



Designation: D3144 – 23

Standard Specification for Crosslinked Poly(Vinylidene Fluoride) and Poly(Vinylidene Fluoride) Copolymer Heat-Shrinkable Tubing for Electrical Insulation¹

This standard is issued under the fixed designation D3144; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers semirigid, flame-retardant, crosslinked poly(vinylidene fluoride) heat-shrinkable tubing for electrical insulation purposes. It is supplied in an expanded form and will shrink to its extruded diameter when heated.

NOTE 1—This standard is similar but not identical to IEC 60684–3–228.

1.2 The values stated in inch-pound units are to be regarded as the standard, except temperature which shall be stated in degrees Celsius. Values in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

- D910 Specification for Leaded Aviation Gasolines
- D1711 Terminology Relating to Electrical Insulation
- D2671 Test Methods for Heat-Shrinkable Tubing for Electrical Use
- D3222 Specification for Unmodified Poly(Vinylidene Fluoride) (PVDF) Molding Extrusion and Coating Materials
- D3636 Practice for Sampling and Judging Quality of Solid

Electrical Insulating Materials

- D5575 Classification System for Copolymers of Vinylidene Fluoride (VDF) with Other Fluorinated Monomers
- D8355 Test Methods for Flammability of Electrical Insulating Materials Used for Sleeving or Tubing
- E176 Terminology of Fire Standards

2.2 Federal Standards:³

- SS-S-550 Sodium Chloride, Technical, for Water-Softening Units

2.3 IEC Standards:⁴

- IEC 60684-3-228 Flexible insulating sleeving, Part 3, Sheet 228: Heat-shrinkable, semi-rigid, polyvinylidene fluoride sleeving, flame retarded, fluid resistant, shrink ratio 2:1

2.4 Military Standards:⁵

- MIL-PRF-5606 Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordinance
- MIL-PRF-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5
- MIL-PRF-7808 Lubrication Oil, Aircraft, Turbine Engine, Synthetic Base
- MIL-PRF-23699 Lubrication Oil, Aircraft, Turbine Engines, Synthetic Base

2.5 SAE Standards:⁶

- SAE-AMS-1424 Anti-Icing and Deicing—Defrosting Fluid

3. Terminology

3.1 Definitions:

- 3.1.1 For definitions pertaining to electrical insulation, refer to Terminology D1711.
- 3.1.2 For definitions pertaining to fire standards, refer to Terminology E176.

¹ This specification is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.07 on Electrical Insulating Materials.

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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 Available from U. S. Government Accountability Office (GAO), 441 G St., NW, Washington, DC 20548, <http://www.gao.gov>.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, <http://quicksearch.dla.mil>.

⁶ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

4. Ordering Information

4.1 When tubings are ordered to this specification, it is up to the purchaser to define the size and color of the required tubing.

5. Materials and Manufacture

5.1 The compound used in the manufacture of heat-shrinkable tubing shall be modified poly(vinylidene fluoride), and the finished compound shall be free of all foreign matter other than intended formulation additives as appropriate.

5.1.1 Poly(vinylidene fluoride) shall be as described in Specification [D3222](#).

5.1.2 Poly(vinylidene fluoride) copolymers shall be as described in Classification [D5575](#).

5.2 The tubing shall be extruded, crosslinked, and then expanded to the required dimensions.

5.3 Poly(vinylidene fluoride) will be subsequently referred to as Grade 1, and poly(vinylidene fluoride) copolymers will be subsequently referred to as Grade 2. If no grade is specified, then Grade 1 shall become the default grade.

6. Chemical Property Requirements

6.1 The material shall conform to the chemical property requirements specified in [Table 1](#).

6.2 Every lot of material manufactured shall be tested for flammability (when applicable). Other chemical requirements shall be permitted to be tested less frequently or at a frequency agreed upon between the purchaser and the seller.

