

PLASTIC TUBING, ELECTRICAL INSULATION, THERMALLY WELDED
Polyethylene Terephthalate, Heat Shrinkable
1.6 to 1 Shrink Ratio

1. SCOPE:

1.1 Form: This specification covers a polyethylene terephthalate plastic in the form of semi-rigid, extra-thin-wall, heat shrinkable tubing.

1.2 Application: Primarily for use as a semi-rigid, electrical insulation tubing, whose diameter can be reduced to a predetermined size by heating to a temperature higher than 135°C (275°F). This tubing is stable under the following conditions:

- 55°C (-67°F) to +135°C (+275°F)
- 55°C (-67°F) to +140°C (+284°F)
- 55°C (-67°F) to +160°C (+320°F)
- 55°C (-67°F) to +170°C (+338°F)
- 55°C (-67°F) to +180°C (+356°F)
- 55°C (-67°F) to +200°C (+392°F)

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

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2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM D2671 - Testing Heat-Shrinkable Tubing for Electrical Use

ASTM D882 - Tensile Properties of Thin Plastic Sheeting

ASTM G21 - Determining Resistance of Synthetic Polymeric Materials to Fungi

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120.

2.3.1 Military Specifications:

MIL-G-5572 - Gasoline, Aviation, Grades 80/87, 100/130, 115/145

MIL-H-5606 - Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance

MIL-T-5624 - Turbine Fuel, Aviation, Grades JP-4 and JP-5

2.3.2 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Material: Shall be a polyethylene terephthalate plastic. Tubing shall have a single longitudinal, thermally-welded seam and shall contain no adhesives or bonding resins.

3.1.1 Wall Thickness: Shall be 0.0023 inch \pm 0.0003 (0.058 mm \pm 0.008)

3.2 Color: Shall be clear.

3.3 Properties: Tubing shall conform to the following requirements; reported \emptyset values shall be the average of all specimens tested for each requirement. Except as otherwise specified herein, tests shall be performed in accordance with ASTM D2671, insofar as practicable.

3.3.1 Recovered Tubing: The following requirements apply to tubing after being \emptyset shrunk on a smooth metallic mandrel by heating to 160°C + 2 (320°F + 4) in a convection-current oven with an air velocity of 100 - 200 feet/minute (0.5 - 1.0 m/s) past the tubing, holding at heat for not less than 3 minutes, removing from the oven, and conditioning for not less than 4 hours at 23°C + 2 (73°F + 4) and 45 - 55% relative humidity. The mandrel shall have a diameter equal to or less than the acceptable maximum tubing ID [+0.000, -0.002 inch (+0.000, -0.05 mm) or 2%, whichever is greater] after unrestricted shrinkage.

