



# Standard Specification for Crosslinked Polyolefin Heat-Shrinkable Tubing for Electrical Insulation<sup>1</sup>

This standard is issued under the fixed designation D 3149; 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 flexible and semirigid crosslinked polyolefin heat-shrinkable tubing used for electrical insulating purposes. It is supplied in an expanded form and will shrink to its extruded diameter when heated.

NOTE 1—This standard is similar to but not identical to IEC 60684–3–209, –211 and –212.

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.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 910 Specification for Aviation Gasolines<sup>2</sup>
- D 1711 Terminology Relating to Electrical Insulation<sup>3</sup>
- D 2671 Test Methods for Heat-Shrinkable Tubing for Electrical Use<sup>4</sup>
- D 3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials<sup>4</sup>
- E 176 Terminology of Fire Standards<sup>5</sup>

### 2.2 Military Standards:<sup>6</sup>

- MIL-STD-104 Limits for Electrical Insulation Color
- MIL-H-5606 Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
- MIL-T-5624 Turbine Fuel, Aviation, Grades JP4 and JP5
- MIL-L-7808 Lubricating Oil, Aircraft, Turbine Engine, Synthetic Base
- MIL-L-23699 Lubricating Oil, Aircraft, Turbine Engines, Synthetic Base
- MIL-A-8243 Anti-Icing and De-Icing Defrosting Fluid

### 2.3 Federal Standards:

SS-S-550 Sodium Chloride, Technical, for Water-Softening Units<sup>7</sup>

### 2.4 IEC Standards:

- 60684–3–209 Flexible insulating sleeving, Part 3, Sheet 209: Heat-shrinkable sleeving, general purpose, flame retarded polyolefin, shrink ratio 2:1<sup>8</sup>
- 60684–3–211 Flexible insulating sleeving, Part 3, Sheet 211: Heat-shrinkable sleeving, general purpose, semi-rigid polyolefin, shrink ratio 2:1<sup>8</sup>
- 60684–3–212 Flexible insulating sleeving, Part 3, Sheet 212: Heat-shrinkable polyolefin sleeving, general purpose, flame retarded, shrink ratio 2:1<sup>8</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 For definitions pertaining to electrical insulation, refer to Terminology D 1711.

3.1.2 For definitions pertaining to fire standards, refer to Terminology E 176.

## 4. Classification

4.1 *Type I*—Flexible, flame-retardant, opaque polyolefin tubing with a secant modulus at 2 % strain less than 25 000 psi (172 MPa).

4.2 *Type II*—Flexible, non-flame-retardant, clear or opaque polyolefin tubing with a secant modulus at 2 % strain less than 25 000 psi (172 MPa).

4.3 *Type III*—Semi-rigid, flame-retardant, opaque polyolefin tubing with a secant modulus at 2 % strain greater than 25 000 psi (172 MPa).

4.4 *Type IV*—Semi-rigid, non-flame-retardant, clear or opaque polyolefin tubing with a secant modulus at 2 % strain greater than 25 000 psi (172 MPa).

## 5. Ordering Information

5.1 When tubing is ordered to this specification, the purchaser should define the type, size, and color of the required tubing.

<sup>1</sup> 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 Flexible and Rigid Insulating Materials.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 05.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 10.02.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.07.

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

<sup>7</sup> May be obtained from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

<sup>8</sup> Available from American National Standards Institute, 11 W. 42nd St., New York, NY 10036.

## 6. Materials and Manufacture

6.1 The polymers used in the manufacture of heat-shrinkable tubing shall be virgin material, that is, material that has been through the manufacturing process only once, and the finished compound shall be free of all foreign matter other than intended formulation additives as appropriate.

6.2 The tubing shall be extruded, cross-linked, and then expanded to the required dimensions.

## 7. Chemical Property Requirements

7.1 The material shall conform to the chemical requirements specified in Table 1.

7.2 Every lot of Type I and Type III material manufactured shall be tested for flammability. Other chemical requirements may be tested less frequently or at a frequency agreed upon by the purchaser and supplier.