7. Physical Property Requirements

7.1 The material shall conform to the mechanical, thermal, and electrical requirements of [Table 2](#).

7.2 Every lot of material manufactured shall be tested for restricted shrinkage, heat shock, tensile strength, and elongation. Other physical requirements shall be permitted to be tested less frequently or at a frequency agreed upon between the purchaser and seller.

8. Dimensional Requirements

8.1 The material shall conform to the dimensional requirements of [Table 3](#).

8.2 Tubing with non-standard dimensions shall be permitted to be supplied when agreed upon between purchaser and seller. Tubing with non-standard dimensions shall be considered to comply with this specification if the requirements of [Table 1](#) and [Table 2](#) are satisfied and the minimum recovered wall thickness equals or exceeds that of the identical or next largest nominal size. The wall for sizes greater than 1 in. shall be at least as thick as that of the 1 in. size.

9. Workmanship

9.1 The tubing shall be homogeneous and essentially free of flaws, defects, pinholes, bubbles, seams, cracks, or inclusions.

9.2 Clear tubing shall be transparent to translucent light tan or in a color as agreed between purchaser and seller.

10. Sampling

10.1 A lot shall consist of all material which is processed at the same time and under the same conditions and submitted for inspection at one time.

10.2 Properties shall be permitted to be tested at any stage in processing when they are unaffected by subsequent processing.

10.3 Select a quantity of the product at random from each lot in accordance with Practice [D3636](#) and [Table 5](#).

10.4 Statistical process control measurements shall be permitted to be used to demonstrate conformance in lieu of the sampling plan noted herein when the demonstrated process capability is greater than the specified AQL.

11. Number of Tests and Retests

11.1 The methods of test define the number of specimens and length required for each test.

11.2 If the results of any test, except for attributes listed in [Table 3](#), do not conform to the requirements prescribed in this specification, perform two additional tests on different specimens from the same lot. Nonconformance to [Table 3](#) requirements on first inspection shall be cause for rejection.

11.3 If either of the two additional tests result in nonconformance, the purchaser has the option of rejecting the lot of material. Notice of nonconformances observed by the purchaser based on tests made according to this specification

TABLE 1 Chemical Property Requirements

Property	Grade 1 Poly(vinylidene fluoride)	Grade 2 Poly(vinylidene fluoride) Copolymers
Fluid resistance, 24 h at 23 ± 3 °C (73 ± 6 °F) JP-4 fuel, MIL-T-5624 Lubricating oil, MIL-L-7808 Lubricating oil, MIL-L-23699 Hydraulic fluid, MIL-H-5606 5% NaCl, SS-S-550 Aviation gasoline, Grade 100, min octane 130, Specification D910 Deicing fluid, MIL-A-8243		
Followed by tests for:		
Dielectric strength, min, V/mil (kV/mm)	500 (19.7)	500 (19.7)
Tensile strength, min, psi (MPa) at 2 in. (50 mm)/min	5000 (34.5)	2000 (13.8)
Flammability, Test Methods D8355 , Test A, max, s	15	15
Water absorption, 24 h at 23 ± 3 °C (73 ± 6 °F), max %	0.5	0.5

TABLE 2 Physical Property Requirements

Property	Grade 1	Grade 2
	Poly(vinylidene fluoride)	Poly(vinylidene fluoride) Copolymers
Restricted shrinkage, Procedure A, 175 ± 3 °C (347 ± 6 °F) 2000 V	no cracking, no dielectric breakdown	no cracking, no dielectric breakdown
Dielectric strength, min, V/mil (kV/mm)	600 (23.6)	600 (23.6)
Heat shock, 300 ± 4 °C (572 ± 7 °F)	no cracking, flowing, or dripping	no cracking, flowing, or dripping
Low-temperature flexibility, -55 ± 2 °C (-67 ± 4 °F) ^A Use Procedure A of Methods D2671 for sizes 3/64 through 1/2 Use Procedure C of Methods D2671 for sizes 3/4 through 1	no cracking	no cracking
Tensile strength, min, psi (MPa), using 1-in. (25 mm) bench marks and 1-in. (25 mm) jaw separation at 2 in. (50 mm)/min	5000 (34.5)	2000 (13.8)
Elongation, min %, using 1-in. (25 mm) bench marks and 1-in. (25 mm) jaw separation at 2 in. (50 mm)/min	150	150
Heat resistance, 168 h at 250 ± 3 °C (482 ± 6 °F)	50	50
Elongation, min, %		
Volume resistivity, min, Ω-cm	10 ¹³	10 ¹³
Secant modulus, min, psi (MPa)	10 ⁵ (690)	10 ⁵ (690)
Specific gravity, max	1.8	1.81

