



Designation: D578/D578M – 05 (Reapproved 2011)<sup>ε1</sup>

## Standard Specification for Glass Fiber Strands<sup>1</sup>

This standard is issued under the fixed designation D578/D578M; 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 ( $\epsilon$ ) 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.*

<sup>ε1</sup> NOTE—Editorial changes were made throughout in August 2011.

### 1. Scope

1.1 This specification covers the requirements for continuous fiber and staple fiber glass strands, including single, plied and multiple wound. It also covers textured glass fiber yarns. This specification is intended to assist ultimate users by designating the general nomenclature for the strand products that are generally manufactured in the glass fiber industry.

1.2 Glass fibers are produced having various compositions. General applications are identified by means of a letter designation. The letter designation represents a family of glasses that have provided acceptable performance to the end-user in the intended application. For example, the composition limits stated for E-Glass in this specification representing the glass fiber family for general and most electrical applications is designated by the letter *E*. Military specifications, such as, MIL-R-60346, recognize the composition limits described in this specification as meeting the respective requirements for E-Glass strands used in reinforced plastic structure applications.

1.3 Glass fiber strands have a variety of general uses under specific conditions, such as high physical or chemical stress, high moisture, high temperature, or electrical environments. Property requirements under specific conditions are agreed upon between the purchaser and the supplier. Electrical property requirements vary with specific end-use applications. For printed circuit board applications, other requirements may be needed such as the use of Institute for Interconnecting and Packaging Electronic Circuits (IPC) Specification EG 4412 A for finished fabric woven from E-Glass for printed circuit boards, or Specification MIL-P-13949 for printed wiring boards applicable to glass fabric base.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in

each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 This specification is one of a series to provide a substitute for Military Specifications: MIL-Y-1140 Yarn, Cord, Sleeving, Cloth and Tape-Glass; and MIL-C-9084 Cloth, Glass Finished for Resin Laminates.

1.6 Additional ASTM specifications in this series have been drafted and appear in current editions of the *Annual Book of ASTM Standards*. These include finished glass fabrics, unfinished glass fabrics, glass tapes, glass sleeveings, glass cords, glass sewing threads, and finished laminates made from finished glass fabrics.

1.7 *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*:<sup>2</sup>

D123 Terminology Relating to Textiles

D1423 Test Method for Twist in Yarns by Direct-Counting

D1907 Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

D2256/D2256M Test Method for Tensile Properties of Yarns by the Single-Strand Method

D2258 Practice for Sampling Yarn for Testing

D2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data (Withdrawn 2008)<sup>3</sup>

D2906 Practice for Statements on Precision and Bias for Textiles (Withdrawn 2008)<sup>3</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D13 on Textiles and is the direct responsibility of Subcommittee D13.18 on Glass Fiber and its Products.

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<sup>2</sup> 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.

<sup>3</sup> The last approved version of this historical standard is referenced on www.astm.org.

[D4963 Test Method for Ignition Loss of Glass Strands and Fabrics](#)

[D7018 Terminology Relating to Glass Fiber and Its Products](#)

2.2 *ASTM Adjunct:*

[TEX-PAC<sup>4</sup>](#)

2.3 *ANSI Standard:*

[ANSI/ASQC Z1.4 Sampling Procedures for Inspection by Attributes<sup>5</sup>](#)

2.4 *Military Standards and Specifications:*

[MIL-P-13949 Specification for Plastic Sheet, Laminated, Metal-Clad For Printed Wiring Board<sup>6</sup>](#)

[MIL-R-60346 Roving, Glass Fibrous \(for Prepreg Tape, Rovings, Filament Winding, and Pultrusion Applications\)<sup>6</sup>](#)

[MIL-G-55636B Glass Cloth, Resin Preimpregnated \(B-STAGE\) \(For Multilayer Printed Wiring Boards\)<sup>6</sup>](#)

[MIL-Y-1140 Specification for Yarn, Cord, Sleeving, Cloth, and Tape-Glass<sup>6</sup>](#)

[MIL-C-9084 Specification for Cloth Finished for Resin Laminates<sup>6</sup>](#)

2.5 *Institute for Interconnecting and Packaging Circuits Standard:*

[IPC EG 4412 A Specification for Finished Fabric Woven from E-Glass for Printed Circuit Boards<sup>7</sup>](#)

### 3. Terminology

3.1 For all terminology related to D13.18, Glass Fiber and Its Products, see Terminology [D7018](#).

3.1.1 The following terms are relevant to this standard: atmosphere for testing textiles, chopped strand, continuous filament yarn, roving, staple glass yarn, strand, textured glass yarn.

3.2 For all other terminology related to textiles, refer to Terminology [D123](#).

### 4. Classification of Glass Fiber

4.1 “C” Glass—A family of glasses composed primarily of the oxides of sodium, calcium, boron, aluminum, and silicon with a certified chemical composition which conforms to an applicable material specification and which produces good acid resistance (excluding HF).

4.2 “E” Glass—A family of glasses composed primarily of the oxides of calcium, aluminum, and silicon, which has the following certified chemical compositions.

4.2.1 The following certified chemical composition applies to glass fiber yarn products for printed circuit boards and aerospace.

Chemical	% by Weight
B <sub>2</sub> O <sub>3</sub>	5 to 10
CaO	16 to 25

<sup>4</sup> PC programs on floppy disk for analyzing Committee D13 interlaboratory data are available through ASTM. Request [ADJD2904](#).

<sup>5</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>7</sup> Available from Institute for Interconnecting and Packaging Electronic Circuits, 7380 N. Lincoln Ave., Lincolnwood, IL 60646.

