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Standard Specification for Glass Fiber Strands[1]

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 (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

ε[1] 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 age 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 sleevings, 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:*[2]

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)[3]

D2906 Practice for Statements on Precision and Bias for Textiles (Withdrawn 2008)[3]

[1] 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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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] 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[4]
2.3 *ANSI Standard:*
ANSI/ASQC Z1.4 Sampling Procedures for Inspection by Attributes[5]
2.4 *Military Standards and Specifications:*
MIL-P-13949 Specification for Plastic Sheet, Laminated, Metal-Clad For Printed Wiring Board[6]
MIL-R-60346 Roving, Glass Fibrous (for Prepreg Tape, Rovings, Filament Winding, and Pultrusion Applications)[6]
MIL-G-55636B Glass Cloth, Resin Preimpreginated (B-STAGE) (For Multilayer Printed Wiring Boards)[6]
MIL-Y-1140 Specification for Yarn, Cord, Sleeving, Cloth, and Tape-Glass[6]
MIL-C-9084 Specification for Cloth Finished for Resin Laminates[6]
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[7]

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 allother 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_2O_3	5 to 10
CaO	16 to 25
Al_2O_3	12 to 16
SiO_2	52 to 56
MgO	0 to 5
Na_2O and K_2O	0 to 2
TiO_2	0 to 0.8
Fe_2O_3	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_2O_3	0 to 10
CaO	16 to 25
Al_2O_3	12 to 16
SiO_2	52 to 62
MgO	0 to 5
Total alkali metal oxides	0 to 2
TiO_2	0 to 1.5
Fe_2O_3	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

[4] PC programs on floppy disk for analyzing Committee D13 interlaboratory data are available through ASTM. Request ADJD2904.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[7] Available from Institute for Interconnecting and Packaging Electronic Circuits, 7380 N. Lincoln Ave., Lincolnwood, IL 60646.

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 S152

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 type Fiber diameter	Yarn number	Manufacturer's code

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 type Fiber diameter	Yarn number	Construction	Manufacturer's code

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:

Segment 1	*Segment 2*
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:

Segment 1	*Segment 2*	*Segment 3*
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*) 988*AB* 4400/(*b*) 998 *BA* 4400
Three − segment description − (*c*) 526*HT* 3100 1325864355/(*d*) 995*AA* 2350 71*B*68820

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*) 988*AB* 113/(*f*) 998*BA* 113
Three − segment description − (*g*) 526*HT* 161 1325864355/(*h*) 995*AA* 211 71*B*68820

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:

Segment 1	*Segment 2*
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 ± 25°C [1157 ± 45°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×.

26.3.2 *Scale,* with divisions that can be read to fiber diameter values of 0.254 µm [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 [⅞ 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 ± 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 ± 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 µm [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

(gage length) to 250 ± 2 mm [10 ± 0.05 in.] from nip to nip. Test five specimens per laboratory sampling unit. Use the preferred constant rate of extension (CRE) type tensile testing machine operated at a speed of 250 ± 6 mm/min [10 ± 0.25 in./min]. When agreed upon between the purchaser and the supplier, a constant rate of load (CRL) type testing machine operated at a rate of speed of loading greater than 28 mN/tex [28 gf/den.]/min or a constant rate of traverse (CRT) type testing machine operated at 300 ± 10 mm/min [12 ± 0.5 in./min] may be used. When using flat clamp faces they should be rubber faced to minimize crushing in the clamps. When test specimens continue to slip or break in the clamps, other clamp facings or protection of the test specimen within contact of the clamp faces should be employed. The test specimen preparation option described in 27.2 has been used successfully.

27.2 *Test Specimen Preparation Option*—When slippage or breakage occurs in the clamps, optionally prepare test specimens as follows:

27.2.1 *Materials:*

27.2.1.1 *White Cardboard,* sub 65 grade.

27.2.1.2 *Paint Brush,* 16 to 25 mm [0.625 to 1.0 in.] wide with bristles 25 mm [1.0 in.] long.

27.2.1.3 *Masking Tape,* 12 mm [0.5 in.] wide.

27.2.2 *Preparation:*

27.2.2.1 Lay a 250 by 330-mm [10 by 13-in.] piece of white cardboard on a flat surface. Draw two legible lines 250 ± 1 mm [10 ± 0.05 in.] from each other across the center section of the cardboard in the 75-mm [10-in.] direction. Draw an additional parallel line 25 mm [1.0 in.] outward from each previously drawn line.

27.2.2.2 Lay six test specimens on the cardboard parallel to the 330-mm [13-in.] direction approximately 25 mm [1.0 in.] apart. Secure the ends of the test specimen to the cardboard outside the previously drawn lines using pieces of 12 mm [0.5 in.] masking tape.

