INTERNATIONAL

Designation: D7248/D7248M − 23

Standard Test Method for High Bearing - Low Bypass Interaction Response of Polymer Matrix Composite Laminates Using 2-Fastener Specimens[1]

This standard is issued under the fixed designation D7248/D7248M; 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 test method determines the uniaxial bearing/bypass interaction response of multi-directional polymer matrix composite laminates reinforced by high-modulus fibers by either double-shear tensile loading (Procedure A) or single-shear tensile or compressive loading (Procedure B) of a two-fastener specimen. The scope of this test method is limited to net section (bypass) failure modes. Standard specimen configurations using fixed values of test parameters are described for each procedure. A number of test parameters may be varied within the scope of the standard, provided that the parameters are fully documented in the test report. The composite material forms are limited to continuous-fiber or discontinuous-fiber (tape or fabric, or both) reinforced composites for which the laminate is balanced and symmetric with respect to the test direction. The range of acceptable test laminates and thicknesses are described in 8.2.1. Test methods for high bypass - low bearing response of polymer matrix composite materials, previously published under Procedure C of this test method, are now published in Test Method D8387/D8387M.

1.2 This test method is consistent with the recommendations of Composite Materials Handbook, CMH-17, which describes the desirable attributes of a bearing/bypass interaction response test method.

1.3 The two-fastener test configurations described in this test method are similar to those in Test Method D5961/D5961M as well as those used by industry to investigate the bearing portion of the bearing/bypass interaction response for bolted joints, where the specimen may produce either a bearing failure mode or a bypass failure mode. Should the test specimen fail in a bearing failure mode rather than the desired bypass mode, then the test should be considered to be a bearing dominated bearing/bypass test, and the data reduction and reporting procedures of Test Method D5961/D5961M should be used instead of those given in this test method.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.4.1 Within the text, the inch-pound units are shown in brackets.

1.5 *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.*

1.6 *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]

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2734 Test Methods for Void Content of Reinforced Plastics
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.05 on Structural Test Methods.

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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.

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

D5766/D5766M Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates

D5961/D5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates

D6484/D6484M Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates

D6742/D6742M Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates

D8387/D8387M Test Method for High Bypass – Low Bearing Interaction Response of Polymer Matrix Composite Laminates

D8509 Guide for Test Method Selection and Test Specimen Design for Bolted Joint Related Properties

E4 Practices for Force Calibration and Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E83 Practice for Verification and Classification of Extensometer Systems

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages

E456 Terminology Relating to Quality and Statistics

E1237 Guide for Installing Bonded Resistance Strain Gages

2.2 *Other Document:*[3]

Composite Materials Handbook, CMH-17 Polymer Matrix Composites, Volume 1, Chapter 7

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and Practice E177 define terms relating to statistics. In the event of a conflict between terms, Terminology D3878 shall have precedence over the other documents.

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [*M*] for mass, [*L*] for length, [*T*] for time, [θ] for thermodynamic temperature, and [*nd*] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard*—Refer to Guide D8509.

3.3 *Symbols:*

A = cross-sectional area of a specimen

CV = coefficient of variation statistic of a sample population for a given property (in percent)

d = fastener or pin diameter

D = specimen hole diameter

d_{csk} = countersink depth

d_{fl} = countersink flushness (depth or protrusion of the fastener in a countersunk hole)

e = distance, parallel to applied force, from hole center to end of specimen; the edge distance

E_x^{br} = bearing chord stiffness in the test direction specified by the subscript

$F_x^{br\_byp}$ = bearing stress at the ultimate bypass strength in the test direction specified by the subscript

$F_x^{gr\_byp\_c}$ = ultimate compressive gross bypass strength in the test direction specified by the subscript

$F_x^{gr\_byp\_t}$ = ultimate tensile gross bypass strength in the test direction specified by the subscript

$F_x^{net\_byp\_c}$ = ultimate compressive net bypass strength in the test direction specified by the subscript

$F_x^{net\_byp\_t}$ = ultimate tensile net bypass strength in the test direction specified by the subscript

g = distance, parallel to applied force, from hole edge to end of specimen

h = specimen thickness

k = calculation factor used in net bypass strength calculations to determine net force portion

L_g = extensometer gauge length

n = number of specimens per sample population

P = force carried by test specimen

P^f = force carried by test specimen at failure

P^{max} = maximum force carried by test specimen prior to failure

s_{n-1} = standard deviation statistic of a sample population for a given property

w = specimen width

x_i = test result for an individual specimen from the sample population for a given property

$\bar{x}$ = mean or average (estimate of mean) of a sample population for a given property