Al <sub>2</sub> O <sub>3</sub>	12 to 16
SiO <sub>2</sub>	52 to 56
MgO	0 to 5
Na <sub>2</sub> O and K <sub>2</sub> O	0 to 2
TiO <sub>2</sub>	0 to 0.8
Fe <sub>2</sub> O <sub>3</sub>	0.05 to 0.4
Fluoride	0 to 1.0

4.2.2 The following certified chemical composition applies to glass fiber products used in general applications.

Chemical	% by Weight
B <sub>2</sub> O <sub>3</sub>	0 to 10
CaO	16 to 25
Al <sub>2</sub> O <sub>3</sub>	12 to 16
SiO <sub>2</sub>	52 to 62
MgO	0 to 5
Total alkali metal oxides	0 to 2
TiO <sub>2</sub>	0 to 1.5
Fe <sub>2</sub> O <sub>3</sub>	0.05 to 0.8
Fluoride	0 to 1.0

4.2.3 Electrical applications include a wide variety of uses. The composition in [4.2.1](#) is identical to IPC EG 4412 A for printed circuit boards and to MIL-G-55636B. Additionally, such fiber glass products often are specified for aerospace applications. Products covered by the composition range in [4.2.2](#) are used in general applications, such as power company equipment, high voltage devices, residential electric boxes, third rail covers, high voltage standoff rods, electrical pultrusion products, light poles, electrical tool covers, and electrical tape. Other applications include roofing, flooring, filtration, panel rovings, gun rovings, smc rovings, chopped strand reinforcements, paper yarns, and industrial yarns.

4.2.4 The nomenclature “E-CR-Glass” is used for boron-free modified E-Glass compositions for improved resistance to corrosion by most acids.

4.3 “S” Glass—A family of glasses composed primarily of the oxides of magnesium, aluminum, and silicon with a certified chemical composition which conforms to an applicable material specification and which produces high mechanical strength.

4.4 “R” Glass—A family of boron-free glasses composed primarily of the oxides of silicon, aluminum, calcium and magnesium, such glasses possessing excellent acid and water durability as well as specific strength and specific modulus levels significantly greater than E glass.

## DESCRIPTION OF GLASS STRANDS

### 5. General

5.1 The construction of glass strands is described in a series of two to four segments of alphabetical or numerical characters.

NOTE 1—In glass fiber strand designations, and in the conversion of yards per pound to tex units, the following rules are used:

- (1) less than 2.50 tex—round to nearest 0.01 tex
- (2) 2.50 tex to less than 5.00 tex—round to nearest 0.05 tex
- (3) 5.00 tex to less than 10.0 tex—round to nearest 0.1 tex
- (4) 10.0 tex to less than 250 tex—round to nearest 1.0 tex
- (5) 250 tex to less than 2000 tex—round to nearest 5.0 tex
- (6) 2000 tex to less than 100 000 tex—round to nearest 100 tex

5.1.1 For strands described in inch-pound units, the approximate yards per pound of the final strand can be computed by

multiplying the yarn number designation of the single yarn or strand by 100 to obtain yards per pound for the single yarn or strand and then dividing by the total number of single yarns or strands in the final yarn. Actual yardage is less because of organic content and twist take-up during plying.

NOTE 2—Letter designations for filament diameter averages are shown in Table 1. The yards per pound stated in Table 2 is an approximate yarn number. The “As Received” yards per pound will be less than the bare glass values stated. This may be contributed by twist take-up, sizing percent, or purchaser agreement to produce to a lower yarn number to meet other requirements for a further manufactured product, or both. For example, EC9 66 1×0 (ECG 75 1/0) stated at approximately 66 tex [7500 yd/lb] will actually be about 68 tex [7300 yd/lb] in the delivered state for use in the electrical laminate industry.”

## 6. Continuous Filament Yarns

6.1 *Descriptions of Continuous Filament Yarns*—The description of continuous filament yarns consists of the following four segments:

Segment 1	Segment 2	Segment 3	Segment 4
Glass family	Yarn number	Construction	Twist level
Fiber form			Twist direction
Fiber diameter			

6.1.1 *Segment One*—The parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, “C” for Continuous, and a symbol for average filament diameter range as directed in Table 1.

6.1.2 *Segment Two*—The second segment of the description of continuous filament yarns specifies the yarn number of the single yarn. For yarns described in SI units, the yarn number is specified in tex. For yarns described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is yards per pound divided by 100.

6.1.2.1 Some manufacturing processes are designed specifically to produce yarns consisting of hollow filaments. For these yarns, the suffix HF is attached to the second segment of the yarn description. For example, 40 HF (125HF) represents a 40 tex [125 × 100 yd/lb] single yarn consisting of hollow filaments.

6.1.3 *Segment Three*—The third segment of the description of continuous filament yarns specifies the number of single yarns in the complete yarn. For yarn described in SI units, the description consists of a count of the single yarns twisted together, a lower case multiplication sign or *x*, and a count of the twisted yarns plied together to form the final yarn. For yarns described in inch-pound units, the description consists of a count of the singles yarns twisted together, a division sign or “/”, and a count of the twisted yarns plied together to form the final yarn.

NOTE 3—If additional stages of plying are involved, a lower case multiplication sign for SI units or a diagonal for inch-pound units, followed by the count of plied yarns being cabled is added for each additional cabling step. The total single yarns in the final yarn will always be the product of all the counts in this segment. When 0 (zero) appears as a count it is considered as 1 (one) for multiplication purposes.

6.1.4 *Segment Four*—The fourth segment of the description of continuous filament yarns specifies the twist level and direction. For yarns described in SI units, the description consists of an *S* or *Z* to show direction of twist immediately followed by the twist level in turns per metre (tpm) to the

nearest 1 tpm. For yarns described in inch-pound units, the description consists of the twist level in turns per inch (tpi) to the nearest 0.1 tpi immediately followed by an *S* or *Z* to show direction of twist.

