Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE MATERIAL SPECIFICATION

AMS 3591

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Revised

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

1. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

2. FORM: Extra thin wall semi-rigid tubing.

3. 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 material is stable under the following conditions:

-55 C (-67 F) to +135 C (+275 F)	Continuous
-55 C (-67 F) to +140 C (+284 F)	15,000 hr
-55 C (-67 F) to +160 C (+320 F)	1,000 hr
-55 C (-67 F) to +170 C (+338 F)	110 hr
-55 C (-67 F) to +180 C (+356 F)	24 hr
-55 C (-67 F) to +200 C (+392 F)	5 hr

4. COMPOSITION: The tubing shall consist entirely of polyethylene terephthalate film with a single longitudinal, thermally welded seam, and shall contain no adhesives or bonding resins.

5. TECHNICAL REQUIREMENTS:

5.1 Color: Clear, unless otherwise ordered.

5.2 Properties: The product shall conform to the requirements of 5.2.1 through 5.2.6 and shall be capable of meeting the requirements of 5.2.7 through 5.2.13. Tests shall be performed in accordance with the issue of specified ASTM methods listed in the latest issue of AMS 2350, insofar as practicable. Unless otherwise specified, the tubing shall be tested after shrinking, on a smooth, metallic mandrel by heating for 5 min. in a mechanical convection oven, which is at 160 C ± 2 (320 F ± 3.6), with an air velocity of 100 - 200 ft per min. past the tubing, removed from the oven, and cooled to room temperature. The mandrel shall have a diameter equal to or less than the acceptable maximum tubing ID (+0.000, - 0.002 in. or 2% whichever is greater) after unrestricted shrinkage.

5.2.1	Tensile Strength, psi, min	20,000	ASTM D638, Speed D See Note 1
5.2.2	Elongation, %, min	75	ASTM D638, Speed D See Note 1
5.2.3	Seam Strength, lb per in. of width, min	25	ASTM D882, Method A
5.2.4	Color Stability	Pass	Note 2
5.2.5	Heat Shock	Pass	Note 3
5.2.6	Flammability	Self Extinguishing	ASTM D876

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5.2.7	Low Temperature Flexibility	Pass	Note 4
5.2.8	Heat Aging	Pass	Note 5
5.2.9	Solvent Resistance	Pass	Note 6
5.2.10	Fungus Resistance	Pass	Note 7
5.2.11	Specific Gravity, max	1.39	ASTM D792, Method A
5.2.12	Water Absorption in 24 hr, %, max	0.5	ASTM D357
5.2.13	Volume Resistivity, ohm-cm, min	10^{15}	ASTM D257
5.2.14	Dielectric Strength, short time test, v per mil, min	3000	ASTM D876

Note 1. Five specimens, each 4 in. long, shall be tested using 1 in. bench marks and 1 in. initial jaw separation. The specimens shall be full sections of tubing for sizes 1/4 and smaller and strip specimens, not less than 1/4 in. wide, cut longitudinally from sizes 3/8 and larger. No metal plugs are necessary when testing full sections of tubing. A specimen break at a bench mark or outside the gage length shall be cause for retest.

Note 2. Three specimens in the expanded form (as supplied), each 4 in. long, shall be conditioned for 48 hr in a mechanical convection oven which is at 160 C ± 3 (320 F ± 5.4) with an air velocity of 100 - 200 ft per min. past the specimens. After conditioning, the specimens shall be removed from the oven and cooled to room temperature. The material shall be clear after exposure.

Note 3. Three specimens in the expanded form (as supplied), each 6 in. long, shall be conditioned for 4 hr in a mechanical convection oven which is at 180 C ± 2 (356 F ± 3.6) with an air velocity of 100 - 200 ft per min. past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and visually examined. Tubing shall not drip, flow, or crack. Also, tubing shall be bent through 180 deg over a steel mandrel of the diameter shown in Table I. The tubing shall remain free from cracks, except that any side cracking caused by flattening of the specimen on the mandrel shall be disregarded.

TABLE I

ID, Inches	Diameter of Mandrel, Inches
1/8 to 3/16, incl	5/16
1/4 to 1, incl	3/4
1 to 7, incl	1-1/8

Note 4. Three specimens, each 6 in. long (6 in. by 1/4 in. strips cut from sizes 3/8 and larger), shall be conditioned at -50 C ± 2 (-58 F ± 3.6) for 4 hours. A fixed steel mandrel, selected in accordance with Table I above, 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 deg about the mandrel in approximately 2 seconds. The specimens shall be free from cracks.

Note 5. Specimens, prepared as in Note 1, shall be conditioned for 168 hr in a mechanical convection oven which is at 155 C ± 5 (311 F ± 9) with an air velocity of 100 - 200 ft per min. past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and tested for elongation. Specimens shall have elongation not less than 40%.

Note 6. Tubing shall have tensile strength not lower than 20,000 psi and dielectric strength not lower than 3,000 v per mil after being immersed for 24 hr ± 2 at 23 C ± 3 (73.4 F ± 5.4) in JP-4 fuel, SAE phosphate ester fluid No. 1, hydraulic oil, aviation gasoline 100/130, and water. Six specimens (a total of 30) each 6 in. long, shall be immersed in each of the fluids. The volume of the fluid shall be not less than 20 times that of the specimens. After immersion, the specimens shall be lightly wiped, air dried for 30 - 60 min. at room temperature, and subjected to the tensile strength and dielectric strength tests; three of each group of six specimens shall be tested for tensile strength and the other three for dielectric strength.