^A See Table 4 for mandrels.

TABLE 3 Dimensional Requirements

Nominal Size, in.	As Supplied		After Heat Shrinking		Longitudinal Change, %
	Inside Diameter, min. in. (mm)	Eccentricity, max, %	Inside Diameter, max, in. (mm)	Wall Thickness, in. (mm)	
3/64	0.046 (1.16)	40	0.023 (0.59)	0.010 ± 0.002 (0.25 ± 0.05)	±10
1/16	0.063 (1.60)	40	0.031 (0.76)	0.010 ± 0.002 (0.25 ± 0.05)	±10
3/32	0.093 (2.34)	40	0.046 (1.16)	0.010 ± 0.002 (0.25 ± 0.05)	±10
1/8	0.125 (3.18)	40	0.062 (1.60)	0.010 ± 0.002 (0.25 ± 0.05)	±10
3/16	0.187 (4.75)	40	0.093 (2.34)	0.010 ± 0.002 (0.25 ± 0.05)	±10
1/4	0.250 (6.35)	40	0.125 (3.18)	0.012 ± 0.003 (0.31 ± 0.08)	±10
3/8	0.375 (9.50)	40	0.187 (4.75)	0.012 ± 0.003 (0.31 ± 0.08)	±10
1/2	0.500 (12.7)	40	0.250 (6.35)	0.012 ± 0.003 (0.31 ± 0.08)	±10
3/4	0.750 (19.1)	40	0.375 (9.50)	0.017 ± 0.003 (0.43 ± 0.08)	±10
1	1.000 (25.4)	40	0.500 (12.7)	0.019 ± 0.003 (0.48 ± 0.09)	±10

TABLE 4 Mandrel Sizes

Heat-shrinkable Tubing Inside Diameter as Supplied, in.	Mandrel Diameter, in. (mm)
3/64 to 1/4	0.312 (7.94)
3/8 to 1/2	0.375 (9.53)
3/4 to 1	0.438 (11.1)

TABLE 5 Sampling Table for Lot Acceptance Tests

Property	Requirement	Inspection Level	AQL	Sampling Unit, ft (m)
Inside diameter as supplied	Table 3	S-3	1.0	4 (1.2)
Inside diameter after unrestricted shrinkage	Table 3	S-3	1.0	4 (1.2)
Wall thickness after shrinkage	Table 3	S-3	1.0	4 (1.2)
Longitudinal change	Table 3	S-2	1.0	4 (1.2)
Straight length size, min	15.1 herein	S-3	1.0	single straight length
Workmanship	9.1 herein	I	2.5	4 (1.2)

shall be reported to the manufacturer within 60 days from receipt of the material.

11.4 Tubing that has been rejected shall be permitted to be replaced or reworked to correct the nonconformances and resubmitted for inspection. Before resubmitting, full particulars

concerning previous rejection and action taken to correct the nonconformances shall be furnished to the inspector.

12. Test Methods

12.1 Use the test methods described in Test Methods D2671 unless stated otherwise in Table 1 or Table 2.

12.2 Use a time of 3 min and a temperature of 200 ± 2 °C (392 ± 4 °F) to recover (shrink) tubings in this specification.

13. Inspection

13.1 The manufacturer or purchaser or both shall have available all the facilities to enable the complete testing to this specification.

14. Certification

14.1 When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.