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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 3591B

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Superseding AMS 3591A

POLYETHYLENE TEREPHTHALATE PLASTIC TUBING, ELECTRICAL INSULATION
Thermally Welded, 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 tubing.

1.2 Application:

This tubing has been used typically 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), but usage is not limited to such applications. This tubing is stable under the following conditions:

-55 to +135 °C	-67 to +275 °F	Continuous
-55 to +140 °C	-67 to +284 °F	15000 hours
-55 to +160 °C	-67 to +320 °F	1000 hours
-55 to +170 °C	-67 to +338 °F	110 hours
-55 to +180 °C	-67 to +356 °F	24 hours
-55 to +200 °C	-67 to +392 °F	5 hours

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The applicable issue of referenced publications shall be the issue in effect on the date of the purchase order.

2.1 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D 882 Tensile Properties of Thin Plastic Sheeting
ASTM D 910 Aviation Gasolines
ASTM D 2671 Testing Heat-Shrinkable Tubing for Electrical Use
ASTM G 21 Determining Resistance of Synthetic Polymeric Materials to Fungi

2.2 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-H-5606 Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-T-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-STD-2073-1 DOD Materiel, Procedures for Development and Application of Packaging Requirements

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 ± 0.0003 (0.058 mm ± 0.008)

3.1.2 Color: Shall be clear.

3.2 Properties:

Tubing shall conform to the following requirements; reported 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 D 2671, insofar as practicable.

3.2.1 Recovered Tubing: The requirements shown in Table 1 apply to tubing after being 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 to 200 feet/minute (0.5 to 1.0 m/s) past the tubing, holding at heat for not less than three minutes, removing from the oven, and conditioning for not less than four hours at 23 °C ± 2 (73 °F ± 4) and 45 to 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.

TABLE 1 - Recovered Tubing Properties

Paragraph	Property	Requirement	Test Method
3.2.1.1	Tensile Strength, minimum	20.0 ksi (138 MPa)	
3.2.1.2	Elongation, minimum	75%	
3.2.1.3	Seam Strength, minimum	25 pounds force/inch (4378 N/m) of width	ASTM D 882, Method A
3.2.1.4	Flammability (See 8.2)	Self Extinguishing	
3.2.1.5	Dielectric Strength, minimum (short time test)	3000 Volts/mil (118 kV/mm)	
3.2.1.6	Volume Resistivity, minimum	10^{15} ohm-cm	
3.2.1.7	Fungus Resistance	Rating of 1 or less	ASTM G 21
3.2.1.8	Low-Temperature Flexibility at -50 °C ± 2 (-58 °F ± 4)	No cracks	4.5.1
3.2.1.9	Heat Aging, After 168 hours ± 2 at 155 °C ± 5 (311 °F ± 9)		
3.2.1.9.1	Elongation, minimum	40%	
3.2.1.10	Solvent Resistance		4.5.2
3.2.1.10.1	Tensile Strength, minimum	20.0 ksi (138 MPa)	
3.2.1.10.2	Dielectric Strength, minimum	3000 Volts/mil (118 kV/mm)	

TABLE 1 - Recovered Tubing Properties (Continued)

Paragraph	Property	Requirement	Test Method
3.2.1.11	Dimensional Change on Heating		
3.2.1.11.1	Diametral	In accordance with Table 1	
3.2.1.11.2	Longitudinal, maximum	-20%	

3.2.2 Expanded Tubing: The requirements shown in Table 2 apply to tubing in the expanded (as-received) condition. Heating for the tests of 3.2.2.1 and 3.2.2.4 shall be performed in an oven as specified in 3.2.1.

TABLE 2 - Expanded Tubing Properties

Paragraph	Property	Requirement	Test Method
3.2.2.1 (R)	Heat Shock, at 200 °C ± 3 (392 °F ± 5)	No dripping, flowing, or cracking	
3.2.2.1.1	Bending after Heat Shock	No cracks	4.5.3
3.2.2.2	Specific Gravity, maximum	1.39	
3.2.2.3	Water Absorption, maximum	0.5%	
3.2.2.4 (R)	Color Stability after 48 hours ± 0.5 at 200 °C ± 3 (392 °F ± 5)	Pass	

3.3 Marking:

Tubing, prior to and after shrinkage, shall be suitable for having numbers or characters printed on it with conventional tubing marking techniques. Marking applied prior to shrinkage shall not be distorted by non-concentric shrinkage.

3.4 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.

3.5 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 3. Measurements shall be made in accordance with ASTM D 2671.

TABLE 3 - Standard Sizes

Size	Expanded (As Supplied) ID, minimum Inches	Expanded (As Supplied) ID, minimum Millimeters	Recovered Dimensions (After Heating) ID, maximum Inches	Recovered Dimensions (After Heating) ID, maximum Millimeters
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

3.5.1 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:

(R)

The vendor of tubing shall supply all samples for vendor's tests and shall be responsible for performing all required tests. 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 for requirements shown in Table 4 are acceptance tests and shall be performed on each lot.

TABLE 4 - Acceptance Tests

Requirement	Paragraph Reference
Tensile Strength	3.2.1.1
Elongation	3.2.1.2
Seam Strength	3.2.1.3
Flammability	3.2.1.4
Heat Shock	3.2.2.1
Color Stability	3.2.2.4

4.2.2 Periodic Tests: Tests for requirements shown in Table 5 are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

TABLE 5 - Periodic Tests

Requirement	Paragraph Reference
Dielectric Strength	3.2.1.5
Volume Resistivity	3.2.1.6
Fungus Resistance	3.2.1.7
Low-Temperature Flexibility	3.2.1.8
Heat Aging	3.2.1.9
Solvent Resistance	3.2.1.10
Dimensional Change on Heating	3.2.1.11
Specific Gravity	3.2.2.2
Water Absorption	3.2.2.3

4.2.3 Preproduction Tests: Tests for all technical requirements are preproduction tests and shall be performed prior to or on the initial shipment of the tubing to a purchaser, when a change in ingredients and/or processing 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 and Testing:

(R) Shall be in accordance with ASTM D 2671 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.

4.3.1.2 (R) When a statistical sampling plan has 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 shall state that such plan was used.

4.3.2 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.

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 6.4 mm) strips cut from sizes 3/8 and larger], shall be conditioned at -50 °C ± 2 (-58 °F ± 4) for four hours. A fixed steel mandrel, selected in accordance with Table 6, 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 6 - Mandrel Diameter

Inside Diameter Inches	Inside Diameter Millimeters	Diameter of Mandrel Inches	Diameter of Mandrel Millimeters
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 (R) Solvent Resistance: Tubing shall be immersed for 24 hours at 23 °C ± 2 (73 °F ± 4) in MIL-T-5624 JP-4 fuel, SAE phosphate ester test fluid No. 1A, MIL-H-5606 hydraulic oil, ASTM D 910, 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 3.2.2.1, shall be bent 180 degrees around the applicable mandrel of Table 6. Any side-cracking, caused by flattening of the specimen on the mandrel, shall be disregarded.

4.6 (R) Reports:

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. This report shall include the purchase order number, lot number, AMS 3591B, vendor's compound number, size, and quantity.