## 8. Physical Property Requirements

8.1 The material shall conform to the color, mechanical, thermal, and electrical requirements of Table 2.

8.2 Every lot of material manufactured shall be tested for restricted shrinkage, heat shock, tensile strength, elongation, low-temperature flexibility and color. Other physical property requirements may be tested less frequently or at a frequency agreed upon by purchaser and seller.

## 9. Dimensional Requirements

9.1 The material shall conform to the dimensional requirements of Table 3.

9.2 Tubing with non-standard dimensions may 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 4 in. shall be at least as thick as that of the 4-in. size.

## 10. Workmanship

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

## 11. Sampling

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

11.2 Properties may be tested at any stage in processing when they are unaffected by subsequent processing.

11.3 Select a quantity of the product at random from each lot in accordance with Practice D 3636 and Table 5.

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

## 12. Number of Tests and Retests

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

12.2 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.

12.3 If either of the two additional tests results in a nonconformance, the lot of material may be rejected at the option of the purchaser. Notice of nonconformance determined by the purchaser based on tests made according to this specification shall be reported to the manufacturer within 60 days from receipt of the material.

12.4 Tubing that has been rejected may be replaced or reworked to correct the nonconformance and resubmitted for inspection. Before resubmitting, full particulars concerning previous rejection and action taken to correct the nonconformance shall be furnished to the inspector.

## 13. Test Methods

13.1 Use the test methods described in Methods D 2671 unless otherwise stated in Table 1 or Table 2.

13.2 Use a time of 3 min and a temperature of  $175 \pm 5^\circ\text{C}$  ( $347 \pm 9^\circ\text{F}$ ) to recover (shrink) heat-shrinkable tubing described in this specification.

**TABLE 1 Chemical Property Requirements**

| Property                                                                                                                                                                                                                                                                                                                                                | Type I                            | Type II          | Type III                          | Type IV      |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|------------------|-----------------------------------|--------------|
| Corrosion (as measured by copper removal), 16 h at $150 \pm 2^\circ\text{C}$ ( $302 \pm 4^\circ\text{F}$ ),<br>Procedure A                                                                                                                                                                                                                              | noncorrosive                      | noncorrosive     | noncorrosive                      | noncorrosive |
| Fluid resistance, 24 h at $24 \pm 3^\circ\text{C}$ ( $75 \pm 6^\circ\text{F}$ ):<br>JP-4 Fuel, MIL-T-5624<br>Lubricating Oil, MIL-L-7808<br>Lubricating Oil, MIL-L-23699<br>Hydraulic Fluid, MIL-H-5606<br>5 % NaCl, SS-S-550<br>Aviation Gas Grade 100, min octane 130,<br>Specification D 910<br>De-icing Fluid, MIL-A-8243<br>Followed by tests for: |                                   |                  |                                   |              |
| Dielectric strength, min, V/mil (kV/mm)                                                                                                                                                                                                                                                                                                                 | 400 (15.75)                       | 400 (15.75)      | 400 (15.75)                       | 400 (15.75)  |
| Tensile strength, min, psi (MPa)                                                                                                                                                                                                                                                                                                                        | 1000 (6.9)                        | 1000 (6.9)       | 1600 (11.0)                       | 1600 (11.0)  |
| Flammability, max, s                                                                                                                                                                                                                                                                                                                                    | 60, <25 % paper indicator burned. | N/A <sup>A</sup> | 60, <25 % paper indicator burned. | N/A          |
| Procedure B                                                                                                                                                                                                                                                                                                                                             | No dripping or flowing.           |                  | No dripping or flowing.           |              |
| Water absorption, 24 h at $23 \pm 2^\circ\text{C}$ ( $73 \pm 4^\circ\text{F}$ ) max, %                                                                                                                                                                                                                                                                  | 0.5                               | 0.2              | 0.5                               | 0.2          |

<sup>A</sup> N/A = not applicable.