NOTE 4—Twist in turns per metre (tpm) equals twist in turns per inch (tpi) times 40. The exact factor 39.37 is rounded to 40 to obtain the twist in turns per metre to the nearest 1 tpm when starting from turns per inch to the nearest 0.1 tpi.

### 6.2 Examples of Descriptions of Continuous Filament Yarns:

6.2.1 *Example 1a, Singles Yarn Using SI Units*—The description of a singles continuous filament yarn using SI units might be:

EC6 33 1 × 0 Z40

where:

- E = symbol for glass family used in general and most electrical applications,
- C = symbol for continuous filament yarn,
- 6 = symbol for filament diameter average range 5.50 to 6.49 μm,
- 33 = nominal yarn number of single yarn, tex,
- 1×0 = one single yarn twisted without plying or cabling, and
- Z40 = a twist level of 40 tpm in the “Z” direction.

The nominal yarn number in tex of the final yarn will be approximately 33 since there is only one strand in the final yarn.

6.2.2 *Example 1b, Singles Yarn Using Inch-Pound Units*—The description of a singles continuous filament yarn using inch-pound units might be:

ECDE 150 1/0 1.0Z

where:

- E = symbol for glass family used in general and most electrical applications,
- C = symbol for continuous filament yarn,
- DE = symbol for filament diameter average range 0.00023 to 0.000269 in.,
- 150 = nominal yarn number of single yarns in hundreds of yards per pound [yd/lb],
- 1/0 = one single yarn twisted without plying or cabling, and
- 1.0Z = a twist level of 1.0 tpi in the “Z” direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 15 000 since there is only one strand in the final yarn.

6.2.3 *Example 2a, Plied Yarn Using SI Units*—The description of a plied continuous filament yarn using SI units might be:

EC9 33 2 × 2 S15Z

where:

- E = symbol for glass family used in general and most electrical applications,
- C = symbol for continuous filament yarn,
- 9 = symbol for filament diameter average range 8.50 to 9.49 μm,

- 33 = nominal yarn number of single yarns, tex,  
 2×2 = two single yarns twisted together and two such  
 yarns plied together, and  
 S152 = a twist level of 152 tpm in the “S” direction.

The nominal yarn number in tex of the final yarn will be approximately 132 or four times 33 tex.

6.2.4 *Example 2b, Plied Yarn Using Inch-Pound Units*—The description of a plied continuous filament yarn using inch-pound units might be:

ECG 150 2/2 3.8S

where:

- E* = symbol for glass family used in general and most electrical applications,  
*C* = symbol for continuous filament yarn,  
*G* = symbol for filament diameter average range 0.00035 to 0.000399 in.,  
 150 = nominal yarn number of single yarns in hundreds of yards per pound,  
 2/2 = two single yarns twisted together and two such yarns plied together, and  
 3.8S = a twist level of 3.8 tpi in the “S” direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 3750 or 150 hundreds of yards per pound divided by four.

## 7. Discontinuous or Staple Filament Yarns

7.1 *Descriptions of Discontinuous or Staple Filament Yarns*—If SI units are used, the description of yarns made from staple fibers contains four segments and the fiber form is designated “D” for discontinuous. If inch-pound units are used, the description of yarns made from staple fibers contains three segments and the fiber form is designated “S” for staple.

7.1.1 The four segments in a description of yarns made from discontinuous fibers when using SI units are:

Segment 1	Segment 2	Segment 3	Segment 4
Glass family	Yarn number	Construction	Twist level
Fiber form			Twist direction
Fiber diameter			

7.1.1.1 *Segment One*—For yarns made from discontinuous filaments and described in SI units, the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, “D” for discontinuous; and a numeric symbol for filament diameter as directed in Table 1.

7.1.1.2 *Segment Two*—For yarns made from discontinuous filaments and described in SI units, the second segment of the description of discontinuous filament yarns specifies the yarn number of the single yarn in tex.

7.1.1.3 *Segment Three*—For yarns made from discontinuous filaments and described in SI units, the third segment of the description of discontinuous filament yarns specifies the number of single yarns in the complete yarn. The description consists of the following with no intervening spaces: (1) a count of the singles yarns twisted together, (2) a lower case multiplication sign or *x*, (3) a count of the twisted yarns plied together to form the final yarn, and (4) a symbol *R* when yarn is reinforced by a single continuous filament yarn (Note 3).

7.1.1.4 *Segment Four*—For yarns made from discontinuous filaments and described in SI units, the fourth segment of the description of discontinuous filament yarns specifies the twist level and direction. The description consists of an *S* or *Z* to show direction of twist immediately followed by the twist level in turns per metre (tpm) to the nearest 1 tpm (Note 4).

7.1.2 The three segments in a description of yarns made from staple fibers when using inch-pound units are:

Segment 1	Segment 2	Segment 4
Glass family	Yarn number ply count	Twist level
Fiber form		Twist direction
Fiber diameter		

7.1.2.1 *Segment One*—For yarns made from staple filaments and described in inch-pound units, the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for fiber form, *S* for staple; and a letter symbol for filament diameter average range as directed in Table 1.

7.1.2.2 *Segment Two*—For yarns made from staple filaments and described in inch-pound units, the second segment of the description of staple filament yarns specifies the number of singles yarn in the complete yarn. The description consists of the following with no intervening spaces: (1) the nominal yarn number of the single yarns in hundreds of yards per pound; that is, yards per pound divided by 100, (2) the divisor sign or “/”, (3) a count of the twisted yarns plied together in the final yarn, and (4) a symbol *R* when yarn is reinforced by a single continuous filament yarn. (Note 3)

7.1.2.3 *Segment Three*—For yarns made from staple filaments and described in inch-pound units, the third segment of the description of staple filament yarns specifies the twist level and direction. The description consists of the twist level in turns per inch (tpi) to the nearest 0.1 tpi immediately followed by an *S* or *Z* to show direction of twist.