δ = extensional displacement

ε = general symbol for strain, whether normal strain or shear strain

ε^{br} = bearing strain

σ^{br} = bearing stress

4. Summary of Test Method

4.1 Refer to Guide D8509 for discussion of bearing/bypass test procedures.

4.2 *Procedure A, Bypass/High Bearing Double Shear:*

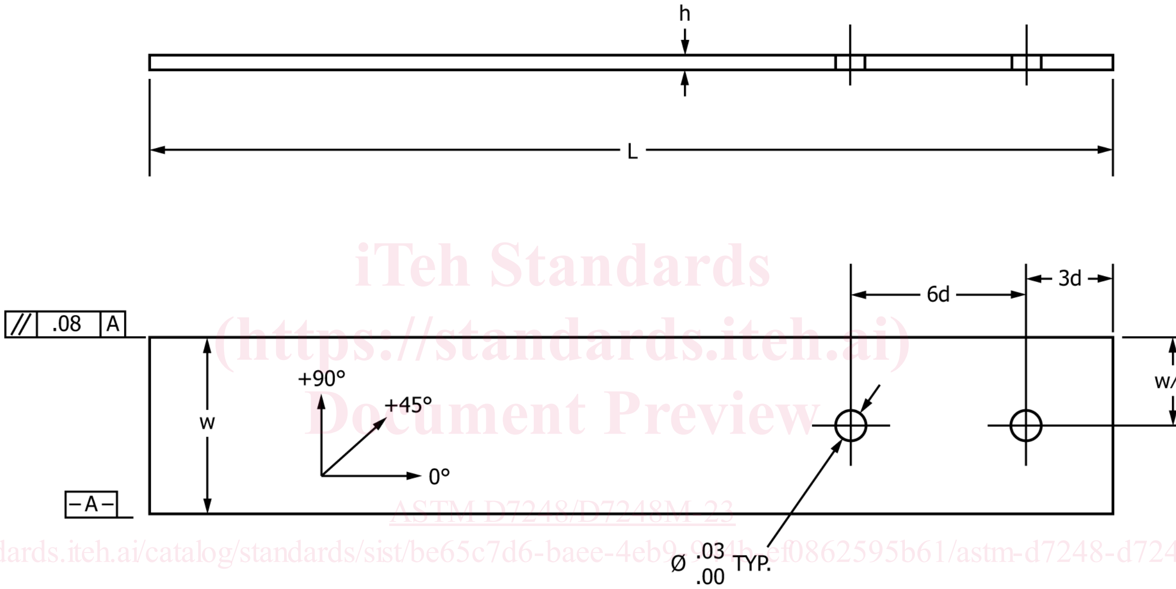
4.2.1 A flat, constant rectangular cross-section test specimen with two centerline holes located near the end of the specimen, as shown in the test specimen drawings of Figs. 1 and 2, is loaded at the hole in bearing. The bearing force is normally applied through a close-tolerance, lightly torqued fastener (or pin) that is reacted in double shear by a fixture similar to that shown in Figs. 3 and 4. The bearing force is created by pulling the assembly in tension in a testing machine. The difference from a standard "bearing" test is that the expected primary failure mode is net section tension, rather than a bearing mode.

[3] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

DRAWING NOTES:
1. INTERPRET DRAWING IN ACCORDANCE WITH ANSI Y14.5M−1982, SUBJECT TO THE FOLLOWING:
2. ALL DIMENSIONS IN MM WITH DECIMAL TOLERANCES AS FOLLOWS:

NO DECIMAL	.X	.XX X
+/−3	+/−1	+/−.3

3. ALL ANGLES HAVE TOLERANCE OF +/− .5°
4. PLY ORIENTATION DIRECTION TOLERANCE RELATIVE TO −A− WITHIN +/− .5°.
5. FINISH ON MACHINED EDGES NOT TO EXCEED 1.6 √ (SYMBOLOGY IN ACCORDANCE WITH ASA B46.1, WITH ROUGHNESS HEIGHT IN MICROMETRES.)
6. VALUES TO BE PROVIDED FOR THE FOLLOWING, SUBJECT TO ANY RANGES SHOWN ON THE FIELD OF DRAWING; MATERIAL, LAY−UP, PLY ORIENTATION REFERENCE RELATIVE TO −A−, OVERALL LENGTH, HOLE DIAMETER, COUNTERSINK DETAILS, COUPON THICKNESS.



Parameters	Standard Dimensions (mm)
fastener diameter, d	6+0.00/−0.03
hole diameter, Ø	6+0.03/−0.00
thickness range, h	2−5
length, L	200
width, w	30+/−1
edge distance, e	18+/−1
countersink	none

FIG. 1 Double-Shear, Two-Fastener Test Specimen Drawing (SI)

4.2.2 Refer to Guide D8509 for additional test details and for the standard test configuration.

4.3 *Procedure B, Bypass/High Bearing Single Shear:*

4.3.1 The flat, constant rectangular cross-section test specimen is composed of two like halves fastened together through two centerline holes located near one end of each half, as

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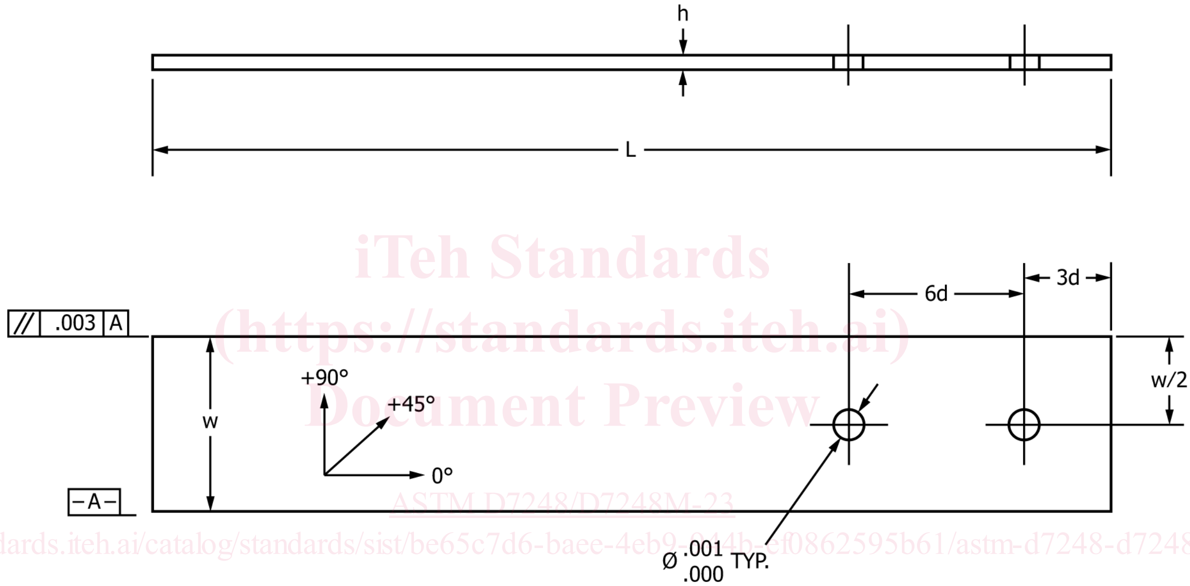
.X	.XX	.XXX
+/−.1	+/−.03	+/−.003