**TABLE 2 Physical Property Requirements**

| Property                                                                                                                                                                                            | Type I                               | Type II                              | Type III                             | Type IV                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Restricted shrinkage, Procedure A, 30 min at 175 ± 3°C (347 ± 6°F), voltage proof 2000 V                                                                                                            | no cracking, no dielectric breakdown | no cracking, no dielectric breakdown | no cracking, no dielectric breakdown | no cracking, no dielectric breakdown |
| Dielectric strength, min, V/mil (kV/mm)                                                                                                                                                             | 500 (19.7)                           | 500 (19.7)                           | 500 (19.7)                           | 500 (19.7)                           |
| Heat shock; 250 ± 3°C (482 ± 6°F)                                                                                                                                                                   | no cracking, flowing, or dripping    | no cracking, flowing, or dripping    | no cracking, flowing, or dripping    | no cracking, flowing, or dripping    |
| Low-temperature flexibility, – 55 ± 2°C (–67 ± 2°F) (see Table 4 for mandrels)<br>Procedure A of Methods D 2671 for sizes 3/64 through 1/2<br>Procedure C of Methods D 2671 for sizes 3/4 through 4 | no cracking                          | no cracking                          | no cracking                          | no cracking                          |
| Tensile strength, min, psi (MPa):<br>Types I and II, 20 in./min (50 cm/min)<br>Types III and IV, 2 in./min (5 cm/min)                                                                               | 1500 (10.3)                          | 1500 (10.3)                          | 2000 (13.8)                          | 2000 (13.8)                          |
| Elongation, min, %:<br>Types I and II, 20 in./min (50 cm/min)<br>Types III and IV, 2 in./min (5 cm/min)                                                                                             | 200                                  | 200                                  | 200                                  | 200                                  |
| Heat resistance, 168 h at 175 ± 3°C (347 ± 6°F), elongation, min, %                                                                                                                                 | 150                                  | 150                                  | 100                                  | 100                                  |
| Color                                                                                                                                                                                               | MIL-STD-104                          | MIL-STD-104                          | MIL-STD-104                          | MIL-STD-104                          |
| Color stability, 24 h at 175 ± 3°C (347 ± 6°F)                                                                                                                                                      | MIL-STD-104                          | MIL-STD-104<br>N/A for clear         | MIL-STD-104                          | MIL-STD-104<br>N/A for clear         |
| Specific gravity, max                                                                                                                                                                               | 1.35                                 | 1.0                                  | 1.35                                 | 1.0                                  |
| Volume resistivity, min, Ω·cm                                                                                                                                                                       | 10 <sup>14</sup>                     | 10 <sup>16</sup>                     | 10 <sup>14</sup>                     | 10 <sup>16</sup>                     |
| Secant modulus, psi (MPa)                                                                                                                                                                           | 25 000 (172) max                     | 25 000 (172) max                     | 25 000 (172) min                     | 25 000 (172) min                     |
| Copper contact corrosion and copper stability, Procedure B<br>168 h at 160 ± 3°C (320 ± 6°F)                                                                                                        |                                      |                                      |                                      |                                      |
| Copper stability, ultimate elongation, min, % followed by:<br>visual examination                                                                                                                    | no blackening or pitting of copper   | no blackening or pitting of copper   | no blackening or pitting of copper   | no blackening or pitting of copper   |
| ultimate elongation, min, %                                                                                                                                                                         | 150                                  | 150                                  | 150                                  | 150                                  |