7.2 *Examples of Descriptions of Staple or Discontinuous Filament Yarns Using SI Units:*

7.2.1 *Example 3a, Yarn from Discontinuous Filaments Using SI Units*—The description of a yarn made from discontinuous filament might be:

CD10 198 1 × 2 S260

where:

- C* = symbol for glass family used in acid resistant applications,  
*D* = symbol for discontinuous filament yarn,  
 10 = symbol for filament diameter average range 6.50 to 7.49 μm,  
 198 = nominal yarn number of single yarns, tex,  
 1×2 = two single yarns plied, and  
 S260 = a twist level of 260 tpm in the “S” direction.

The nominal yarn number in tex of the final yarn will be approximately 396 since two strands of 198 tex are combined in the final yarn.

7.2.1.1 If the above yarn were reinforced by a single strand of continuous filament yarn, *R* would be added to the second segment of the description to give: CD10 198R 1×2 S260 (Note 4).

7.2.2 *Example 3b, Yarn from Staple Filaments Using Inch-Pound Units*—The description of a staple filament yarn using inch-pound units might be:

CSH 25/2 6.5S

where:

- C = symbol for glass family used in acid resistant applications,
- S = symbol for staple filament yarn,
- H = symbol for filament diameter average range 0.00040 to 0.000449 in.,
- 25/2 = nominal yarn number of single yarns in hundreds of yards per pound and two such yarns plied together, and
- 6.5S = a twist level of 6.5 tpi in the “S” direction.

The nominal yarn number in yards per pound of the final yarn will be approximately 1250 or 25 hundreds of yards per pound divided by two.

7.2.2.1 If the above yarn were reinforced by a single strand of continuous filament yarn, *R* would be added to the second segment of the description to give: CSH 25/2R 6.5S (Note 4).

## 8. Textured Yarns

8.1 The description of textured yarns consist of either three or four segments.

8.1.1 *Three Segment Description of Textured Yarns*—The segments in a three segment description of textured yarns are:

Segment 1	Segment 2	Segment 3
Glass family	Yarn number	Manufacturer's code
Yarn type		
Fiber diameter		

8.1.1.1 *Segment One*—For textured yarns the parts of Segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for yarn type, *T* for textured; and a symbol for filament diameter as directed in Table 1.

8.1.1.2 *Segment Two*—The second segment of the description of textured yarns specifies the yarn number of the final yarn, not necessarily of the single yarns. For yarns described in SI units, the yarn number is specified in tex (Note 1). For yarns described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is, yards per pound divided by 100.

8.1.1.3 *Segment Three*—The third segment of the description of textured yarns specifies the manufacturer's product code.

8.1.2 *Four Segment Description of Textured Yarns*—The segments in a four segment description of textured yarns are:

Segment 1	Segment 2	Segment 3	Segment 4
Glass family	Yarn number	Construction	Manufacturer's code
Yarn type			
Fiber diameter			

8.1.2.1 *Segment One*—For textured yarns the parts of segment one are respectively the symbol for the glass family as directed in Section 4; the symbol for yarn type, *T* for textured; and a symbol for filament diameter as directed in Table 2.

8.1.2.2 *Segment Two*—The second segment of the description of textured yarns specifies the yarn number of the final yarn, not necessarily of the single yarns. For yarns described in SI units, the yarn number is specified in tex (Note 2). For yarns

described in inch-pound units, the yarn number is specified in hundreds of yards per pound, that is, yards per pound divided by 100.

8.1.2.3 *Segment Three*—The third segment of the description of textured yarns specifies the number of single yarns in the complete yarn. For yarn described in SI units, the description consists of a count of the singles yarns, a lower case multiplication sign or *x*, and a count of the single yarns fabricated together to form the final yarn. For yarns described in inch-pound units, the description consists of a count of the single yarns, a division sign or “/”, and a count of the single yarns fabricated together to form the final yarn.

8.1.2.4 *Segment Four*—The fourth segment of the description of textured yarns specifies the manufacturer's product code.

### 8.2 Examples of Descriptions of Textured Yarns:

8.2.1 *Examples 5a and 5b, Textured Yarns Using SI Units*—The description of a textured yarn using SI units might be:

Three – segment description – (ET 9 134 (Manufacturer's Code))  
 Four – segment description – (ET 9 134 1  
 × 2 (Manufacturer's Code))

where:

- E = symbol for glass family used in general and most electrical applications,
- T = symbol for textured yarn,
- 9 = symbol for filament diameter average range 0.00035 to 0.000399 in.,
- 134 = nominal yarn number, tex,
- 1×2 = one singles yarn and two such yarns fabricated together, and
- manufacturer's code = further identification as necessary by manufacturer to define process, sizing, etc.

The actual tex of the final yarn may vary and result in a higher value. This is dependent upon the yarn number of the input yarn and the degree of texture.

8.2.2 *Examples 5c and 5d, Textured Yarns Using Inch-Pound Units*—The description of a textured yarn using inch-pound units might be:

Three – segment description – (ETG 37 (Manufacturer's Code))  
 Four – segment description  
 – (ETG 37 1 / 2 (Manufacturer's Code))

where:

- E = symbol for glass family used in general and most electrical applications,
- T = symbol for textured yarn,
- G = symbol for filament diameter average range 0.00035 to 0.000399 in.,
- 37 = nominal yarn number in hundreds of yards per pound,
- 1/2 = one singles yarn and two such yarns fabricated together, and

manufacturer's code = further identification as necessary by manufacturer to define process, sizing, etc.