3. ALL ANGLES HAVE TOLERANCE OF +/− .5°.
4. PLY ORIENTATION DIRECTION TOLERANCE RELATIVE TO [−A−] WITHIN +/− .5°.
5. FINISH ON MACHINED EDGES NOT TO EXCEED 64√ SYMBOLOGY IN ACCORDANCE WITH ASA B46.1, WITH ROUGHNESS HEIGHT IN MICROINCHES.)
6. VALUES TO BE PROVIDED FOR THE FOLLOWING, SUBJECT TO ANY RANGES SHOWN ON THE FIELD OF DRAWING; MATERIAL, LAY−UP, PLY ORIENTATION REFERENCE RELATIVE TO [−A−], OVERALL LENGTH, HOLE DIAMETER, COUNTERSINK DETAILS, COUPON THICKNESS.



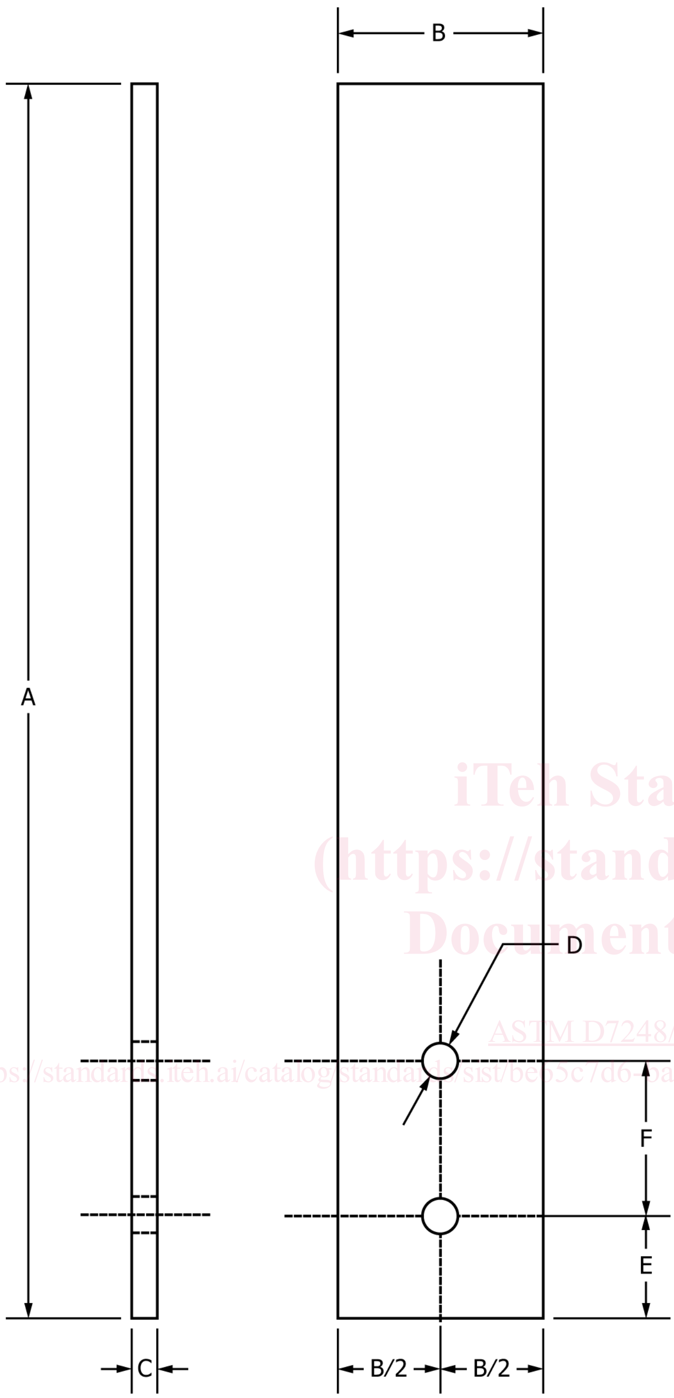
Parameters	Standard Dimensions (inches)
fastener diameter, d	0.250+0.000/−0.001
hole diameter, Ø	0.250+0.001/−0.000
thickness range, h	0.080−0.208
length, L	8.00
width, w	1.25+/−0.03
edge distance, e	0.75+/−0.03
countersink	none

FIG. 2 Double-Shear, Two-Fastener Test Specimen Drawing (Inch-Pound)

shown in the test specimen drawings of Figs. 5 and 6. The eccentricity in applied force that would otherwise result is minimized by a doubler bonded to each grip end of the specimen, resulting in a force line-of-action along the interface between the specimen halves, through the centerline of the hole(s).

4.3.1.1 *Unstabilized Configuration (No Support Fixture)*—The ends of the test specimen are gripped in the jaws of a test machine and loaded in tension.

4.3.1.2 *Stabilized Configuration (Using Support Fixture)*—The test specimen is face-supported in a multi-piece bolted support fixture, as shown in Fig. 7. The test specimen/fixture



Recommended Material: 17-4PH Stainless Steel 1 GPa [145 ksi] yield stress						
	A	B	C	D	E	F
mm	200	30	3	6	18	36
inch	8.00	1.25	0.12	0.25	0.75	1.50

FIG. 3 Fixture Loading Plate for Procedure A (2 Required)

assembly is clamped in hydraulic wedge grips and the force is sheared into the support fixture and then sheared into the specimen. Either tensile or compressive force may be applied.