27.2.2.3 Uniformly apply a resin or equivalent bonding mixture[8] to ends of the test specimen between the 25-mm [1-in.] spaced lines. Do not include the center 250 mm [10 in.] between drawn lines.

27.2.2.4 Place a 25 ± 1-mm [1.0 ± 0.05-in.] strip of cardboard over the resin impregnated area of the test specimen. Allow to dry a minimum of 16 h.

NOTE 11—When a substitute mixture is used, drying time may vary.

27.2.2.5 Cut the cardboard and specimen assembly into strips without touching the test specimens.

27.2.2.6 Load the cut test specimen assembly strip in the clamps of the tensile tester having the 250-mm [10-in.] exposed portion between both clamps. Cut the cardboard backing across, midway between the ends, taking care not to damage the test specimen.

27.3 *Precision and Bias*—The precision and bias of the procedure in Specification D578 for breaking strength are as specified in Test Method D2256/D2256M.

28. Ignition Loss

28.1 Determine the ignition loss of each laboratory sampling unit as directed in Test Method D4963.

29. Packaging and Marking

29.1 During the sampling and testing of the shipment, verify the correctness of packaging and marking.

CONFORMANCE AND KEYWORDS

30. Conformance

30.1 The purchaser and the supplier shall agree on a procedure to establish conformance, including control charts furnished by the supplier, a sequential sampling plan, or double-sampling plan outlined in 30.2.

30.2 In the absence of a control chart or sequential sampling plan, proceed as directed in 30.2.1 – 30.2.3.

30.2.1 If the test results for a lot conform to the requirements for all characteristics listed in Sections 12 – 17, and Tables 1–6, the lot shall be considered acceptable.

30.2.2 If the test results for one or more characteristics do not conform to the requirements, take a new laboratory sample from either the original lot sample or a new lot sample. Test the new sample for the characteristic(s) that did not conform to the requirements in the first test and average the results of the first and second samples as if they were oner test of double the original number of specimens. If the new average(s) conform(s) to the specified requirements, the lot shall be considered acceptable.

30.2.3 If the test results obtained as directed in 30.2.2 do not conform to the specified requirements, the lot shall be considered unacceptable.

31. Keywords

31.1 breaking strength; chopped glass strand; construction designation; diameter; glass fiber; glass roving; glass strands; glass yarns; ignition loss (organic content); workmanship; yarn number

[8] A mixture by weight of 60 parts CIBA Geigy 6004 Epoxy resin and General Mills Versimid 125 polyamide resin has been found suitable for this purpose.

TABLE 1 Letter Designations for Glass Strand Filament Diameters

Filament Size Designation		Nominal Range for Filament Diameter Average	
Inch-Pound System, Letter	SI System, Number	in.	μm[A]
B	3.5	0.00013 to 0.000159	3.30 to 4.05
C	4.5	0.00016 to 0.000189	4.06 to 4.82
D	5	0.00019 to 0.000229	4.83 to 5.83
DE	6	0.00023 to 0.000269	5.84 to 6.85
E	7	0.00025 to 0.000299	6.35 to 7.61
F	8	0.00030 to 0.000345	7.62 to 8.88
G	9	0.00035 to 0.000399	8.89 to 10.15
H	11	0.00040 to 0.000449	10.16 to 11.42
J	12	0.00045 to 0.000499	11.43 to 12.69
K	13	0.00050 to 0.000549	12.70 to 13.96
L	14	0.00055 to 0.000599	13.97 to 15.23
M	16	0.00060 to 0.000649	15.24 to 16.50
N	17	0.00065 to 0.000699	16.51 to 17.77
P	18	0.00070 to 0.000749	17.78 to 19.04
Q	20	0.00075 to 0.000799	19.05 to 20.31
R	21	0.00080 to 0.000849	20.32 to 21.58
S	22	0.00085 to 0.000899	21.59 to 22.85
T	23	0.00090 to 0.000949	22.86 to 24.12
U	24	0.00095 to 0.000999	24.13 to 25.40

[A] The low values stated for each micrometre range are exact equivalents to inches, rounded to the nearest hundredth micrometre. The high values stated for each micrometre range are slightly higher than exact equivalents to inches to provide continuation between ranges. They are consistent for inch-pound and SI filament size descriptions commonly used in the industry. In some publications, the SI designation for H filament size has been shown as 10.