The actual yards per pound of the final yarn may vary and result in a lower value. This is dependent upon the yarn number of the input yarn and the degree of texture.

## 9. Rovings

9.1 *Descriptions of Rovings*—The description of rovings consists of either two or three segments.

9.1.1 *Two Segment Description for Rovings*—The segments in a two segment description of rovings are:

<i>Segment 1</i>	<i>Segment 2</i>
Product type	Yarn number

9.1.1.1 *Segment One*—For rovings, the first segment of the description of glass rovings represents the manufacturer's product type, which includes binder (sizing) and sliver (strand). It consists of number or letter designations, or both letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code may directly follow the product type, or may be separated by a space.

9.1.1.2 *Segment Two*—For rovings, the second segment of the description specifies the yarn number of the total roving. For rovings described in SI units, the yarn number is specified in tex. For such rovings described in inch-pound units, the yarn number is specified in yards per pound.

NOTE 5—Roving yield is synonymously used for yarn number of roving products in the glass fiber industry. The term yarn number is used throughout Specification D578 to represent the more universal term.

9.1.2 *Three Segment Description for Rovings*—The segments in a three segment description of rovings are:

<i>Segment 1</i>	<i>Segment 2</i>	<i>Segment 3</i>
Product type	Yarn number	Manufacturer's product code

9.1.2.1 For rovings, the first and second segments of the three segment description are as described in 9.1.1.1 and 9.1.1.2. The third segment references a manufacturer's product code and may be represented by letters or numbers, or both.

### 9.2 *Examples of Descriptions of Rovings:*

9.2.1 *Examples 6a, 6b, 6c, and 6d, Rovings Using SI Units*—The description of rovings using SI units might be:

Two – segment description – (a) 988AB 4400/(b) 998 BA 4400  
 Three – segment description – (c) 526HT 3100 1325864355/(d)  
 995AA 2350 71B68820

where:

988AB = manufacturer's product type and manufacturer's code,  
 988BA = manufacturer's product type and manufacturer's code,  
 526HT = manufacturer's product type,  
 4400 = nominal yarn number for total roving, tex,  
 3100 = nominal yarn number for total roving in tex,  
 2350 = nominal yarn number for total roving in tex, and  
 1325864355 = manufacturer's product code.  
 71B68820 = manufacturer's product code

9.2.2 *Examples 6e, 6f, 6g and 6h, Rovings Using Inch-Pound Units*—The description of rovings using inch-pound units might be:

Two – segment description – (e) 988AB 113/(f) 998BA 113  
 Three – segment description – (g) 526HT 161 1325864355/(h)  
 995AA 211 71B68820

where:

988AB = manufacturer's product type and manufacturer's product code,  
 988BA = manufacturer's product type and manufacturer's product code,  
 526HT = manufacturer's product type,  
 113 = nominal yarn number for total roving, yd/lb,  
 161 = nominal yarn number for total roving, yd/lb,  
 1325864355 = manufacturer's product code, and  
 71B68820 = manufacturer's product code.

9.3 It is customary for producers of glass fiber rovings to indicate the compatibility of the binder (sizing) applied to the rovings to the matrix resins in which they can be used.

9.3.1 The designation shall follow the form "[matrix resin] compatible."

9.3.2 Examples of this designation would be "epoxy compatible" or "polyester compatible."

9.3.3 The resin compatibility is not part of the three segment description outlined in 9.1.2, but is available upon request from the manufacturer of the roving.

NOTE 6—Discontinued MIL-R-60346 referred to the resin compatibility by the term "Class 1" for epoxy compatible rovings and "Class 2" for polyester compatible rovings.

## 10. Chopped Strand from Continuous Filament Strands

10.1 *Descriptions of Chopped Strand from Continuous Filament Strands*—The description of chopped strand from continuous filament strands consists of either two, three, or four segments. For chopped strand used to reinforce thermoplastic and thermosetting plastic compounds, the description consists of two segments. For dry sized glass chopped strand, the description consists of three segments. For wet sized glass chopped strand, the description consists of four segments.

10.1.1 *Two Segment Description for Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds*—The segments in a description for chopped strand used to reinforce thermoplastic and thermosetting compounds are:

<i>Segment 1</i>	<i>Segment 2</i>
Product type	Strand length

10.1.1.1 *Segment One*—The first segment of the description of chopped strand used to reinforce thermoplastic and thermosetting compounds represents the manufacturer's product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the product type.

10.1.1.2 *Segment Two*—The second segment of the description of chopped strand used to reinforce thermoplastic and thermosetting compounds specifies the length of the chopped strand. For chopped strands described in SI units, the nominal

chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.1.2 *Three Segment Description for Dry Sized Chopped Strand*—The segments in a description of dry chopped strand are:

Segment 1	Segment 2	Segment 3
Filament diameter	Sizing or product type	Strand length

10.1.2.1 *Segment One*—The first segment of the description of dry sized chopped strand represents the nominal filament diameter range. When using SI units, this segment consists of a number specifying the nominal filament diameter range in micrometers as directed in Table 1. When using inch pound units, this segment consists of one or two letters as directed in Table 1.

10.1.2.2 *Segment Two*—The second segment of the description of dry sized chopped strand represents the manufacturer's sizing or product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the sizing or product type.