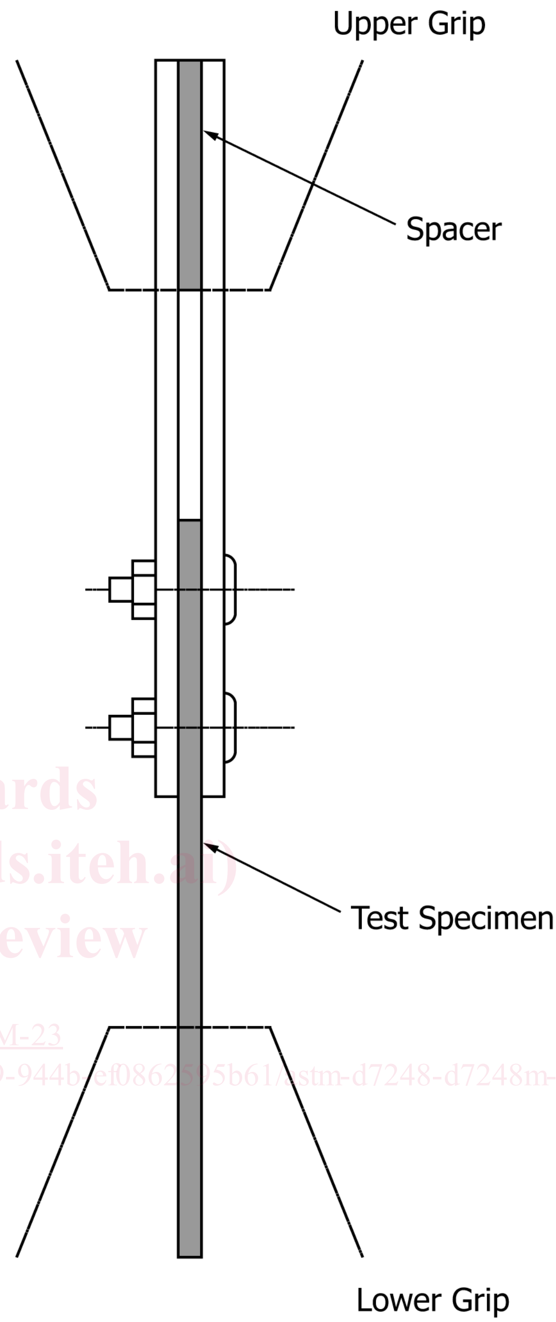


FIG. 4 Fixture Assembly for Procedure A

The stabilization fixture is required for compressive loading. For tensile loading, the fixture is optional, but is often used to simulate actual stabilized joint configurations.

4.3.2 Refer to Guide D8509 for additional test details and for the standard test configuration.

5. Significance and Use

5.1 Refer to Guide D8509.

6. Interferences

6.1 Refer to Guide D8509.

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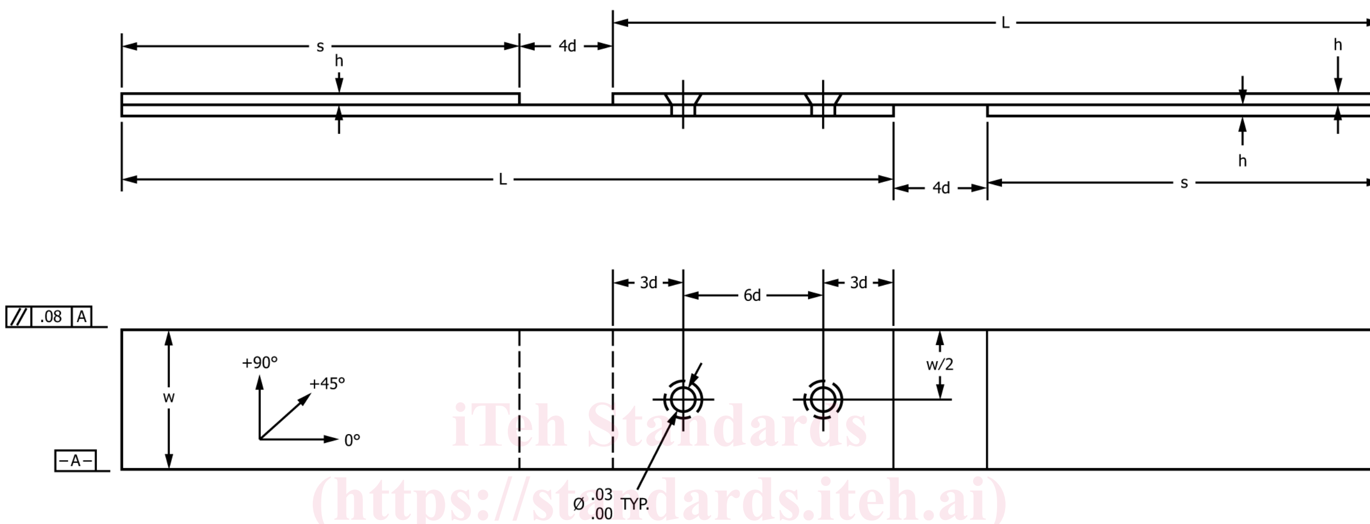
NO DECIMAL	.X	.XX X
+/−3	+/−1	+/−.3

3. ALL ANGLES HAVE TOLERANCE OF +/− .5°.
4. PLY ORIENTATION DIRECTION TOLERANCE RELATIVE TO −A− WITHIN +/− .5°.
5. FINISH ON MACHINED EDGES NOT TO EXCEED 1.6 √ SYMBOLOGY IN ACCORDANCE WITH ASA B46.1, WITH ROUGHNESS HEIGHT IN MICROMETRES.)
6. VALUES TO BE PROVIDED FOR THE FOLLOWING, SUBJECT TO ANY RANGES SHOWN ON THE FIELD OF DRAWING; MATERIAL, LAY−UP, PLY ORIENTATION REFERENCE RELATIVE TO −A−, OVERALL LENGTH, HOLE DIAMETER, COUNTERSINK DETAILS, COUPON THICKNESS, DOUBLER MATERIAL, DOUBLER ADHESIVE.



