set of specimen wedge grips fits into a mating set of wedges that fits into the upper and lower wedge housing block assemblies. By using wedges of different thicknesses, specimens of varying thickness can be tested in this fixture. As indicated in Fig. 5, the wedge grips are sometimes provided with slots at the outer ends, to accommodate end bars. The ends of the specimen can be butted against these bars during grip screw tightening, to ensure that an equal length of specimen is gripped by each pair of wedge grips. These bars can be removed prior to the test, or remain in place to provide an



Notes:
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3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- ±0.5°.

FIG. 4 Compression Test Specimen Drawing, (Inch-Pound without Tabs)

(uncontrolled) degree of end-loading to the otherwise shear-loaded specimen. These bars also promote equal movement of each of the wedges of a pair during specimen loading, thus reducing induced specimen bending. Typically, the upper wedge housing block assembly is attached to the upper crosshead of the test machine while the lower wedge housing block assembly rests on a lower platen.

7.2.2 *Specimen Alignment Jig*—Compression test results generated by this test method are sensitive to the alignment of the specimen with respect to the longitudinal axis of the wedges in the test fixture. Specimen alignment can be accomplished by using an alignment jig or gage block that mechanically holds the specimen captive outside the fixture housing blocks (as shown in Fig. 8), or by using a custom jig or machinist's square for a specimen inserted into wedge grips already in the fixture housing blocks. Alignment jigs and procedures other than those described are acceptable provided they perform the same function.

7.3 *Testing Machine*—The testing machine shall be in conformance with Practices E 4, and shall satisfy the following requirements:

7.3.1 *Testing Machine Heads*—The testing machine shall have two loading heads, with at least one movable along the testing axis.

7.3.2 *Fixture Attachment*—Typically the upper portion of the fixture is attached directly to the upper crosshead, and a flat platen attached to the lower crosshead is used to support the lower portion of the fixture. The platen should be at least 20 mm [0.75 in.] thick. The fixture may be coupled to the testing machine with a joint capable of eliminating angular restraint, such as a hemispherical ball on the machine that fits into a hemispherical recess.

NOTE 3—The use of a joint capable of eliminating angular restraint, such as a hemispherical ball, and the use of rigid, parallel crossheads should both be considered for this test method (**3**). To determine the most appropriate test configuration, a test fixture check-out procedure using untabbed aluminum specimens with back-to-back strain gages can be performed to determine the effect of attachment configuration on the accuracy and repeatability of test results.

7.3.3 *Drive Mechanism*—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled displacement rate with respect to the stationary