Note 7. Fungus resistance shall be determined in accordance with ASTM D1924 except that the incubation period shall be 28 days and the test organisms shall be Aspergillus niger, Aspergillus flavus, Penicillium luteum, and Trichoderma T-1. Three specimens, each 3 in. long, shall be used for each organism. At the end of the incubation period, not more than traces of growth on the specimens are permissible.

5.3 Dimensions After Shrinkage:

5.3.1 Diametral: Three specimens in the expanded form (as supplied) each 6 in. long, shall be measured for length and inside diameter. The specimens shall be conditioned for 5 min. in a mechanical convection oven which is at 160 C ± 2 (320 F ± 3.6) on a smooth metallic mandrel which has a diameter equal to or less than the maximum tubing ID (+0.000, -0.002 or 2%, whichever is greater) after shrinkage. The air velocity shall be 100 - 200 ft per min. past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and then measured. Longer heating at such temperature shall cause no additional shrinkage. Prior to and after conditioning, the dimensions of the tubing shall be in accordance with Table II. Measurements shall be made in accordance with ASTM D876.

5.3.2 Longitudinal: In reaching its recovered dimensions, the tubing shall not exhibit a longitudinal change greater than that listed in Table II computed as follows:

$$\% \text{ Change} = \frac{\text{Length after heating - Length before heating}}{\text{Length before heating}} \times 100$$

6. QUALITY: The product shall be uniform in quality and condition, clean, smooth, and free from foreign materials and from imperfections detrimental to fabrication, appearance, or performance of parts.

7. STANDARD SIZES AND TOLERANCES: Tubing shall be supplied in lengths of 36 in., +1, -0, or in continuous coils, as ordered.

TABLE II

Expanded (As Supplied)		Recovered Dimensions (After Heating)	
ID, Inches min	Wall Thickness Inch	ID, Inches max	Longitudinal Change %, max
1/8 (0.125)	0.0023 ± 0.0003	0.075	-20
3/16 (0.187)	0.0023 ± 0.0003	0.110	-20
1/4 (0.250)	0.0023 ± 0.0003	0.150	-20
3/8 (0.375)	0.0023 ± 0.0003	0.225	-20
7/16 (0.437)	0.0023 ± 0.0003	0.280	-20
1/2 (0.500)	0.0023 ± 0.0003	0.300	-20
9/16 (0.562)	0.0023 ± 0.0003	0.350	-20
5/8 (0.625)	0.0023 ± 0.0003	0.375	-20
3/4 (0.750)	0.0023 ± 0.0003	0.450	-20
7/8 (0.875)	0.0023 ± 0.0003	0.525	-20
1 (1.000)	0.0023 ± 0.0003	0.600	-20
1-3/8 (1.375)	0.0023 ± 0.0003	0.825	-20
1-1/2 (1.500)	0.0023 ± 0.0003	0.900	-20

TABLE II (Continued)

Expanded (As Supplied)		Recovered Dimensions (After Heating)	
ID, Inches min	Wall Thickness Inch	ID, Inches max	Longitudinal Change %, max
2 (2.000)	0.0023 ± 0.0003	1.200	-20
2-1/2 (2.500)	0.0023 ± 0.0003	1.500	-20
3 (3.000)	0.0023 ± 0.0003	1.800	-20
4 (4.000)	0.0023 ± 0.0003	2.400	-20
5 (5.000)	0.0023 ± 0.0003	3.000	-20
6 (6.000)	0.0023 ± 0.0003	3.600	-20
7 (7.000)	0.0023 ± 0.0003	4.200	-20

8. REPORTS:

8.1 Unless otherwise specified, the vendor of the product shall furnish with each shipment three copies of a report showing the results of tests made on the product to determine conformance to the requirements of 5.2.1 through 5.2.6 and a statement that the product conforms to all other requirements of this specification. This report shall include the purchase order number, material specification number, vendor's compound number, size, and quantity.

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

9. PACKAGING:

9.1 Packaging shall be accomplished in such a manner as to ensure that the product, during shipment and storage, will not be permanently distorted and will be protected against damage from exposure to weather or any normal hazard. Unless otherwise specified, standard packages shall contain the following quantities:

ID, Inches	Quantity
1/8 to 1, incl	3 ft pieces or 500 ft reels
1-3/8 to 3, incl	3 ft pieces or 250 ft reels
4 to 7, incl	3 ft pieces or 100 ft reels

9.2 Each package shall be permanently and legibly marked with AMS 3591, size, quantity, purchase order number, manufacturer's identification, and date of manufacture.

10. APPROVAL:

10.1 To assure adequate performance characteristics, compounds shall be approved by purchaser before material for production use is supplied, unless such approval be waived. Results of tests on production material shall be essentially equivalent to those on the approved sample.

10.2 Vendor shall establish for this material the control factors of processing which will produce tubing meeting all requirements of this specification. These shall constitute the approved procedures and shall be used for manufacturing tubing. If necessary to make any changes in control factors of processing which could affect quality or properties of the tubing, vendor shall submit for reapproval a statement of the revised procedures and, when requested, sample tubing. No production tubing incorporating the revised procedures shall be shipped prior to receipt of approval.