Parameters	Standard Dimensions of Specimen (mm)	
	without support fixture	with support fixture
fastener diameter, d	6 + 0.00/−0.03	6 + 0.00/−0.03
hole diameter, Ø	6 + 0.03/−0.00	6 + 0.03/−0.00
thickness range, h	2–5	2–5
length, L	210	210
width, w	30 +/− 1	30 +/− 1
edge distance, e	18 +/− 1	18 +/− 1
countersink	none (optional)	none (optional)
doubler length, s	108	108

FIG. 5 Single-Shear, Two-Fastener Test Specimen Drawing (SI)

7. Apparatus

7.1 *Micrometers*—A micrometer with a 4 mm to 8 mm [0.16 in. to 0.32 in.] nominal diameter ball interface shall be used to measure the specimen thickness when at least one surface is irregular (such as the bag-side of a laminate). A micrometer with a 4 mm to 8 mm [0.16 in. to 0.32 in.] nominal diameter ball interface or with a flat anvil interface shall be used to measure the specimen thickness when both surfaces are smooth (such as tooled surfaces). A micrometer or caliper, with a flat anvil interface, shall be used to measure the width of the specimen. The accuracy of the instruments shall be suitable for reading to within 1 % of the sample dimensions. For typical specimen geometries, an instrument with an accuracy of ±0.0025 mm [±0.0001 in.] is adequate for the thickness measurement, while an instrument with an accuracy of ±0.025 mm [±0.001 in.] is adequate for the width measurement. Additionally, a micrometer or gauge capable of determining the hole diameters to ±0.025 mm [±0.001 in.] shall be used.

NOTE 2—The accuracies given above are based on achieving measurements that are within 1 % of the sample width and thickness.

7.2 *Loading Fasteners or Pins*—The fastener (or pin) type shall be specified as an initial test parameter and reported. The assembly torque (if applicable) shall be specified as an initial test parameter and reported. This value may be a measured torque or a specification torque for fasteners with lock-setting features. If washers are utilized, the washer type, number of washers, and washer location(s) shall be specified as initial test parameters and reported. The reuse of fasteners is not recommended due to potential differences in through-thickness

DRAWING NOTES:

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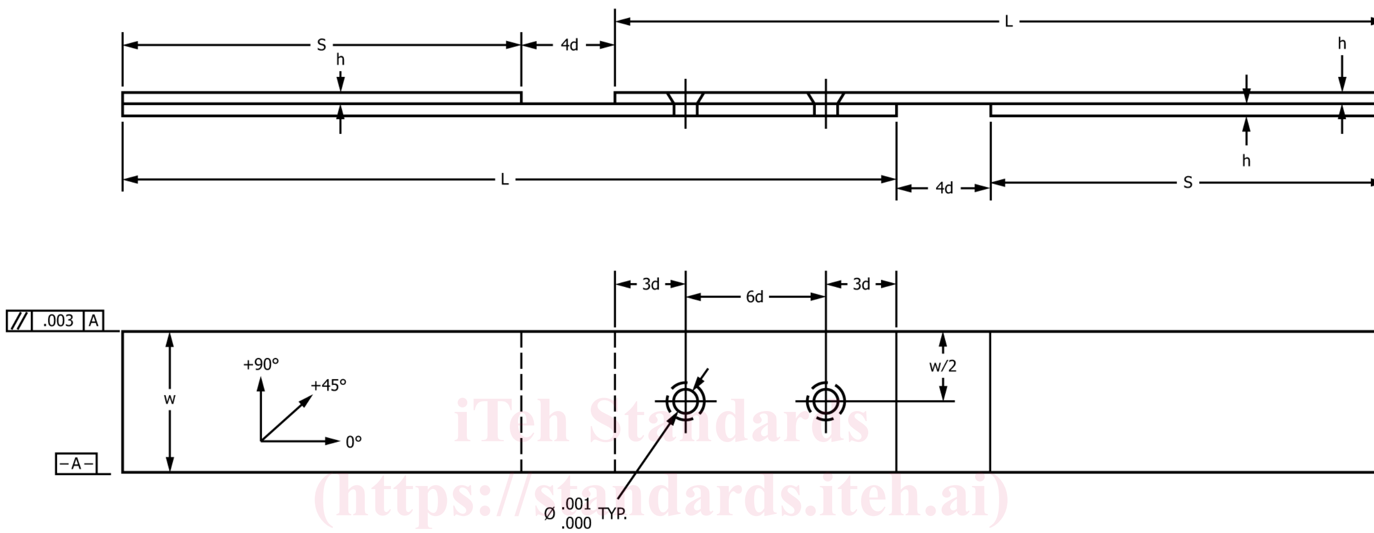
.X	.XX	.XXX
+/–.1	+/–.03	+/–.003

3. ALL ANGLES HAVE TOLERANCE OF +/– .5°.
4. PLY ORIENTATION DIRECTION TOLERANCE RELATIVE TO -A- WITHIN +/– .5°.
5. FINISH ON MACHINED EDGES NOT TO EXCEED 64√ SYMBOLOGY IN ACCORDANCE WITH ASA B46.1, WITH ROUGHNESS HEIGHT IN MICROINCHES.)
6. VALUES TO BE PROVIDED FOR THE FOLLOWING, SUBJECT TO ANY RANGES SHOWN ON THE FIELD OF DRAWING; MATERIAL, LAY-UP, PLY ORIENTATION REFERENCE RELATIVE TO -A-, OVERALL LENGTH, HOLE DIAMETER, COUNTERSINK DETAILS, COUPON THICKNESS, DOUBLER MATERIAL, DOUBLER ADHESIVE.