10.1.2.3 *Segment Three*—The third segment of the description of dry sized chopped strand specifies the length of the chopped strand. For chopped strands described in SI units, the nominal chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.1.3 *Four Segment Description for Wet Sized Chopped Strand*—The segments in a description of wet chopped strand are:

Segment 1	Segment 2	Segment 3	Segment 4
Filament diameter	Sizing or product type	Moisture content	Strand length

10.1.3.1 *Segment One*—The first segment of the description of wet sized chopped strand represents the nominal filament diameter range. When using SI units, this segment consists of a number specifying the nominal filament diameter range in micrometres as directed in Table 1. When using inch-pound units, this segment consists of one or two letters as directed in Table 1.

10.1.3.2 *Segment Two*—The second segment of the description of wet sized chopped strand represents the manufacturer's sizing or product type. It consists of numbers that are sometimes followed by letter designations, or both, letter and number designations that reference the manufacturer's code. The designation for the manufacturer's code will directly follow the product type.

10.1.3.3 *Segment Three*—The third segment of the description of wet sized chopped strand specifies the nominal percent moisture content. This segment consists of a number representing the percent moisture content in both SI units and inch pound units.

NOTE 7—Some manufacturers omit this segment when describing wet sized chopped strand.

10.1.3.4 *Segment Four*—The fourth segment of the description of wet sized chopped strand specifies the length of the chopped strand. For chopped strands described in SI units, the

nominal chopped length is specified in millimetres. For chopped strands described in inch-pound units the nominal chopped length is specified in inches.

10.2 *Examples of Descriptions of Chopped Strands:*

10.2.1 *Example 7a, Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds Using SI Units*—The description of chopped strand used to reinforce thermoplastic and thermosetting compounds using SI units might be:

405AB 13 mm

where:

405AB = manufacturer's product type and process code, and  
13 = length, mm.

10.2.2 *Example 7b, Dry Sized Chopped Strand Using SI Units*—The description of dry sized chopped strand using SI units might be:

9 μm 685 13 mm

where:

9 = symbol for filament diameter average range 8.50 to 9.49 μm,  
685 = manufacturer's sizing code or process code, or both, and  
13 = length, mm.

10.2.3 *Example 7c, Wet Sized Chopped Strand Using SI Units*—The description of wet sized chopped strand using SI units might be:

16 μm 775 14.5 32 mm

where:

16 = symbol for filament diameter average range 15.5 to 16.49 μm,  
775 = manufacturer's sizing code or process code, or both,  
14.5 = moisture content, % (Note 7), and  
32 = length, mm.

10.2.4 *Example 7d, Chopped Strand Used to Reinforce Thermoplastic and Thermosetting Compounds Using Inch-Pound Units*—The description of chopped strand used to reinforce thermoplastic and thermosetting compounds using inch-pound units might be:

405AB ½ in.

where:

405AB = manufacturer's product type and process code, and  
½ = length, in.

10.2.5 *Example 7e, Dry Sized Chopped Strand Using Inch-Pound Units*—The description of dry chopped strand using inch-pound units might be:

G685 ½ in.

where:

G = symbol for filament diameter average range 0.00035 to 0.000399 in.,

685 = manufacturer's sizing code or process code, or both, and  
 ½ = length, in.

10.2.6 *Example 7f, Wet Sized Chopped Strand Using Inch-Pound Units*—The description of wet sized chopped strand using inch-pound units might be:

M 775 14.5 1¼ in.

where:

M = symbol for filament diameter average range 0.00060 to 0.000649 in.  
 775 = manufacturer's sizing code or process code, or both,  
 14.5 = moisture content, %, and  
 1¼ = length, in.

## 11. Ordering Information

11.1 The purchase order or other agreement shall specify: specification conformance number, title, and year of issue; designation of strand construction; product quantity; and any special provisions.

## REQUIREMENTS

### 12. Material

12.1 The fibers shall be free of any free alkali metal oxides, such as soda or potash, and from foreign particles, dirt, and other impurities. The glass classification shall be agreed upon between the purchaser and the supplier in an applicable material specification or other agreement. The composition of the E-Glass classification of glass fiber shall be within the limits specified in 4.2.1 or 4.2.2 as agreed upon between the purchaser and supplier.

### 13. Workmanship

13.1 As agreed upon between the purchaser and the supplier, the defects listed in Table 3 shall be considered cause for rejection of the package in which they occur. The allowable quality level (AQL) shall be agreed upon between the purchaser and the supplier.

### 14. Physical Properties

14.1 The nominal and physical properties of glass fiber strands shall conform to the requirements of Tables 1, 2, 4, and 5, as applicable. The tolerances shall be subject to the tolerances as agreed upon between the purchaser and the supplier. However, the following maximum tolerances apply:

14.1.1 *Yarn Number, Tex [Yards per Pound], Individual Value*—Plus or minus 10 % for continuous filament yarns. Plus or minus 20 % for discontinuous or staple yarns. Plus or minus 15 % for textured yarns. Plus or minus 8.5 % for roving produced by either conventional or nonconventional roving winding processes, except certain rovings produced by other than conventional winding processes shall have a ±13 % tolerance when agreed upon between the purchaser and the supplier.

NOTE 8—Historically, it has been conventional practice to attenuate glass through bushings having 204 or 408 holes to produce strands containing those numbers of filaments. Then, rovings were made from

those strands having 1, 12, 15, 20, 30, and 60 ends. Although this practice is still used by some suppliers, others are attenuating fiber glass through bushings consisting of up to several thousand holes to make heavy rovings containing only a single strand. Since the strands are not twisted, rovings made with the larger single strands are equivalent, for most purposes, to those made with the smaller conventional made multiple strands. Since many older material specifications specify in accordance with the older multiple strand designation, a purchasing activity should review and agree upon with the supplier activity, the acceptability of the single strand roving having an equivalent yarn number.

14.1.1.1 The tex [yards per pound] as determined in Section 23 and specified in Tables 2, 4, and 5 are the bare glass nominal. A commercial yarn normally has a size (binder) treatment which will increase tex [decrease yards per pound] in proportion to the amount of size.