TABLE 2 Physical Properties of Continuous Filament Yarns

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC5 2.75 1×0	ECD 1800 1/0	20 to 40	0.5 to 1.0	...	...	2.75	180 000	1.1	0.25
EC5 2.75 1×2	ECD 1800 1/2	...	...	152 to 176	3.8 to 4.4	5.5	90 000	...	...
EC5 5.5 1×0	ECD 900 1/0	20 to 40	0.5 to 1.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	160 to 200	4.0 to 5.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	120 to 160	3.0 to 4.0	...	...	5.5	90 000	2.2	0.5
EC5 5.5 1×0	ECD 900 1/0	400	10.0	...	...	5.5	90 000	2.2	0.5
EC6 8.25	ECDE 600 1/0	20 to 40	0.5 to 1.0	...	...	8.25	60 000	3.3	0.75
EC5 5.5 1×2	ECD 900 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	11	45 000	4.9	1.1
EC5 5.5 1×2	ECD 900 1/2	...	...	340	8.5	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	20 to 40	0.5 to 1.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	40 to 80	1.0 to 2.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	80 to 120	2.0 to 3.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	160 to 200	4.0 to 5.0	...	...	11	45 000	4.9	1.1
EC5 11 1×0	ECD 450 1/0	400	10	...	...	11	45 000	...	...
EC6 16 1×0	ECDE 300 1/0	20 to 40	0.5 to 1.0	...	...	16	30 000	8.0	1.9
EC5 5.5 1×3	ECD 900 1/3	...	...	152 to 176	3.8 to 4.4	16.5	30 000	8.0	1.8
EC5 5.5 1×3	ECD 900 1/3	...	...	340	8.5	16.5	30 000	8.0	1.8
EC5 11 2×0	ECD 450 2/0	160 to 200	4.0 to 5.0	...	...	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	...	...	60	1.5	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	22	22 500	9.8	2.2
EC5 11 1×2	ECD 450 1/2	...	...	340	8.5	22	22 500	9.8	2.2
EC5 22 1×0	ECD 225 1/0	40 to 80	1.0 to 2.0	...	...	22	22 500	10.7	2.4
EC5 22 1×0	ECD 225 1/0	20 to 40	0.5 to 1.0	...	...	22	22 500	10.7	2.4
EC5 22 1×0	ECD 225 1/0	160 to 200	4.0 to 5.0	...	...	22	22 500	10.7	2.4
EC7 22 1×0	ECE 225 1/0	20 to 40	0.5 to 1.0	...	...	22	22 500	9.8	2.2
EC7 22 1×0	ECE 225 1/0	160 to 200	4.0 to 5.0	...	...	22	22 500	9.8	2.2
EC7 22 1×0	ECE 225 1/0	400	10.0	...	...	22	22 500	9.8	2.2
EC5 11 3×0	ECD 450 3/0	160 to 200	4.0 to 5.0	...	...	33	15 000	17.3	3.9
EC5 11 1×3	ECD 450 1/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	33	15 000	17.3	3.9
EC5 11 1×3	ECD 450 1/3	...	...	340	8.5	33	15 000	17.3	3.9
EC3.5 33 1×0	ECB 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	17.8	4.0
EC3.5 33 1×0	ECB 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	17.8	4.0
EC4.5 33 1×0	ECC 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	15.6	3.5
EC4.5 33 1×0	ECC 150 1/0	120 to 160	3.0 to 4.0	...	...	33	15 000	15.6	3.5
EC6 33 1×0	ECDE 150 1/0	20 to 40	0.5 to 1.0	...	...	33	15 000	15.6	3.5
EC6 33	ECDE 150	90	2.25	...	...	33	15 000	15.6	3.5

