



Standard Specification for FEP-Fluorocarbon Tube¹

This standard is issued under the fixed designation D 3296; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 The tubing is intended for electrical, mechanical, chemical, and medical applications manufactured from extrusion resins made from the copolymer of tetrafluoroethylene and hexafluoropropylene (FEP-fluorocarbon). This specification is for virgin material only and does not address recycled material as it is not appropriate for FEP tubing.

NOTE 1—Abbreviations are in accordance with Terminology D 1600.
NOTE 2—There is no similar ISO standard.

1.2 The values stated in SI units are to be regarded as the standard. The values given in brackets are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section 8 of this specification: *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

- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
- D 618 Practice for Conditioning Plastics for Testing
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D 883 Terminology Relating to Plastics
- D 1600 Terminology for Abbreviated Terms Relating to Plastics
- D 1675 Test Method for Polytetrafluoroethylene

¹ This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials (Section 20.15.12).

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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.

- D 2116 Specification for FEP-Fluorocarbon Molding and Extrusion Materials
- D 4894 Specification for Polytetrafluoroethylene (PTFE) Granular Molding and Ram Extrusion Materials
- IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification shall be in accordance with Terminology D 883.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot, n*—one production run or uniform blend of two or more production runs.

4. Classification

4.1 This specification provides for three types of FEP-fluorocarbon tubing differentiated by size schedules as follows:

4.1.1 *Type I*—Tubing based upon the American Wire Gage (AWG) sizes.

4.1.2 *Type II*—Tubing based upon fractional inch sizes (see Note 2).

4.1.3 *Type III*—Tubing of all other sizes, as agreed by buyer and seller. This type shall conform to the Dimensional Tolerances for FEP Tubing, as listed in Table 3.

4.2 The types are further differentiated in accordance with increasing wall thicknesses as follows:

4.2.1 *Class A*—Tubing having walls tabulated in Table 1 listed as light-weight wall.

4.2.2 *Class C*—Tubing having walls tabulated in Table 1 listed as standard wall (see Note 3).

4.2.3 *Class D*—Tubing having walls tabulated in Table 2 listed as chemical tubing.

4.2.4 *Class E*—Tubing having walls listed as heavy or conforming to the Dimensional Tolerances for FEP Tubing as listed in Table 3.

NOTE 3—Tubing having electrical internal diameters and wall thickness dimensions were deleted because of lack of demand.

NOTE 4—Class B has been deleted because of lack of demand.

*A Summary of Changes section appears at the end of this standard.

TABLE 1 Dimensions and Tolerances for Type I FEP-Fluorocarbon Tubing—Dimensions, mm [in.]

AWG Size	Inside Diameter		Wall Thickness						
			Class A			Class C			
	min	max	nom	min	max	nom	min	max	
				Lightweight Wall			Standard Wall		
24	0.51 [0.020]	0.69 [0.027]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.305 [0.012]	0.254 [0.010]	0.356 [0.014]	
22	0.64 [0.025]	0.81 [0.032]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.305 [0.012]	0.254 [0.010]	0.356 [0.014]	
20	0.81 [0.032]	1.02 [0.040]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
19	0.91 [0.036]	1.12 [0.044]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
18	1.01 [0.040]	1.25 [0.049]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
17	1.14 [0.045]	1.37 [0.054]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
16	1.30 [0.051]	1.55 [0.061]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
15	1.45 [0.057]	1.70 [0.067]	0.152 [0.006]	0.102 [0.004]	0.203 [0.008]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
14	1.63 [0.064]	1.88 [0.074]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
13	1.83 [0.072]	2.08 [0.082]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
12	2.06 [0.081]	2.31 [0.091]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
11	2.31 [0.091]	2.57 [0.101]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
10	2.59 [0.102]	2.85 [0.112]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.406 [0.016]	0.330 [0.013]	0.483 [0.019]	
9	2.90 [0.114]	3.15 [0.124]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
8	3.28 [0.129]	3.58 [0.141]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
7	3.66 [0.144]	4.01 [0.158]	0.203 [0.008]	0.152 [0.006]	0.254 [0.010]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
6	4.12 [0.162]	4.52 [0.178]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
5	4.62 [0.182]	5.03 [0.192]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
4	5.18 [0.204]	5.69 [0.224]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
3	5.82 [0.229]	6.33 [0.249]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
2	6.55 [0.258]	7.06 [0.278]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
1	7.34 [0.289]	7.90 [0.311]	0.254 [0.010]	0.178 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	
0	8.26 [0.325]	8.81 [0.347]	0.254 [0.012]	0.229 [0.007]	0.330 [0.013]	0.508 [0.020]	0.406 [0.016]	0.610 [0.024]	

TABLE 2 Dimensions and Tolerances for Type II FEP-Fluorocarbon Tubing—Dimensions, mm [in.]