Parameters	Standard Dimensions of Specimen (inches)	
	without support fixture	with support fixture
fastener diameter, d	0.250+0.000/–0.001	0.250+0.000/–0.001
hole diameter, Ø	0.250+0.001/–0.000	0.250+0.001/–0.000
thickness range, h	0.080–0.208	0.080–0.208
length, L	8.25	8.25
width, w	1.25+/–0.03	1.25+/–0.03
edge distance, e	0.75+/–0.03	0.75+/–0.03
countersink	none (optional)	none (optional)
doubler length, s	4.25	4.25

FIG. 6 Single-Shear, Two-Fastener Test Specimen Drawing (Inch-Pound)

clamp-up for a given torque level, caused by wear of the threads or deformation of the locking features.

7.3 *Torque Wrench*—If using a torqued fastener, a torque wrench used to tighten the fastener shall be capable of determining the applied torque to within ±10 % of the desired value.

7.4 *Fixture:*

7.4.1 *Procedure A*—The force shall be applied to the specimen by means of a double-shear clevis similar to that shown in Figs. 3 and 4, using the loading fasteners or pins. The fixture shall allow a bearing strain indicator to monitor the hole deformation relative to the fixture as shown in Fig. 8.

NOTE 3—The double shear loading straps do not have the bosses around the hole as used for the Test Method D5961/D5961M bearing test method in order to more closely simulate actual joint configurations and to simplify the fixture. With flat loading straps the through-thickness clamp-up force will be distributed over a larger area and therefore the specimen is expected to experience greater bearing damage and lower (conservative) bearing/bypass strengths.

7.4.2 *Procedure B*—The force shall be applied to the specimen by means of a mating single-shear attachment (normally identical to the specimen) using two fasteners. The mating material, thickness, edge distance, length, and hole clearance shall be specified as part of the test parameters. The line of action of the force shall be adjusted by specimen doublers to be coincident and parallel to the interface between the test specimen and the joint mate. If the mating attachment is permanently deformed by the test, it shall be replaced after each test, as required. The mating attachment and support

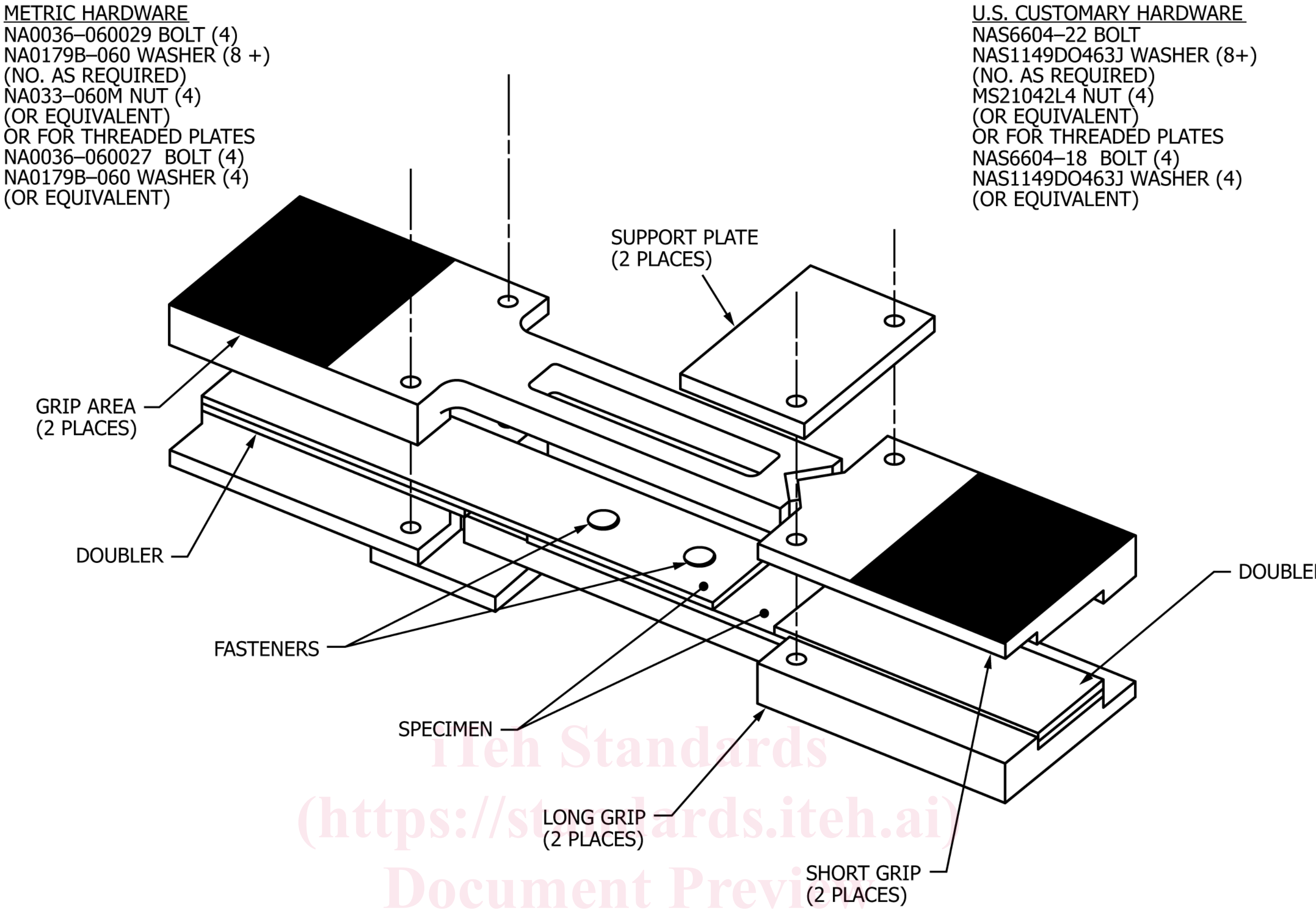


FIG. 7 Support Fixture Assembly for Procedure B (for details of the Support Fixture, see Test Method D5961/D5961M)

fixture (if used) will allow a bearing strain indicator to measure the required hole deformation relative to the mating attachment, as shown in Fig. 8.