**TABLE 3 Dimensional Requirements**

| Nominal Size, in.  | As Supplied                                         |                                           |                                                     | After Heat Shrinking                    |                                           |                        |
|--------------------|-----------------------------------------------------|-------------------------------------------|-----------------------------------------------------|-----------------------------------------|-------------------------------------------|------------------------|
|                    | Types I, II, III, IV Inside Diameter, min, in. (mm) | Types I, II, III, IV Eccentricity, max, % | Types I, II, III, IV Inside Diameter, min, in. (mm) | Types I and II Wall Thickness, in. (mm) | Types III and IV Wall Thickness, in. (mm) | Longitudinal Change, % |
| 3/64               | 0.046 (1.16)                                        | 40                                        | 0.023 (0.59)                                        | 0.016 ± 0.003 (0.41 ± 0.08)             | 0.020 ± 0.003 (0.56 ± 0.08)               | ±5                     |
| 1/16               | 0.063 (1.60)                                        | 40                                        | 0.031 (0.76)                                        | 0.017 ± 0.003 (0.43 ± 0.08)             | 0.020 ± 0.003 (0.51 ± 0.08)               | ±5                     |
| 3/32               | 0.093 (2.34)                                        | 40                                        | 0.046 (1.16)                                        | 0.020 ± 0.003 (0.51 ± 0.08)             | 0.020 ± 0.003 (0.51 ± 0.08)               | ±5                     |
| 1/8                | 0.125 (3.18)                                        | 40                                        | 0.062 (1.60)                                        | 0.020 ± 0.003 (0.51 ± 0.08)             | 0.020 ± 0.003 (0.51 ± 0.08)               | ±5                     |
| 3/16               | 0.187 (4.75)                                        | 40                                        | 0.093 (2.34)                                        | 0.020 ± 0.003 (0.51 ± 0.08)             | 0.025 ± 0.003 (0.63 ± 0.08)               | ±5                     |
| 1/4                | 0.250 (6.35)                                        | 40                                        | 0.125 (3.18)                                        | 0.025 ± 0.003 (0.63 ± 0.08)             | 0.025 ± 0.003 (0.63 ± 0.08)               | ±5                     |
| 3/8                | 0.375 (9.50)                                        | 40                                        | 0.187 (4.75)                                        | 0.025 ± 0.003 (0.63 ± 0.08)             | 0.030 ± 0.003 (0.76 ± 0.08)               | ±5                     |
| 1/2                | 0.500 (12.7)                                        | 40                                        | 0.250 (6.35)                                        | 0.025 ± 0.003 (0.63 ± 0.08)             | 0.030 ± 0.003 (0.76 ± 0.08)               | ±5                     |
| 3/4 <sup>A</sup>   | 0.750 (19.1)                                        | 40                                        | 0.375 (9.50)                                        | 0.030 ± 0.003 (0.76 ± 0.08)             |                                           | ±5                     |
| 1 <sup>A</sup>     | 1.000 (25.4)                                        | 40                                        | 0.500 (12.7)                                        | 0.035 ± 0.005 (0.89 ± 0.13)             |                                           | ±5                     |
| 1 1/2 <sup>A</sup> | 1.500 (38.1)                                        | 40                                        | 0.750 (19.1)                                        | 0.040 ± 0.006 (1.02 ± 0.15)             |                                           | ±5                     |
| 2 <sup>A</sup>     | 2.000 (50.1)                                        | 40                                        | 1.000 (25.4)                                        | 0.045 ± 0.007 (1.15 ± 0.18)             |                                           | ±5                     |
| 3 <sup>A</sup>     | 3.000 (76.4)                                        | 40                                        | 1.500 (38.1)                                        | 0.050 ± 0.008 (1.27 ± 0.20)             |                                           | ±5                     |
| 4 <sup>A</sup>     | 4.000 (101.6)                                       | 40                                        | 2.000 (50.1)                                        | 0.055 ± 0.009 (1.40 ± 0.25)             |                                           | ±5                     |

<sup>A</sup> Types I and II only.

**TABLE 4 Mandrel Sizes for Low-Temperature Flexibility Testing**

| Nominal Tubing Size, in. | Mandrel Diameter, in. (mm) |
|--------------------------|----------------------------|
| 3/64 to 1/4              | 5/16 (8)                   |
| 3/8 to 1/2               | 3/8 (10)                   |
| 3/4 to 2                 | 7/16 (11)                  |
| 3 to 4                   | 7/8 (22)                   |

**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 recovery | 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)                |

## **14. Inspection**

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

## **15. Certification**

15.1 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.

15.2 When original identity cannot be established, certification can only be based on the sampling procedure as defined in Section 10.

## **16. Packaging, Marking, and Shipping**

16.1 The tubing shall be supplied in lengths of  $48 + 1, -0$  in. ( $1220 + 25, -0$  mm) unless otherwise specified.

16.2 The tubing shall be packaged in conformance with good commercial practice unless otherwise specified. Individual types, sizes, and colors shall be neatly bundled or boxed. The exterior shipping container shall be acceptable by parcel post or common carrier.

16.3 Each bundle or container of tubing shall be distinctly identified by a tag or label. The name of the manufacturer, the expanded and recovered dimensions of the tubing, the length, quality, and other appropriate information shall be shown thereon.

## **17. Keywords**

17.1 crosslinked polyolefin heat-shrinkable tubing; electrical insulation; heat-shrinkable tubing; polyolefin

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