Designation: D 3296 – 98

Standard Specification for FEP-Fluorocarbon Tube[1]

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 parentheses are for information only.

1.3 The following safety hazards caveat pertains only to the test methods portion, Section ,7 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:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement[3]

D 1457 Specification for PTFE Molding and Extrusion Materials[4]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 1675 Test Method for Polytetrafluoroethylene Tubing[3]

D 1898 Practice for Sampling of Plastics[3]

D 2116 Specification for FEP-Fluorocarbon Molding and Extrusion Materials[3]

E 691 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of a Test Method[5]

3. Classification

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

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

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

3.1.3 *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.

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

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

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

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

3.2.4 *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.

3.3 A one-line system may be used to specify materials covered by 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: Specification D 3296 – 98,		I		A			

For this example, the line callout would be Specification D

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials (Section 20.15.12).

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[2] *Annual Book of ASTM Standards*, Vol 10.01.

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

[4] Discontinued 1996; Replaced by D 4895.

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

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

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

3296 – 98, IA, and would specify form of FEP-Fluoro ethylenepropylene 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.[6] Provision for special notes is included so that other information can be provided when required. An example would be in Specification D 3296 – 98 where dimensions and tolerances are specified for each AWG size within type and class. When special notes are used, they should be preceded by a comma.

[6] See the ASTM *Form and Style Manual*. Available from ASTM Headquarters.

4. Physical Requirements

4.1 The tubing shall be made of FEP-fluorocarbon meeting the requirements of Specification D 2116 and may contain a maximum of 2 weight % of additives.

4.2 The inside diameter and wall thickness and tolerances of the tubing shall be as shown in Tables 1-3 when determined in accordance with 7.1.3.1 and 7.1.3.2.

4.3 The specific gravity of the tubing shall be between 2.12 and 2.19 inclusive when determined in accordance with 7.1.4.

4.4 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 7.1.5.

4.5 The tubing shall have a minimum dielectric breakdown

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)		

as shown in Table 4 when determined in accordance with 7.1.6. Except, use a tight fitting mandrel as the inner electrode and metal foil approximately 20-mm (¾-in.) wide as the outer electrode for samples having nominal inner diameter less than 4.80 mm (.189). For all other tubing, slit along the longitudinal axis and flatten. Test the sample between the electrodes as described in Test Methods D 149.

4.6 The tubing shall remain free from cracks and exhibit no splitting when tested for heat resistance in accordance with 7.1.8.

5. Sampling

5.1 Unless otherwise agreed upon between the purchaser and the seller, the materials shall be sampled in accordance with the sampling procedure prescribed in Practice D 1898. Adequate statistical sampling shall be considered an acceptable alternative. A lot shall consist of all material made from the same lot(s) of raw material that is of the same type, size, and class fabricated at the same time.

6. Number of Tests and Retests

6.1 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.

7. Test Methods

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

7.1.1 *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.

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

7.1.2 *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.

7.1.3 *Dimensions and Tolerances:*

7.1.3.1 *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.

7.1.3.2 *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 Tables Table 1,Table 2, or Table 3.

7.1.4 *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.

7.1.5 *Tensile Strength and Elongation*—Determine the tensile strength and elongation as specified in 7.1.5.1 through 7.1.5.3 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.

7.1.5.1 *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 1457.

7.1.5.2 *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 1457. For longitudinal specimens, slit the tubing parallel to the axis and flatten out, prior to punching out specimens.

7.1.5.3 *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 knots 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.

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

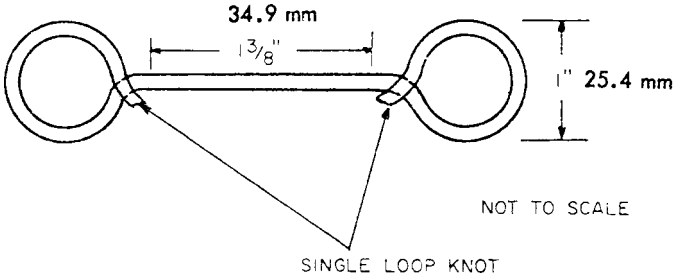

FIG. 1 Tension Specimen for Tubing Less Than 2.29 mm (0.090 in.)

7.1.7 *Dimensional Stability*—Cut three specimens each 305 mm (12 in.) long, measured to the nearest 1.6 mm (1⁄16 in.). Place the specimens in a circulating-air oven at 200 ± 2°C for 3 h. Then remove the specimens from the oven and allow to cool to 23 ± 1°C. Again measure the length to the nearest 1.6 mm (1⁄16 in.). Calculate the change in length as a percentage of the original length.

7.1.8 *Heat Resistance*—Place three specimens, each 305 mm (12 in.) long, in a circulating-air oven at 200 ± 2°C for 5 h. At the completion of this heat-aging, the specimens shall be subjected to the low-temperature flexibility test of 7.1.9.

7.1.9 *Low-Temperature Flexibility*—Place three specimens, each 305 mm (12 in.) long, in a circulating-air oven at 200 ± 2°C for 5 h, cool to room temperature, and then condition at −55 ± 2°C for 4 h. Condition a fixed mandrel, selected in accordance with Table 4, at the same temperature. After completion of the conditioning period and while still maintained at conditioning temperature, wrap the specimens rapidly about the mandrel for not less than two complete wraps. The speed of wrapping shall be approximately 2 s/360° wrap.

8. Inspection

8.1 The tubing shall be visually and dimensionally inspected to verify compliance with the requirements of this specification.

9. Packaging and Package Marking

9.1 *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.

10. Precision and Bias

10.1 Table 5 is based on a round robin conducted in 1985–1986 in accordance with Practice E 691, involving seven materials tested by six laboratories. For each material, the sheeting from which the test specimens were to be cut was obtained from one source. Using a steel rule die, one set of test specimens for each laboratory was cut by one of the laboratories. Sheeting and a duplicate die were furnished each participating laboratory and used to cut a second set of test specimens. Each test result was the average of five individual determinations. Each laboratory obtained four test results on each material, two test results each on the specimens furnished and two on the specimens cut by the laboratory doing the testing.

10.1.1 The properties used in the analysis are tensile strength and elongation at break.

NOTE 5—**Caution:** The following explanations of I_r and I_R (10.3 through 10.3.3) are intended only to present a meaningful way of considering the approximate precision of this test method. The data in Table 5 should not be applied rigorously to acceptance or rejection of material, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories.

10.2 Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 10.3 through 10.3.3 would then be valid for such data.

10.3 *Concept of I_r and I_R*—If CV_r and CV_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens:

10.3.1 *I_r: Repeatability*—In comparing two test results for the same material, obtained by the same operator using the same equipment on the same day, the two test results should be judged not equivalent if they differ by more than the I_r value for that material.

10.3.2 *I_R: Reproducibility*—In comparing two test results for the same material, obtained by different operators using different equipment on different days, the two test results should be judged not equivalent if they differ by more than the I_R value for that material.

10.3.3 Any judgment in accordance with 10.3.1 and 10.3.2 would have an approximate 95 % (0.95) probability of being correct.

10.4 *Bias*—Bias is systematic error that contributes to the difference between a test result and a true (or reference) value. There are no recognized standards on which to base an estimate of bias for this test procedure.

11. Keywords

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

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