ID Size Fractions	Class D			Class D	
	Inside Diameter		Wall Dimensions		
	nom	max	min	Thickness	Tolerances
0.79 [1/32]	0.79 [0.031]	0.89 [0.035]	0.69 [0.027]	0.41 [0.016]	±0.076 [±0.003]
1.59 [1/16]	1.59 [0.062]	1.70 [0.067]	1.45 [0.057]	0.76 [0.030]	±0.127 [±0.005]
2.38 [3/32]	2.38 [0.094]	2.49 [0.098]	2.24 [0.088]	0.76 [0.030]	±0.127 [±0.005]
3.18 [1/8]	3.18 [0.125]	3.30 [0.130]	3.05 [0.120]	0.76 [0.030]	±0.127 [±0.005]
4.76 [3/16]	4.76 [0.188]	4.90 [0.193]	4.65 [0.183]	0.76 [0.030]	±0.127 [±0.005]
6.35 [1/4]	6.35 [0.250]	6.53 [0.257]	6.17 [0.243]	0.76 [0.030]	±0.127 [±0.005]
7.94 [5/16]	7.94 [0.312]	8.13 [0.320]	7.72 [0.304]	0.76 [0.030]	±0.127 [±0.005]
9.52 [3/8]	9.52 [0.375]	9.73 [0.383]	9.32 [0.367]	0.76 [0.030]	±0.127 [±0.005]
11.11 [7/16]	11.11 [0.438]	11.38 [0.448]	10.87 [0.428]	0.76 [0.030]	±0.152 [±0.006]
12.70 [1/2]	12.70 [0.500]	12.95 [0.510]	12.45 [0.490]	0.76 [0.030]	±0.152 [±0.006]
14.29 [9/16]	14.29 [0.563]	14.53 [0.572]	14.02 [0.552]	0.76 [0.030]	±0.152 [±0.006]
15.88 [5/8]	15.88 [0.625]	16.18 [0.637]	15.57 [0.613]	0.76 [0.030]	±0.152 [±0.006]
17.46 [11/16]	17.46 [0.688]	17.78 [0.700]	17.17 [0.676]	0.81 [0.032]	±0.152 [±0.006]
19.05 [3/4]	19.05 [0.750]	19.41 [0.764]	18.69 [0.736]	1.02 [0.040]	±0.178 [±0.007]
22.23 [7/8]	22.23 [0.875]	22.63 [0.891]	21.82 [0.859]	1.14 [0.045]	±0.178 [±0.007]
25.40 [1]	25.40 [1.000]	25.91 [1.020]	24.89 [0.980]	1.27 [0.050]	±0.203 [±0.008]
31.75 [1 1/4]	31.75 [1.250]	32.26 [1.270]	31.24 [1.230]	1.27 [0.050]	±0.203 [±0.008]
38.10 [1 1/2]	38.10 [1.500]	38.74 [1.525]	37.47 [1.475]	1.27 [0.050]	±0.203 [±0.008]
50.80 [2]	50.80 [2.000]	51.44 [2.025]	50.17 [1.975]	1.27 [0.050]	±0.203 [±0.008]

4.3 A one-line system is used to specify materials in this specification. The system uses predefined cells to refer to specific aspects of this specification, as illustrated as follows:

Specification			
Standard Number Block	Type	Class	Special Notes
:	:	:	:
Example: Specifica- tion D 3296 – 98,	I	A	:

For this example, the line callout would be Specification D 3296 – 03, IA, and would specify form of FEP-Fluoro ethyl-

enepropylene that has all of the properties listed for that type, grade, and class in the appropriate specified properties or tables, or both, in the specification identified. A comma is used as the separator between the standard number and the type. Separators are not needed between the type, grade, and class.³ Provision for special notes are included so that other information can be provided when required. An example would be in Specification D 3296 – 03 where dimensions and tolerances are specified for each AWG size within type and class. When special notes are used, a comma should precede them.

³ See the ASTM *Form and Style Manual*. Available from ASTM Headquarters.