3.3.1.1 Tensile Strength, minimum 20,000 psi (140 MPa)

3.3.1.2 Elongation, minimum 75%

3.3.1.3 Seam Strength, minimum 25 pounds/inch of width ASTM D882,
(110 N/25 mm of width) Method A

3.3.1.4	Flammability (See 8.2)	Self Extinguishing	
3.3.1.5	Dielectric Strength, minimum (short time test)	3000 V/mil (118,110 V/mm)	
3.3.1.6	Volume Resistivity, minimum	10^{15} ohm-cm	
3.3.1.7	Fungus Resistance Ø	Rating of 1 or less	ASTM G21
3.3.1.8	Low-Temperature Flexibility, at $-50^{\circ}\text{C} \pm 2$ ($-60^{\circ}\text{F} \pm 4$)	No cracks	4.5.1
3.3.1.9	Heat Aging, 168 hours ± 2 at $155^{\circ}\text{C} \pm 5$ ($310^{\circ}\text{F} \pm 9$)		
3.3.1.9.1	Elongation, minimum	40%	
3.3.1.10	Solvent Resistance		4.5.2
3.3.1.10.1	Tensile Strength, minimum	20,000 psi (138 MPa)	
3.3.1.10.2	Dielectric Strength, minimum	3000 V/mil (118,110 V/mm)	
3.3.1.11	Dimensional Change on Heating		
3.3.1.11.1	Diametral	In accordance with Table I	
3.3.1.11.2	Longitudinal, maximum	-20%	
3.3.2	<u>Expanded Tubing</u> : The following requirements apply to tubing in the expanded (as-received) condition. Heating for the tests of 3.3.2.1 and 3.3.2.4 shall be performed in an oven as specified in 3.3.1.		
3.3.2.1	Heat Shock, at $180^{\circ}\text{C} \pm 2$ Ø ($355^{\circ}\text{F} \pm 4$)	No dripping, flowing, or cracking	
3.3.2.1.1	Bending after Heat Shock	No cracks	4.5.3
3.3.2.2	Specific Gravity, maximum	1.39	
3.3.2.3	Water Absorption, maximum Ø	0.5%	
3.3.2.4	Color Stability after 48 hours ± 0.5 at $160^{\circ}\text{C} \pm 3$ ($320^{\circ}\text{F} \pm 5$)	Pass	
3.4	<u>Marking</u> : Tubing, prior to and after shrinkage, shall be suitable for having Ø numbers or characters printed on it with conventional tubing marking techniques. Marking applied prior to shrinkage shall not be distorted by non-concentric shrinkage.		

3.5 Quality: Tubing, as received by purchaser, shall be uniform in quality and condition, smooth, and free from foreign materials and from imperfections detrimental to usage of the tubing.

3.6 Standard Sizes and Tolerances: Tubing shall be supplied in lengths of 36 inches, +1, -0 (914 mm, +25, -0) or in continuous coils, as ordered and in standard sizes shown in Table I. Measurements shall be made in accordance with ASTM D2671.

TABLE I

Size	Expanded (As Supplied) ID, minimum		Recovered Dimensions (After Heating) ID, maximum	
	Inches	Millimetres	Inches	Millimetres
1/8	0.125	3.18	0.075	1.90
3/16	0.187	4.75	0.110	2.79
1/4	0.250	6.35	0.150	3.81
3/8	0.375	9.52	0.225	5.72
7/16	0.437	11.10	0.280	7.11
1/2	0.500	12.70	0.300	7.62
9/16	0.562	14.27	0.350	8.89
5/8	0.625	15.88	0.375	9.52
3/4	0.750	19.05	0.450	11.43
7/8	0.875	22.22	0.525	13.34
1	1.000	25.40	0.600	15.24
1-3/8	1.375	34.92	0.825	20.96
1-1/2	1.500	38.10	0.900	22.86
2	2.000	50.80	1.200	30.48
2-1/2	2.500	63.50	1.500	38.10
3	3.000	76.20	1.800	45.72
4	4.000	101.60	2.400	60.96
5	5.000	127.00	3.000	76.20
6	6.000	152.40	3.600	91.44
7	7.000	177.80	4.200	106.68

3.6.1 Dimensional requirements (lengths, inside diameters, wall thicknesses, tolerances, and longitudinal change) of short lengths of tubing used for identification purposes shall be as agreed upon by purchaser and vendor.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of tubing shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.6. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the tubing conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to the following requirements are classified as acceptance tests and shall be performed on each lot:

Requirement	Paragraph Reference
Tensile Strength	3.3.1.1
Elongation	3.3.1.2
Seam Strength	3.3.1.3
Flammability	3.3.1.4
Heat Shock	3.3.2.1
Color Stability	3.3.2.4

4.2.2 Periodic Tests: Tests to determine conformance to the following requirements are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

Requirement	Paragraph Reference
Volume Resistivity	3.3.1.6
Fungus Resistance	3.3.1.7
Low-Temperature Flexibility	3.3.1.8
Heat Aging	3.3.1.9
Solvent Resistance	3.3.1.10
Specific Gravity	3.3.2.2
Water Absorption	3.3.2.3

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of the tubing to a purchaser, when a change in material, processing, or both requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling: Shall be in accordance with ASTM D2671 and the following; except as specified in 4.5, the number of determinations for each requirement shall be as specified in the applicable test procedure or, if not specified therein, not less than three.