14.1.2 *Breaking Strength*—No individual break shall be less than the specified minimum requirement in Tables 2, 4, and 5.

14.2 When required for roving and chopped strand, the nominal and physical properties shall be agreed upon between the purchaser and the supplier in an applicable material specification or other agreement, subject to the requirements of Table 2 and 14.1.1.

### 15. Ignition Loss (Organic Content)

15.1 The ignition loss (organic content) shall be within the tolerances as agreed upon between the purchaser and the supplier, or as specified in an applicable material specification or other agreement.

### 16. Packaging

16.1 The glass fiber strand shall be put up on packages, and in containers whose dimensions shall be agreed to between the purchaser and supplier.

16.2 Each package of strand, put up as specified, shall be further packaged to afford adequate protection against physical damage during shipment from the supply source to the receiving activity. The supplier may use his standard practice when it meets this requirement.

16.3 For government procurement, the contracting instrument shall specify the put up (see 11.1) and AQL (see 13.1).

### 17. Marking

17.1 Each package of strand shall be marked to show the construction designation of the glass fiber strand as specified in Sections 5 – 10. Each container of packages shall be marked as agreed upon between the purchaser and supplier.

### 18. Sampling, Inspection, and Number of Specimens

18.1 *Lot Size*—A lot shall consist of each shipment, date code, or consignment of a single strand designation. This may constitute all or part of any one customer order. The lot size is the total number of packages of strand in the incoming shipment date code, or consignment.

NOTE 9—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between packages of strand and between test specimens from a package of strand to produce a sampling plan with meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.



18.2 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of shipping units specified in Practice **D2258**. Consider shipping cases or other shipping units to be the primary sampling units.

18.3 *Laboratory Sample*—As a laboratory sample for acceptance testing, take at random from each shipping unit in the lot sample the number of packages or ends directed in **18.3.1** and **18.3.2**. Preferably, the same number of packages should be taken from each shipping unit in the lot sample. If differing numbers of packages are to be taken from shipping units in the lot sample, determine at random which shipping units are to have each number of packages drawn.

18.3.1 *Workmanship*—Take at random the number of packages or ends of strand as directed in ANSI/ASQC Z1.4. Select an acceptable quality level (AQL) that is agreeable to both the purchaser and the supplier.

18.3.2 *Other Properties*—Take at random the number of bobbins or packages of strand specified in Table 6.

18.4 *Test Specimens*—Proceed as follows:

18.4.1 *Workmanship*—Use the packages of strand in the laboratory sample as the specimens. Evaluate the results of inspecting the specimens using ANSI/ASQC Z1.4, normal inspection, and an acceptable quality level agreed upon between the purchaser and the supplier.

18.4.2 *Other Properties*—Take the number of specimens per laboratory sampling unit specified in the applicable test method.

## TEST METHODS

### 19. Conditioning

19.1 Condition the laboratory samples without preconditioning for a period of at least 5 h in the atmosphere for testing glass textiles, unless otherwise specified.

### 20. Material

20.1 Upon prior agreement, accept the supplier's certification that the material is of the correct family of glass fiber as specified in Section 4. Verify that the fiber is the specified filament type during testing for strand construction as directed in Section 22. Determine the freedom from undesirable impurities during inspection for workmanship as directed in Section 21.

### 21. Workmanship

21.1 Examine the outer surface of each package of strand in the laboratory sample by counting the defects listed in Table 3 regardless of their proximity to one another, except where two or more defects represent a single local condition. In such cases, count only the most serious defect.

### 22. Strand Construction

22.1 Verify the number of single strands and the number of plied or cabled strands on each package of strand in the laboratory sample while determining the twist direction or twist level as directed in Section 24 or 25.

### 23. Yarn Number

23.1 Determine the yarn number of bare glass yards per pound as directed in Test Method **D1907**, Option 1, excluding preconditioning.

23.1.1 Prior to conditioning, place the skein in a muffle furnace and heat to  $625 \pm 25^\circ\text{C}$  [ $1157 \pm 45^\circ\text{F}$ ] for 15 min.

23.2 *Calculations:*

23.2.1 Calculate the yards per pound from the length and average mass of the specimens using **Eq 1** or **Eq 2**:

$$Y = (453.6 \times L)/A \quad (1)$$

$$Y = (7000 \times L)/B \quad (2)$$

where:

$Y$  = yarn number, yd/lb,  
 $L$  = specimen length, yd,  
 $A$  = average mass of specimens, g, and  
 $B$  = average mass of specimens, grains.

23.2.2 Calculate the tex equivalents using **Eq 3** and **4**:

$$\text{Tex} = A/(0.0009144L) \quad (3)$$

$$\text{Tex} = 496055/Y \quad (4)$$

where:

$A$  = average mass of specimens, g,  
 $L$  = specimen length, yd, and  
 $Y$  = yarn number, yd/lb.

23.2.3 Calculate the yarn construction designation using **Eq 5**:

$$YC = \frac{Y}{100} \quad (5)$$

where:

$YC$  = yarn number, hundreds of yd/lb, and  
 $Y$  = yarn number, yd/lb.

### 24. Direction of Twist

24.1 Verify the direction of twist in each laboratory sampling unit as directed in Test Method **D1423**.

### 25. Twist Level

25.1 Determine the twist level in each laboratory sampling unit as directed in Test Method **D1423**.

### 26. Filament Diameter

26.1 *Scope*—This test method covers the determination of the average diameter of textile glass fibers by the microprojector method.