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
1×0 EC6 33	1/0 ECDE 150	120 to 160	3.0 to 4.0	...	...	33	15 000	15.6	3.5
1×0 EC9 33	1/0 ECG 150	20 to 40	0.5 to 1.0	...	...	33	15 000	13.3	3.0
1×0 EC9 33	1/0 ECG 150	40 to 80	1.0 to 2.0	...	...	33	15 000	13.3	3.0
1×0 EC9 33	1/0 ECG 150	52	1.3	...	...	33	15 000	13.3	3.0
1×0 EC9 33	1/0 ECG 150	120 to 160	3.0 to 4.0	...	...	33	15 000	13.3	3.0
1×0 EC9 33	1/0 ECG 150	224	5.6	...	...	33	15 000	13.3	3.0
1×0 EC9 33	1/0 ECG 150	280	7.0	...	...	33	15 000	13.3	3.0
1×0 EC13 40HF	1/0 ECK 125 HF	20 to 40	0.5 to 1.0	...	...	40	12 500	14.2	3.2
1×0 EC5 11	1/0 ECD 450	160 to 200	4.0 to 5.0	...	...	44	11 250	19.6	4.4
4×0 EC5 11	4/0 ECD 450	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	19.6	4.4
2×2 EC5 22	2/2 ECD 225	160 to 200	4.0 to 5.0	...	...	44	11 250	21.4	4.8
2×0 EC5 22	2/0 ECD 225	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	21.4	4.8
1×2 EC5 22	1/2 ECD 225	...	...	340	8.5	44	11 250	21.4	4.8
1×2 EC7 22	1/2 ECE 225	160 to 200	4.0 to 5.0	...	...	44	11 250	19.6	4.4
2×0 EC7 22	2/0 ECE 225	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	44	11 250	19.6	4.4
1×2 EC7 22	1/2 ECE 225	...	...	340	8.5	44	11 250	19.6	4.4
1×2 EC11 45	1/2 ECH 110	20 to 40	0.5 to 1.0	...	...	45	11 000	18.2	3.9
1×0 EC6 50	1/0 ECDE 100	20 to 40	0.5 to 1.0	...	...	50	10 000	17.8	4.0
1×0 EC6 50	1/0 ECDE 100	28	0.7	...	...	50	10 000	17.8	4.0
1×0 EC6 50	1/0 ECDE 100	80	2.0	...	...	50	10 000	17.8	4.0
1×0 EC9 50	1/0 ECG 100	20 to 40	0.5 to 1.0	...	...	50	10 000	...	...
1×0 EC8 55	1/0 ECF 90	40	1.0	...	...	55	9 000	27	6.0
1×0 EC5 11	1/0 ECD 450	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	29.4	6.6
3×2 EC5 22	3/2 ECD 225	160 to 200	4.0 to 5.0	...	...	66	7 500	32.0	7.2
3×0 EC5 22	3/0 ECD 225	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	32.0	7.2
1×3 EC7 22	1/3 ECE 225	120 to 160	3.0 to 4.0	...	...	66	7 500	29.4	6.6
3×0 EC7 22	3/0 ECE 225	160 to 200	4.0 to 5.0	...	...	66	7 500	29.4	6.6
3×0 EC7 22	3/0 ECE 225	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	66	7 500	29.4	6.6
1×3 EC3.5 33	1/3 ECB 150	80 to 120	2.0 to 3.0	...	...	66	7 500	35.6	8.0
2×0 EC3.5 33	2/0 ECB 150	120 to 160	3.0 to 4.0	...	...	66	7 500	35.6	8.0
2×0 EC3.5 33	2/0 ECB 150	...	...	112 to 152	2.8 to 3.8	66	7 500	...	...
1×2 EC6 33	1/2 ECDE 150	120 to 160	3.0 to 4.0	...	...	66	7 500	31.1	7.0
2×0 EC6 33	2/0 ECDE 150	...	...	112 to 152	2.8 to 3.8	66	7 500	...	...
1×2 EC4.5 33	1/2 ECC 150	40 to 80	1.0 to 2.0	...	...	66	7 500	47.2	10.6
2×0 EC4.5 33	2/0 ECC 150	120 to 160	3.0 to 4.0	...	...	66	7 500	33.4	7.5
2×0	2/0								

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC9 33 2×0	ECG 150 2/0	120 to 160	3.0 to 4.0	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	160 to 200	4.0 to 5.0	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	224	5.6	...	...	66	7 500	28.5	6.4
EC9 33 2×0	ECG 150 2/0	320	8.0	...	...	66	7 500	28.5	6.4
EC9 33 1×2	ECG 150 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	66	7 500	26.5	6.0
EC6 66 1×0	ECDE 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	28	0.7	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC6 66 1×0	ECDE 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	80 to 120	2.0 to 3.0	...	...	66	7 500	25.4	5.7
EC4.5 66 1×0	ECC 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	78	0.7	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	40 to 80	1.0 to 2.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	280	7.0	...	...	66	7 500	25.4	5.7
EC9 66 1×0	ECG 75 1/0	320	8.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	20 to 40	0.5 to 1.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	80 to 120	2.0 to 3.0	...	...	66	7 500	25.4	5.7
EC13 66 1×0	ECK 75 1/0	120 to 160	3.0 to 4.0	...	...	66	7 500	25.4	5.7
EC5 22 4×0	ECD 225 4/0	120 to 160	3.0 to 4.0	...	...	88	5 625	46.3	10.4
EC7 22 2×2	ECD 225 2/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	88	5 625	42.7	9.6
EC7 22 2×2	ECE 225 2/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	88	5 625	39.1	8.8
EC11 90 1×0	ECH 55 1/0	20 to 40	0.5 to 1.0	...	...	90	5 500	42.3	9.5
EC13 90 1×0	ECK 55 1/0	20 to 40	0.5 to 1.0	...	...	90	5 500	42.3	9.5
EC9 100 1×0	ECG 50 1/0	20 to 40	0.5 to 1.0	...	...	99	5 000	44.0	10.0
EC5 11 3×3	ECD 450 3/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	99	5 000	44.0	9.9
EC6 33 3×0	ECDE 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	...	...
EC6 33 1×3	ECDE 150 1/3	...	...	112 to 152	2.8 to 3.8	99	5 000	46.7	10.5
EC4.5 33 3×0	ECC 150 3/0	40 to 80	1.0 to 2.0	...	...	99	5 000	48.9	11.0
EC4.5 33 3×0	ECC 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	48.9	11.0
EC9 33 3×0	ECG 150 3/0	120 to 160	3.0 to 4.0	...	...	99	5 000	42.7	9.6
EC9 33 3×0	ECG 150 3/0	160 to 200	4.0 to 5.0	...	...	99	5 000	42.7	9.6
EC9 33	ECG 150	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	99	5 000	40.0	9.0