TABLE 3 Dimensions and Tolerances for Type III FEP-Fluorocarbon Tubing—Dimensions, mm [in.]

Class E Inside Diameter		Class E Wall Thickness	
Nominal Inside Diameter mm [in.]	Inside Diameter Tolerance mm [in.]	Nominal Thickness mm [in.]	Thickness Tolerance mm [in.]
0 to 0.25 [0.000 to 0.010]	±0.03 [0.001]	0 to 0.13 [0.000 to 0.005]	±0.030 [0.001]
0.26 to 0.50 [0.011 to 0.020]	±0.05 [0.002]	0.14 to 0.30 [0.006 to 0.012]	±0.050 [0.002]
0.51 to 0.75 [0.021 to 0.030]	±0.08 [0.003]	0.31 to 0.48 [0.013 to 0.019]	±0.080 [0.003]
0.76 to 2.54 [0.031 to 0.100]	±0.10 [0.004]	0.49 to 0.74 [0.020 to 0.029]	±0.100 [0.004]
2.55 to 4.32 [0.101 to 0.170]	±0.13 [0.005]	0.75 and > [0.030 and]	±0.130 [0.005]
4.33 to 6.35 [0.171 to 0.250]	±0.15 [0.006]		
6.36 to 19.05 [0.251 to 0.750]	±0.18 [0.007]		
19.06 to 25.39 [0.751 to 0.999]	±0.25 [0.010]		
25.4 and [1.000 and]	±0.38 [0.015]		

5. Physical Requirements

5.1 The tubing shall be made of FEP-fluorocarbon meeting the requirements of Specification D 2116.

5.2 The inside diameter and wall thickness and tolerances of the tubing shall be as shown in Tables 1-3 when determined in accordance with 8.1.3.1 and 8.1.3.2.

5.3 The specific gravity of the tubing shall be between 2.12 and 2.19 inclusive when determined in accordance with 8.1.4.

5.4 The tubing shall have a minimum tensile strength of 10.0 MPa [1500 psi] and a minimum elongation of 250 % when determined in accordance with 8.1.5.

5.5 The tubing shall have a minimum dielectric breakdown as shown in Table 4 when determined in accordance with 8.1.6.

5.6 The tubing shall remain free from cracks and exhibit no splitting when tested for heat resistance in accordance with 8.1.8.

6. Sampling

6.1 Sampling shall be statistically adequate to satisfy the requirements of Section 9.

7. Number of Tests and Retests

7.1 One set of test specimens shall be considered sufficient for testing each batch. The average result of the specimens tested shall conform to the requirements of this specification.

8. Test Methods

8.1 The properties enumerated in this specification shall be determined in accordance with the following methods.

8.1.1 *Conditioning*—Conditioning is not required except in referee cases. When conditioning is required, condition the test specimens at 23°C for a period of at least 4 h prior to test. If the test material has been exposed to temperatures below 20°C

within 24 h prior to test, the conditioning shall be for at least 24 h and as outlined in Practice D 618.

8.1.2 *Test Conditions*—Conduct tests at the standard laboratory temperature of 23 ± 2°C [73.4 ± 3.6°F]. The maintenance of constant humidity is not necessary; in referee cases the standard laboratory atmosphere including 50 ± 5 % relative humidity shall apply.

8.1.3 *Dimensions and Tolerances:*

8.1.3.1 *Inside Diameter*—Determine the inside diameter in accordance with Method D 1675, except that no individual measurements shall be allowed to exceed the tolerances specified in Table 1, Table 2, or Table 3.

8.1.3.2 *Wall Thickness*—Determine the wall thickness in accordance with the procedures described in Method D 1675, except that no individual measurements shall be allowed to exceed the tolerances specified in Table 1, Table 2, or Table 3.

8.1.4 *Specific Gravity*—Determine the specific gravity in accordance with Method A of Test Methods D 792. Add 2 drops of wetting agent (liquid detergent) to the water in order to reduce the surface tension and ensure complete wetting of the specimen.

8.1.5 *Tensile Strength and Elongation*—Determine the tensile strength and elongation as specified in 8.1.5.1 through 8.1.5.3 on five transverse specimens, using a testing speed of 50.8 mm [2 in.]/min. Average the test results for the longitudinal and the transverse specimens separately. Discard specimens that break in the jaws of the tension tester, and make new tests.

8.1.5.1 *Tubing Having an Inside Diameter of 15.9 mm [0.625 in.] and Over*—Determine the tensile strength and elongation in both the longitudinal and transverse directions in accordance with Specification D 4894.