26.2 *Significance and Use:*

26.2.1 The microprojection procedure for testing glass fibers is considered satisfactory for acceptance testing of commercial shipments. In cases of disagreement arising from differences in values reported by the purchaser and supplier when using this method for acceptance testing, the statistical bias, if any, between the laboratories of the purchaser and the supplier shall be determined with each comparison being based on testing specimens randomly drawn from one sample of material of the type being evaluated.

### 26.3 Apparatus:

26.3.1 *Microprojector*, equipped with mechanical stage, controls, screen, and optics to provide a magnification of 1000 $\times$ .

26.3.2 *Scale*, with divisions that can be read to fiber diameter values of 0.254  $\mu\text{m}$  [ $10^{-5}$  in.].

26.3.3 *Magnifier*.

26.3.4 *Scissors*.

26.3.5 *Pick Needles*.

26.3.6 *Glass Slides*, 25 by 76 mm [1 by 3 in.].

26.3.7 *Square Cover Glasses*, 22 mm [ $7/8$  in.].

26.3.8 *Mounting Mediums*, that at 25°C [77°F], one has a refractive index of 1.600 to 1.6008 for E-Glass Fiber and a second has a refractive index of  $1.470 \pm 0.0002$  for S-2 Glass.

### 26.4 Procedure:

26.4.1 *Mounting and Measuring Fibers*—Place one drop of mounting medium in the middle of a 25 by 76-mm [1 by 3-in.] slide. Select a test specimen of about 75 fibers. Immerse the tips of the fibers in the mounting medium and separate the fibers with pick needles or similar tool. Arrange them approximately parallel to each other on the glass slide. A binocular microscope or a magnifier may facilitate this separation. Place one edge of the cover glass in contact with the slide and allow it to settle slowly to facilitate the removal of air bubbles.

26.4.1.1 For E-Glass Fiber, use a mounting medium having a refractive index on 1.600 to 1.6008 and for S-2 Glass, use a mounting medium having a refractive index on  $1.470 \pm 0.0002$  at 25°C [77°F].

NOTE 10—If the filaments will not separate due to excessive binder, or type binder, or organic compounds are affecting the measurement of the diameter of the filaments, the test specimen should be burned off as directed in Section 23.

26.4.2 *Manipulation of the Microprojector*—Insert the prepared slide in the mechanical stage of the microprojector. Slowly and carefully focus the fibers by adjusting the position of the light source, moving the condenser, regulating the aperture and field diaphragms, and manipulating the adjustment to provide optimum illumination, freedom of aberrations, and maximum resolution of the projected image of the fiber (edges should be black lines of minimum width—failure to do this will definitely impact preciseness).

26.4.3 *Measurement of Filament Diameter*—Begin at the left edge of the mount and measure the diameter of each fiber, which is clearly defined, as it is brought into the field of view by traversing the stage. Restrict the area of measurement to that part of the fiber which appears within the middle of the field. Place the zero line of the scale so that it just touches the left edge of the fiber image, and observe where the extreme right edge of the image crosses the scale ruling. Read the diameter to the nearest 0.25  $\mu\text{m}$  [ $10^{-5}$  in.] and average for the laboratory sampling unit and for the lot.

26.4.4 *Number of Measurements*—Measure a total of 50 fibers per specimen.

26.5 *Report*—Report that the test for fiber diameter was made as directed in Section 26 of Specification D578. Describe the material or product sampled and the method of sampling.

Report the average filament diameter for each laboratory sampling unit and for the lot.

### 26.6 Precision and Bias:

26.6.1 *Summary*—Based upon limited information from one laboratory, the single-operator and within-laboratory components of variation and critical differences shown in Tables 7 and 8 are approximate. These tables are constructed to illustrate what one laboratory found when all the observations were taken by the same well-trained operator using the same piece of equipment and specimens randomly drawn from the sample of material. For this laboratory, in comparing two averages, the differences should not exceed the single-operator precision values shown in Table 8 for the respective number of tests in 95 out of 100 cases. Differences for other laboratories may be larger or smaller. The number of laboratories available to perform the procedures in this test method has diminished over the last few years. If additional laboratories are identified to perform these tests, between-laboratory precision can be established.

26.6.2 *Single-laboratory Test Data*—A single-laboratory test was run in 1991 in which a randomly drawn sample of 600 denier glass fiber strand was selected and four slides prepared, two by each of two different operators. Two operators in the laboratory each measured 60 specimens from each of the four prepared slides using the fiber diameter test method in Specification D578. Thirty of the sixty fibers from each slide were measured on one day and thirty specimens from each slide were measured on a second day for a total of 240 measurements. Analysis of the data was conducted using Practice D2904, Practice D2906, and Adjunct TEX-PAC. The components of variance for fiber diameter of glass fiber strands expressed as standard deviations were calculated to be the values listed in Table 7.

26.6.3 *Precision*—Since tests were conducted in only one laboratory, estimates of between laboratory precision may be either underestimated or overestimated to a considerable extent and should be used with special caution. Before a meaningful statement can be made about two specific laboratories, the amount of statistical bias, if any, between them must be established, with each comparison being based on recent data obtained on specimens taken from a lot of material of the type being evaluated so as to be as nearly homogeneous as possible and then randomly assigned in equal numbers to each of the laboratories. However, when agreed upon between the contractual parties, for the approximate components of variance reported in Table 7, two averages of observed values may be considered significantly different at the 95 % probability level if the difference equals or exceeds the critical differences listed in Table 8, for fiber diameter of glass fiber strands.

26.6.4 *Bias*—The procedure in Specification D578 for measuring the filament diameter of glass filaments has no bias because the value of that property can be defined only in terms of a test method.

## 27. Breaking Strength

27.1 *Procedure*—Determine the breaking strength of strand as directed in Test Method D2256/D2256M, Option 1A, excluding preconditioning. Set the distance between clamps