7.5 *Support Fixture (Procedure B)*—If compressive loads are applied or if requested in the test plan, a support fixture shall be used to stabilize the specimen. The fixture is a face-supported test fixture as shown in Fig. 7. The fixture consists of two short-grip/long-grip assemblies, two support plates, and stainless steel shims as required to maintain a nominally zero (0.00 mm to 0.12 mm [0.000 in. to 0.005 in.] tolerance) gap between the support plates and the long grips. If this gap does not meet the minimum requirement, shim the contact area between the support plate and the short grip with stainless steel shim stock. If the gap is too large, shim between the support plate and the long grip, holding the shim stock on the support plate with tape. The fixture should be checked for conformity to engineering drawings. Each short-grip/long-grip assembly is line-drilled and must be used as a matched set. The threading of the support plate is optional. The fixture is hydraulically gripped on each end and the force is sheared by means of friction through the fixture and into the test specimen. A cutout exists on both faces of the fixture for a thermocouple, fastener(s) and surface-mounted extensometer. The long and short fixtures have an undercut along the corner of the specimen grip area so that specimens are not required to be chamfered and to avoid damage caused by the radius. The fixtures also allow a slight clearance between the fixture and the gauge section of the specimen, in order to minimize grip failures and friction effects. This fixture does not allow specimens to be end loaded.

7.5.1 *Support Fixture Details*—The detailed drawings for manufacturing the support fixture are contained in Test Method D5961/D5961M. Other fixtures that meet the requirements of this section may be used. The following general notes apply to these figures:

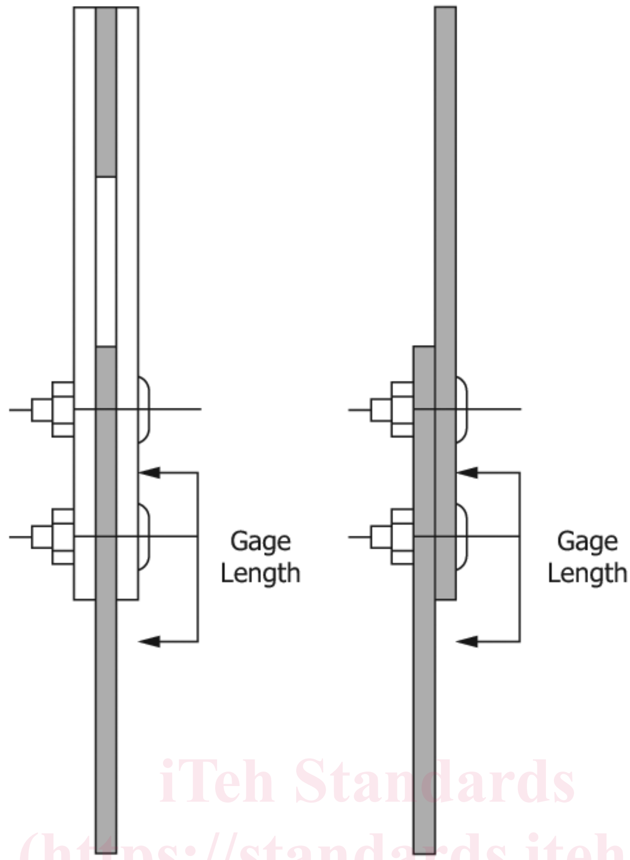
7.5.1.1 Machine surfaces to a 3.2 [125] finish unless otherwise specified.

7.5.1.2 Break all edges.

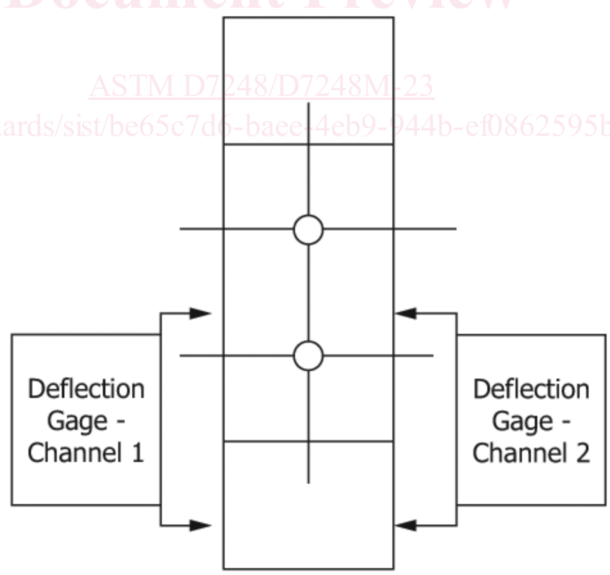
7.5.1.3 Specimen-gripping area shall be thermal sprayed using high-velocity oxygen fueled (HVOF), electro-spark deposition (ESD), or equivalent process.

7.5.1.4 The test fixture may be made of low-carbon steel for ambient temperature testing. For non-ambient environmental conditions, the recommended fixture material is a non-heat-treated ferritic or precipitation-hardened stainless steel (heat treatment for improved durability is acceptable but not required).