4.3.1 For Acceptance Tests: Not less than 16 feet (5 m) of tubing from each lot.

4.3.1.1 A lot shall be all tubing of the same size from one production run and presented for vendor's inspection at one time. A lot may be packaged in smaller quantities and delivered under the basic lot approval provided lot identification is maintained.

4.3.1.2 When a statistical sampling plan and acceptance quality level (AQL) have been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3.1 and the report of 4.6.1 shall state that such plan was used.

4.3.3 For Periodic Tests and Preproduction Tests: As agreed upon by purchaser and vendor.

4.4 Approval:

4.4.1 Sample tubing shall be approved by purchaser before tubing for production use is supplied, unless such approval be waived by purchaser. Results of tests on production tubing shall be essentially equivalent to those on the approved sample tubing.

4.4.2 Vendor shall establish parameters for the process control factors which will produce acceptable tubing; these shall constitute the approved procedures and shall be used for manufacturing production tubing. If necessary to make any change in parameters for the process control factors, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, test specimens, sample tubing, or both. Production tubing incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 Control factors for producing tubing include, but are not limited to, the following:

Geometry of weld tooling
Thermal bonding temperatures
Pressure and feed rate
Methods of inspection

4.4.2.1.1 Any of the above process control factors for which parameters are considered proprietary by the vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation.

4.5 Test Methods:

4.5.1 Low-Temperature Flexibility: Three specimens, each 6 inches (152 mm) long [6 x 1/4 inch (152 x 6 mm) strips cut from sizes 3/8 and larger], shall be conditioned at $-50^{\circ}\text{C} + 2$ ($-58^{\circ}\text{F} + 4$) for four hours. A fixed steel mandrel, selected in accordance with Table II, shall be conditioned at this temperature. Upon completion of this conditioning, and at this same temperature, the specimens shall be wrapped not less than 360 degrees about the mandrel in approximately two seconds. The specimens, after wrapping, shall be free from cracks. Any side-cracking, caused by flattening of the specimen on the mandrel, shall be disregarded.

TABLE II

Inside Diameter		Diameter of Mandrel	
Inches	Millimetres	Inches	Millimetres
1/8 to 3/16, incl	3.2 to 4.8, incl	5/16	7.9
1/4 to 1, incl	6.4 to 25.4, incl	3/4	19.0
1 to 7, incl	25.4 to 177.8, incl	1-1/8	28.6

4.5.2 Solvent Resistance: Tubing shall be immersed for 24 hours at $23^{\circ}\text{C} + 2$ ($73^{\circ}\text{F} + 4$) in MIL-T-5624 JP-4 fuel, SAE phosphate ester test fluid No. 1A, MIL-H-5606 hydraulic oil, MIL-G-5572, Grade 100/130, aviation gasoline, and water, using separate specimens for each fluid. After immersion, remove specimens from test fluid, rinse, dry, and test for tensile strength and dielectric strength.

4.5.3 Bending After Heat Shock: Specimens from the heat shock test of 3.3.2.1 shall be bent 180 degrees around the applicable mandrel of Table II. Any side-cracking, caused by flattening of the specimen on the mandrel, shall be disregarded.

4.6 Reports:

4.6.1 The vendor of tubing shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements and, when performed, to the periodic test requirements and stating that the tubing conforms to the other technical requirements of this specification. This report shall include the purchase order number, AMS 3591A, vendor's compound number, lot number, size, and quantity.

4.6.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 3591A, contractor or other direct supplier of tubing, supplier's compound number, part number, and quantity. When tubing for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of tubing to determine conformance to the requirements of this specification and shall include in the report either a statement that the tubing conforms or copies of laboratory reports showing the results of tests to determine conformance.