8.1.5.2 *Tubing Having an Inside Diameter less than 15.9 mm [0.625 in.] to 2.3 mm [0.090 in.] Inclusive*—Determine the tensile strength and elongation in the longitudinal direction in accordance with Specification D 4894. For longitudinal specimens, slit the tubing parallel to the axis and flatten out, prior to punching out specimens.

8.1.5.3 *Tubing Having an Inside Diameter less than 2.3 mm [0.090 in.]*—Test specimens as filaments. Make nonsliptype loop knots in each end of the specimen so that there are 34.9 mm [1⅜ in.] between the knot of the loops (see Fig. 1). Place loops over the drum of a standard wire specimen holder in the tension-testing machine and pull in this position.

TABLE 4 Minimum Dielectric Breakdown for FEP-Fluorocarbon Plastic Tubing

Nominal Wall Thickness		Dielectric Breakdown Volts min, V
mm	in.	
0.152 to 0.173	0.006 to 0.0069	9 000
0.178 to 0.226	0.007 to 0.0089	10 000
0.229 to 0.252	0.009 to 0.0099	11 500
0.254 to 0.302	0.010 to 0.0119	12 500
0.305 to 0.379	0.012 to 0.0149	14 600
0.380 to 0.404	0.015 to 0.0159	15 000
0.406 to 0.506	0.016 to 0.0199	16 300
over 0.508	Over 0.020	17 000

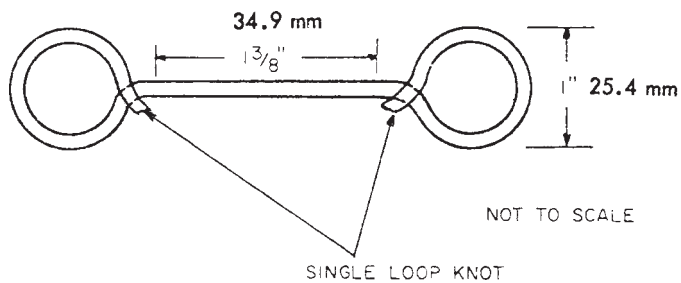


FIG. 1 Tension Specimen for Tubing Less Than 2.29 mm

8.1.6 *Dielectric Breakdown Voltage*—Determine the dielectric breakdown voltage of the tubing in accordance with Test Methods D 149.

8.1.6.1 Tubing having a nominal diameter less than 4.80 mm [0.189 in.], use a tight fitting mandrel as the inner electrode and metal foil approximately 20 mm [$\frac{3}{4}$ in.] wide as the outer electrode.

8.1.6.2 For all other tubing, slit along the longitudinal axis and flatten.

8.1.7 *Dimensional Stability*—Cut three specimens each 305 mm [12 in.] long, measured to the nearest 1.6 mm [$\frac{1}{16}$ in.]. Place the specimens in a circulating-air oven at $200 \pm 2^\circ\text{C}$ for 3 h. Then remove the specimens from the oven and allow to

cool to $23 \pm 1^\circ\text{C}$. Again measure the length to the nearest 1.6 mm [$\frac{1}{16}$ in.]. Calculate the change in length as a percentage of the original length.

8.1.8 *Heat Resistance*—Examine specimens as tested in 8.1.7. Tubing should be free of cracks and exhibit no splitting.

9. Inspection

9.1 The tubing shall be visually and dimensionally inspected to verify compliance with the requirements of this specification. When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the other requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

10. Packaging and Package Marking

10.1 *Packaging*—The material shall be packaged in standard commercial containers so constructed as to ensure acceptance by common or other carrier for safe transportation at the lowest rate to the point of delivery, unless otherwise specified in the contract or order.

11. Keywords

11.1 extruded material; FEP extruded tubing; fluorocarbon tubing; fluoropolymers; melt-processible fluorocarbon polymer; polytetrafluoroethylene copolymers; thin-walled tubing

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

D 3296 - 03:

- (1) Updated standards listed in Section 2 and throughout this specification.
- (2) Added Section 3. Subsequent sections were renumbered.
- (3) Revised paragraph 4.3.
- (4) Revised paragraph 5.5.

- (5) Revised paragraph 6.1.
- (6) Revised paragraph 8.1.8.
- (7) Added paragraphs 8.1.6.1 and 8.1.6.2.
- (8) Revised paragraph 9.
- (9) Deleted Precision and Bias section.

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