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
1×3 EC5 11 3×4	1/3 ECD 450 3/4	...	...	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC5 11 4×3	ECD 450 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC5 22 3×2	ECD 225 3/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	64.0	14.4
EC7 22 3×2	ECE 225 3/2	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	132	3 750	58.7	13.2
EC3.5 33 4×0	ECB 150 4/0	40 to 80	1.0 to 2.0	...	...	132	3 750	71.2	16.0
EC6 33 4×0	ECDE 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	...	TBD
EC6 33 2×2	ECDE 150 2/2	...	...	112 to 152	2.8 to 3.8	132	3 750	...	TBD
EC6 33 1×4	ECDE 150 1/4	...	...	112 to 152	2.8 to 3.8	132	3 750	...	TBD
EC4.5 33 4×0	ECC 150 4/0	40 to 80	1.0 to 2.0	...	...	132	3 750	62.3	14.0
EC4.5 33 1×0	ECC 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	62.3	14.0
EC9 33 4×0	ECG 150 4/0	120 to 160	3.0 to 4.0	...	...	132	3 750	56.9	12.8
EC9 33 4×0	ECG 150 4/0	160 to 200	4.0 to 5.0	...	...	132	3 750	56.9	12.8
EC9 33 2×2	ECG 150 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	132	3 750	53.4	12.0
EC4.5 66 2×0	ECC 75 2/0	80 to 120	2.0 to 3.0	...	...	132	3 750	50.7	11.4
EC4.5 66 2×0	ECC 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC6 66 2×0	ECDE 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	280	7.0	...	...	132	3 750	50.7	11.4
EC9 66 2×0	ECG 75 2/0	320	8.0	...	...	132	3 750	50.7	11.4
EC9 66 1×2	ECG 75 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	132	3 750	50.7	11.4
EC13 66 2×0	ECK 75 2/0	120 to 160	3.0 to 4.0	...	...	132	3 750	50.7	11.4
EC6 134 1×0	ECDE 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC6 134 1×0	ECDE 37 1/0	80 to 120	2.0 to 3.0	...	...	134	3 700	49.8	11.2
EC6 134 1×0	ECDE 37 1/0	120 to 160	3.0 to 4.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	40 to 80	1.0 to 2.0	...	...	134	3 700	49.8	11.2
EC9 134 1×0	ECG 37 1/0	120 to 160	3.0 to 4.0	...	...	134	3 700	49.8	11.2
EC13 134 1×0	ECK 37 1/0	20 to 40	0.5 to 1.0	...	...	134	3 700	49.8	11.2
EC5 11 3×5	ECD 450 3/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	165	3 000	70.3	15.8
EC5 11 4×4	ECD 450 4/4	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	176	2 813	78.3	17.6
EC9 33 2×3	ECG 150 2/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	80.1	18.0
EC9 33 3×2	ECG 150 3/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	80.1	18.0
EC9 66 3×0	ECG 75 3/0	120 to 160	3.0 to 4.0	...	...	198	2 500	76.1	17.1
EC9 66 1×3	ECG 75 1/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	198	2 500	76.1	17.1
EC9 100 1×2	ECG 50 1/2	120 to 160	3.0 to 4.0	...	...	198	2 500	...	...