NOTE 4—Experience has shown that fixtures may be damaged in use;



(a) Side Views Showing Transducer Gage Lengths



(b) Matched Transducers of Bearing/Bypass Strain Indicator Mounted on Coupon Edge (Single Shear Configuration Shown)

FIG. 8 Transducer Gauge Length and Location

thus, periodic re-inspection of the fixture dimensions and tolerances is important.

NOTE 5—The Test Method D5961/D5961M support fixture has been successfully used for 30 mm [1.25 in.] wide bearing/bypass tests provided careful specimen alignment is achieved. Optional spacers should be added to the fixture to reduce the grip area width to 30.5 mm [1.27 in.]. Such spacers should be thinner than the test sample (to ensure the fixture adequately seats against the specimen surfaces) and should be no longer than the short grips, to ensure that they do not provide a contacting surface which could restrict the motion of the long grip and permit load to be transferred through the fixture. Alternately, a reduced width fixture may be fabricated. Similarly, wider fixtures of the same basic design may be used for specimens that are wider than 36 mm [1.5 in.].

7.6 *Testing Machine*—The testing machine shall be in conformance with Practices E4, and shall satisfy the following requirements:

7.6.1 *Testing Machine Configuration*—The testing machine shall have both an essentially stationary head and a movable head. A short loading train and rigidly mounted hydraulic grips shall be used for Procedure B when using the support fixture.

7.6.2 *Drive Mechanism*—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled velocity with respect to the stationary head. The velocity of the movable head shall be capable of being regulated as specified in 11.3.

7.6.3 *Force Indicator*—The testing machine force-sensing device shall be capable of indicating the total force being carried by the test specimen. This device shall be essentially free from inertia-lag at the specified rate of testing and shall indicate the force with an accuracy over the force range(s) of interest of within ±1 % of the indicated value.

7.6.4 *Grips*—Each head of the testing machine shall be capable of holding one end of the test assembly so that the direction of force applied to the specimen is coincident with the longitudinal axis of the specimen. Wedge grips shall apply sufficient lateral pressure to prevent slippage between the grip face and the test specimen or support fixture.

7.7 *Bearing Deformation Indicator*—Bearing deformation data shall be determined by an indicator device able to measure longitudinal hole deformation simultaneously on opposite edges of the specimen, as shown in Fig. 8 (the average of which corrects for in-plane joint rotation). The arms of the indicator device must fit within the stabilization fixture when a specimen with a width less than 38 mm [1.5 in.] is tested in the standard fixture. Transducer gauge lengths on the order of 50 mm [2.0 in.] are typically used. The transducers of the bearing deformation indicator may provide either individual signals to be externally averaged or an electronically averaged signal. The indicator may consist of two matched strain-gauge extensometers or displacement transducers such as LVDTs or DCDTs. Attachment of the bearing deformation indicator to the specimen shall not cause damage to the specimen surface. Transducers shall satisfy, at a minimum, Practice E83, Class B-2 requirements for the displacement range of interest, and shall be calibrated over that range in accordance with Practice E83. The transducers shall be essentially free of inertia-lag at the specified speed of testing.

NOTE 6—A matched set of extensometers mounted on opposite faces would be required to quantify and correct for out-of-plane joint rotation, which is the primary variable of concern in a single-shear loading configuration.

7.8 *Conditioning Chamber*—When conditioning materials at non-laboratory environments, a temperature-/vapor-level controlled environmental conditioning chamber is required that shall be capable of maintaining the required temperature to within ±3 °C [±5 °F] and the required relative humidity level to within ±3 %. Chamber conditions shall be monitored either on an automated continuous basis or on a manual basis at regular intervals.

7.9 *Environmental Test Chamber*—An environmental test chamber is required for test environments other than ambient testing laboratory conditions. This chamber shall be capable of maintaining the gauge section of the test specimen at the required test environment during the mechanical test within ±3 °C [±5 °F].

7.10 *Strain-Indicating Device*—Strain data, when required, shall be determined by means of bonded resistance strain gauges.

7.10.1 *Bonded Resistance Strain Gauge Selection*—Strain gauge selection is based on the type of material to be tested. A minimum active gauge length of 3 mm [0.125 in.] is recommended for composite laminates fabricated from unidirectional layers. Larger strain gauge sizes may be more suitable for some textile fabrics. Gauge calibration certification shall comply with Test Method E251. Strain gauges with a minimum normal strain range of approximately 3 % are recommended. When testing textile fabric laminates, gauge selection should consider the use of an active gauge length that is at least as great as the characteristic repeating unit of the fabric. Some guidelines on the use of strain gauges on composite materials follow.

7.10.1.1 Surface preparation of fiber-reinforced composites in accordance with Guide E1237 can penetrate the matrix material and cause damage to the reinforcing fibers, resulting in improper coupon failures. Reinforcing fibers should not be exposed or damaged during the surface preparation process. The strain gauge manufacturer should be consulted regarding surface preparation guidelines and recommended bonding agents for composites, pending the development of a set of standard practices for strain gauge installation surface preparation of fiber-reinforced composite materials.

7.10.1.2 Consideration should be given to the selection of gauges having larger resistances to reduce heating effects on low conductivity materials. Resistances of 350 Ω or higher are preferred. Additional consideration should be given to the use of the minimum possible gauge excitation voltage consistent with the desired accuracy (1 V to 2 V is recommended) to reduce the power consumed by the gauge. Heating of the coupon by the gauge may affect the performance of the material directly or it may affect the indicated strain as a result of a difference between the gauge temperature compensation factor and the coefficient of thermal expansion of the coupon material.

7.10.1.3 Consideration of some form of temperature compensation is recommended, even when testing at standard laboratory atmosphere. Temperature compensation may be required when testing in non-ambient temperature environments.

7.10.1.4 Consideration should be given to the transverse sensitivity of the selected strain gauge. The strain gauge