TABLE 2 *Continued*

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[B]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
EC11 198 1×0	ECH 25 1/1	20 to 40	0.5 to 1.0	...	...	198	2 500	75.6	17.0
EC5 11 4×5	ECD 450 4/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	220	2 250	100	22.6
EC5 22 2×5	ECD 225 2/5	...	...	152 to 176	3.8 to 4.4	220	2 250	107	24
EC7 22 2×5	ECE 225 2/5	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	220	2 250	107	24
EC13 40HF 2/3	ECK 125 HF 2/3	80 to 140	2.0 to 3.5	7.6 to 136	1.9 to 3.4	238	2080	85.4	19.2
EC13 40HF 1×6	ECK 125 HF 1/6	80 to 140	2.0 to 3.5	7.6 to 136	1.9 to 3.4	238	2080	85.4	19.2
EC5 22 4×3	ECD 225 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	265	1 875	128	28.8
EC7 22 4×3	ECE 225 4/3	160 to 200	4.0 to 5.0	152 to 176	3.8 to 4.4	265	1 875	117	26.4
EC9 33 1×2	ECG 150 1/2	...	...	112 to 152	2.8 to 3.8	265	1 875	...	...
EC9 33 4×2	ECG 150 4/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	107	24.0
EC9 66 4×0	ECG 75 4/0	120 to 160	3.0 to 4.0	...	...	265	1 875	101	22.8
EC9 66 2×2	ECG 75 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	101	22.8
EC9 134 2×0	ECG 37 2/0	120 to 160	3.0 to 4.0	...	...	265	1 875	101	22.8
EC13 66 2×2	ECK 75 2/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	265	1 875	101	22.8
EC9 134 1×2	ECG 37 1/2	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	270	1 850	101	22.8
EC13 275 1×0	ECK 18 1/0	20 to 40	0.5 to 1.0	...	...	275	1 800	102	23.0
EC9 33 3×3	ECG 150 3/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	300	1 665	120	27.0
EC9 33 3×4	ECG 150 3/4	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	160	36.0
EC9 33 4×3	ECG 150 4/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	160	36.0
EC9 66 2×3	ECG 75 2/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	395	1 250	152	34.2
EC9 134 1×3	ECG 37 1/3	120 to 160	3.0 to 4.0	112 to 152	2.8 to 3.8	405	1 230	152	34.2
EC9 33 4×4	ECG 150 4/4	120 to 160	3.0 to 4.0	100 to 140	2.5 to 3.5	530	938	213	48.0
EC9 66 2×4	ECG 75 2/4	...	...	112 to 152	2.8 to 3.8	530	938	203	45.6
EC9 33 4×5	ECG 150 4/5	...	...	100 to 140	2.5 to 3.5	660	750	285	64
EC9 33 4×6	ECG 150 4/6	...	...	100 to 140	2.5 to 3.5	795	625	342	76.8
EC9 33 4×7	ECG 150 4/7	...	...	100 to 140	2.5 to 3.5	925	536	399	89.6
EC4 2.2 1×0	ECBC 2250 1×0	20 to 40	0.5 to 1.0	...	...	2.20	225.000	0.9	0.20
EC4 3.31 1×0	ECBC 1500 1×0	20 to 40	0.5 to 1.0	...	...	3.31	150.000	1.3	0.30
EC4.5 4.13 1×0	ECC 1200 1×0	20 to 40	0.5 to 1.0	...	...	4.13	120.000	1.65	0.375

[A] For engineering information only, and may be made by substituting other yarn equivalents, providing fiber diameter and other properties are not affected. For example, when EC9 66 2 × 2 (ECG 75 2/2) is substituted with EC9 112 1 × 2 (ECG 37 1/2), the final yarn number remains the same.

[B] The yards per pound stated in Table 1 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 combination thereof. 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.

TABLE 3 Visual Examination of Yarn

Visual Characteristic	Defect
Appearance and Workmanship	Any cut, chaf, damage, or excessive filamentation, affecting serviceability[A]
	Finish other than specified
	Spot or stain[A]
	Embedded foreign matter[A]
Put-up (Package/Bobbin Build)	Any defect or package abnormality affecting the free unhampered unwinding of yarn or affecting the secure holding of yarn winds on the bobbin or package
	Not put up on bobbin or package as specified

[A] Clearly visible at normal inspection distance of approximately 1 m [3 ft].

TABLE 4 Physical Properties of Typical (Discontinuous) Staple Filament Glass Yarns

Yarn Designation[A]		Nominal Twist				Approximate Yarn Number (Bare Glass)[13]		Breaking Strength, Individual Minimum	
		"Z"		"S"					
SI Unit (tex)	Inch-Pound Unit	tpm	tpi	tpm	tpi	tex	yd/lb	N	lbf
ED7 71R 1×0	ESE 70/1R	340	8.5	...	...	71	7000	7.6	1.7
ED7 99R 1×0	ESE 50/1R	340	8.5	...	...	99	5000	12.5	2.8
CD9 198R 1×0	CSG 25/1R	340	8.5	...	...	198	2500	20.9	4.7
CD9 198 1×0	CSG 25/1	340	8.5	...	...	198	2500	20.9	4.7
ED7 198 1×0	ESE 25/1	340	8.5	...	...	198	2500	20.9	4.7
CD9 260R 1×0	CSG 19/1R	280	7.0	...	...	260	1900	...	...
CD9 260 1×0	CSG 19/1	160	4.0	...	...	260	1900	...	...
CD9 395R 1×0	CSG 12.5/1R	160	4.0	...	...	385	1285	40.0	9.0
ED7 395 1×0	ESE 12.5/1	160	4.0	...	...	385	1285	40.0	9.0
CD9 395 1×0	CSG 12.5/1	160	4.0	...	...	385	1285	40.0	9.0
CD9 415 1×0	CSG 12/1	160	4.0	...	...	415	1200	...	...
CD9 495 1×0	CSG 10/1	160	4.0	...	...	510	975	46.7	10.5
CD9 550 1×0	CSG 9/1	160	4.0	...	...	570	870	...	...
CD9 590 1×0	CSG 8.4/1	160	4.0	...	...	590	840	...	...
CD9 620 1×0	CSG 8/1	160	4.0	...	...	636	780	...	...
CD9 800 1×0	CSG 6.2/1	160	4.0	...	...	795	624	...	...
CD9 825 1×0	CSG 6/1	160	4.0	...	...	855	580	...	...
CD9 990 1×0	CSG 5/1	80	2.0	...	...	980	505	...	...
CD9 1240 1×0	CSG 4/1	80	2.0	...	...	1235	402	...	...
CD9 1415 1×0	CSG 3.5/1	80	2.0	...	...	1480	335	...	...
CD10 1415 1×0	CSH 3.5/1	80	2.0	...	...	1480	335	93.4	21.0
CD9 1770 1×0	CSG 2.8/1	80	2.0	...	...	1850	268	122	27.5
CD9 1985 1×0	CSG 2.5/1	168	4.2	...	...	2000	247	...	...
CD9 2900 1×0	CSG 1.7/1	80	2.0	...	...	3000	167	...	...
CD10 2900 1×0	CSH 1.7/1	80	2.0	...	...	3000	167	187	42.0
CD9 3300 1×0	CSG 1.5/1	80	2.0	...	...	3500	140	...	...
CD9 3500 1×0	CSG 1.4/1	80	2.0	...	...	3900	128	227	51.0
ED7 71R 1×2	ESE 70/2R	340	8.5	260	6.5	142	3500	19.0	4.3
ED7 99R 1×2	ESE 50/2R	340	8.5	260	6.5	198	2500	24.9	5.6
ED7 124R 1×2	ESE 40/2R	340	8.5	260	6.5	248	2000	32.0	7.2
ED7 160R 1×2	ESE 31/2	340	8.5	260	6.5	320	1550	38.2	8.6
ED7 198R 1×2	ESE 25/2	340	8.5	260	6.5	385	1285	40.9	9.2
CD9 198R 1×2	CSG 25/2R	340	8.5	260	6.5	385	1285	...	...
CD9 198 1×2	CSG 25/2	340	8.5	260	6.5	385	1285	...	...
CD9 198R 1×4	CSG 25/4R	...	...	140	3.5	770	644	...	...
CD9 198 1×4	CSG 25/4	...	...	140	3.5	770	644	...	...
CD9 260R 1×2	CSG 19/2R	...	...	220	5.5	505	978	...	...
CD9 260 1×2	CSG 19/2	...	...	220	5.5	505	978	...	...
CD9 395R 1×2	CSG 12.5/2R	...	...	140	3.5	775	642	...	...
ED7 395 1×2	ESE 12.5/2	160	4.0	140	3.5	775	642	80.0	18.0
CD9 395 1×2	CSG 12.5/2	160	4.0	140	3.5	775	642	...	...
CD9 395 2×4	CSG 12.5/2/4	...	...	120	3.0	3100	160	...	...
CD9 395 2×4×6	CSG 12.5/2/4/6	...	...	80	2.0	9200	54	...	...
CD9 415 1×2	CSG 12/2	...	...	140	3.5	805	618	...	...
ED7 472 1×2	ESE 10.5/2	160	4.0	140	3.5	945	525	93.4	21.0
CD9 495 1×2	CSG 10/2	...	...	140	3.5	965	515	...	...
CD9 550 1×2	CSG 9/2	...	...	140	3.5	1070	463	...	...
ED7 590 1×2	ESE 8.4/2	160	4.0	140	3.5	1180	420	109	24.6
CD9 590 1×2	CSG 8.4/2	160	4.0	140	3.5	1180	420	...	...
CD9 620 1×2	CSG 8/2	...	...	140	3.5	1205	412	116	26.0
CD9 620 1×5	CSG 8/5	...	...	80	2.0	3000	165	...	...
ED7 800 1×2	ESE 6.2/2	160	4.0	140	3.5	1555	319	164	37.0
CD9 800 1×2	CSG 6.2/2	160	4.0	140	3.5	1555	319	...	...
CD9 825 1×2	CSG 6/2	160	4.0	140	3.5	1605	309	...	...
CD9 990 1×2	CSG 5/2	...	...	80	2.0	1930	257	...	...
CD9 1770 1×2	CSG 2.8/2	...	...	80	2.0	3800	130	...	...
CD9 1985 1×2	CSG 2.5/2	...	...	80	2.0	4100	120	...	...
CD9 2100 1×4	CSG 2.4/4	40	1.0	...	...	8300	60	511	115
CD10 2100 1×4	CSH 2.4/4	40	1.0	...	...	8300	60	...	...
CD9 2100 1×8	CSG 2.4/8	40	1.0	...	...	16000	31	...	...
CD9 2900 1×3	CSG 1.7/3	...	...	48	1.2	8900	56	560	126
CD9 3300 1×2	CSG 1.5/2	...	...	48	1.2	6500	76	...	...
CD9 3300 1×4	CSG 1.5/4	...	...	48	1.2	13100	38	...	...
CD9 3500 1×2	CSG 1.4/2	...	...	80	2.0	6900	72	...	...
CD9 3500 1×3	CSG 1.4/3	...	...	48	1.2	10300	48	...	...

TABLE 5 Physical Properties of Typical Textured Glass Yarns

Yarn Designation		Approximate Yarn Number		Breaking Strength Minimum, avg	
SI Unit (tex)	Inch-Pound Unit	tex	yd/lb	N	lbf
ET6 33	ETDE 150	35	14 300	5.6	1.2
ET6 50	ETDE 100	53	9400	6.7	1.5
ET4.5 66	ETC 75	70	7100	11.1	2.5
ET6 66	ETDE 75	70	7100	6.7	1.5
ET6 99	ETDE 50	106	4700	13.3	3.0
ET9 134	ETG 37	139	3500	17.8	4.0
ET4.5 134	ETC 37	141	3500	22.2	5.0
ET6 134	ETDE 37	143	3500	22.2	5.0
ET4.5 198	ETC 25.0	198	2500	...	...
ET6 198	ETDE 25.0	198	2500	27	6.0
ET4.5 275	ETC 18.0	275	1800	...	...
ET6 275	ETDE 18	282	1800	35.6	8.0
ET9 275	ETG 18.0	282	1800	35.6	8.0
ET4.5 420	ETC 11.8	420	1180	...	...
ET6 425	ETDE 11.6	430	1160	52	15.0
ET9 430	ETG 11.6	430	1160	89	20.0
ET6 550	ETDE 9.0	550	900	66.7	15.0
ET9 550	ETG 9.0	550	900	133	30.0
ET6 825	ETDE 6.0	825	600	89	20.0
ET9 825	ETG 6.0	825	600	89	20.0
ET9 990	ETG 5.0	990	505	89	20.0
ET6 1100	ETDE 4.5	1100	450	178	40.0
ET9 1100	ETG 4.5	1100	450	111	25.0
ET6 1415	ETDE 3.5	1415	350	267	60.0
ET9 1415	ETG 3.5	1415	350	133	30.0
ET6 1804	ETDE 2.75	1804	275	...	...
ET9 1804	ETG 2.75	1804	275	...	...
ET9 1835	ETG 2.70	1835	271	160	36.0
ET6 2205	ETDE 2.25	2205	225	...	...
ET9 2205	ETG 2.25	2205	225	...	...
ET9 2610	ETG 1.9	2610	190	267	60.0
ET6 2800	ETDE 1.75	2800	175	267	60.0
ET9 2800	ETG 1.75	2800	175	267	60.0
ET9 3545	ETG 1.4	3545	140	267	60.0
ET9 4510	ETG 1.1	4510	110	267	60.0
ET96614	ETG 0.75	6614	75	289	65.0

TABLE 6 Sample Size Determination

Lot Size, Packages per Lot	Sample Size, Number of Packages
15 or less	2
16 to 40	3
41 to 110	5
111 to 300	7
301 to 500	10
501 or more	15

TABLE 7 Fiber Diameter inches × 10^{-5}

Components of Variance Expressed as Standard Deviations[A]			
Material	Grand Average	Single-Operator Precision	Within-Laboratory Precision
600 Denier Glass Fiber Strand	43.0	2.80	0

[A] The square roots of the components of variance are being reported to express the variability in the appropriate units of measure rather than as the squares of those units of measure.

TABLE 8 Fiber Diameter inches × 10^{-5}

Critical Differences for the Conditions Noted[A]			
Material	Number of Observations in each Average	Single-Operator Precision	Within-Laboratory Precision
600 Denier Glass Fiber Strand	30	1.42	1.42
	50	1.10	1.10
	100	0.78	0.78
	200	0.55	0.55

[A] The critical differences were calculated using $t = 1.960$, which is based on infinite degrees of freedom.