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

AEROSPACE MATERIAL SPECIFICATION

AMS 3638C
Superseding AMS 3638B
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PLASTIC TUBING, ELECTRICAL INSULATION
Irradiated Polyolefin, Pigmented, Semi-Rigid, Heat Shrinkable
2 to 1 Shrink Ratio

1. SCOPE:

1.1 Form: This specification covers an irradiated, thermally-stabilized, flame resistant, modified polyolefin plastic in the form of semi-rigid, thin wall, heat shrinkable tubing.

1.2 Application: Primarily as a semi-rigid, electrical insulation tubing whose diameter can be reduced to a predetermined size by heating to temperatures higher than 121 C (250 F). This material is stable under the following conditions:

-55 C (-67 F) to 135 C (275 F)	Continuous
-55 C (-67 F) to 150 C (302 F)	2000 hr
-55 C (-67 F) to 175 C (347 F)	336 hr
-55 C (-67 F) to 200 C (392 F)	48 hr
-55 C (-67 F) to 250 C (482 F)	8 hr
-55 C (-67 F) to 300 C (572 F)	2 hr

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

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

2.1.1 Aerospace Material Specification:

AMS 2350 - Standards and Test Methods

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

ASTM D149 - Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM D257 - D-C Resistance or Conductance of Insulating Materials
ASTM D471 - Change in Properties of Elastomeric Vulcanizates Resulting from Immersion in Liquids
ASTM D570 - Water Absorption of Plastics
ASTM D573 - Accelerated Aging of Vulcanized Rubber by the Oven Method
ASTM D638 - Tensile Properties of Plastics
ASTM D792 - Specific Gravity and Density of Plastics by Displacement
ASTM D876 - Testing Nonrigid Vinyl Chloride Polymer Tubing
ASTM D882 - Tensile Properties of Thin Plastic Sheeting
ASTM D1924 - Determining Resistance of Plastics to Fungi

2.3 Government Publications: Available from Superintendent of Documents, Government Printing Office, Washington, D. C. 20402

2.3.1 Federal Specification:

UU-T-450 - Tissue, Facial

SAE Technical Board rules provide that: "All technical reports, including standards and recommended practices approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

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2.3.2 Military Specifications:

MIL-H-5606 - Hydraulic Fluid, Petroleum Base, Aircraft, Missiles and Ordnance
MIL-T-5624 - Turbine Fuel, Aviation, Grades JP-4 and JP-5

2.3.3 Military Standard:

MIL-STD-104 - Limit for Electrical Insulation Color

3. TECHNICAL REQUIREMENTS:

3.1 Composition: The material shall be an irradiated, thermally-stabilized, flame-resistant, modified polyolefin.

3.2 Color: The tubing shall be furnished in the color specified in Table II for the respective size. Unless otherwise specified, the colors shall be in accordance with MIL-STD-104.

3.3 Properties: The product shall conform to the requirements of 3.3.1 through 3.3.5 and shall be capable of meeting the requirements of 3.3.6 through 3.3.17. Tests shall be conducted in accordance with specified ASTM methods, insofar as practicable. Unless otherwise specified, tubing shall be tested after being shrunk by heating for 3 min. in a mechanical convection oven which is at 200 C ± 5 (392 F ± 9), with an air velocity of 100 - 200 ft per min. (508 - 1016 mm/s) past the tubing, removed from the oven, and cooled to room temperature.

3.3.1 Tensile Strength, min		ASTM D638, Speed D (See 3.3.1.1)
Sizes 3/64 to 1/4, incl	2500 psi (17.2 MN/m^2)	
Sizes 3/8 to 1/2, incl	2000 psi (13.8 MN/m^2)	

3.3.1.1 Five specimens, each 4 in. (101.6 mm) long, shall be tested, using 1 in. (25.4 mm) bench marks and 1 in. (25.4 mm) 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. (6.35 mm) wide cut longitudinally from sizes 3/8 and larger. Metal plugs are not necessary when testing full sections of tubing. A specimen break at a bench mark or outside the gage length shall be cause for retest.

3.3.2 Elongation, min	200%	ASTM D638, Speed D (See 3.3.1.1)
3.3.3 Secant Modulus at 2% Strain, max	45,000 psi (310.3 MN/m^2)	ASTM D882 (See 3.3.3.1)

3.3.3.1 Five specimens in the expanded form (as supplied), each 12 in. (304.8 mm) long, shall be tested. The specimens shall be full sections of tubing for sizes 1/4 and smaller and strip specimens not less than 1/2 in. (12.7 mm) wide cut longitudinally from sizes 3/8 and larger. Metal plugs are not necessary when testing full sections of tubing. Initial strain rate shall be 0.1 in. per in. per min. (0.1 mm/mm/min.).

3.3.4 Heat Shock: Shall pass the test of 3.3.4.1.

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3.3.4.1 Three specimens in the expanded form (as supplied), each 6 in. (152.4 mm) long, shall be conditioned for 4 hr in a mechanical convection oven which is at 250 C ± 5 (482 F ± 9), with an air velocity of 100 - 200 ft per min. (508 - 1016 mm/s) past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and examined visually. Tubing shall not drip, flow, or crack. Tubing shall then be bent through 180 deg (3.14 rad) over a 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

Size	Diameter of Mandrel	
	Inch	(Millimeters)
3/64 to 3/16, incl	5/16	(7.94)
1/4 to 1/2, incl	3/8	(9.52)

3.3.5 Flammability: Shall pass the test of 3.3.5.1.

3.3.5.1 Five specimens, each 5 in. (127 mm) long, shall be marked 1 in. (25.4 mm) from each end with contrasting color ink. Each specimen shall be mounted at an angle of approximately 45 deg (0.785 rad) in a draft free chamber by a clamp that completely closes the upper end of the tubing. An 8 x 8 in. (203.2 x 203.2 mm) piece of tissue paper conforming to UU-T-450 shall be centered approximately 9-1/2 in. (241 mm) below the test specimen and at least 1/2 in. (12.7 mm) from the table top, in such a manner that any dripping particle will fall on the tissue paper. A 1 in. (25.4 mm) high blue flame from a standard 3/8 in. (9.52 mm) diameter Bunsen burner shall then be applied to the lowest point of each specimen. When specimen has been burned to the lower ink mark, the flame shall be removed and the specimen shall remain undisturbed until burning ceases. Failure of more than one specimen to extinguish within 3 in. (76.2 mm), failure of more than one specimen to extinguish within 60 sec, or flaming of the tissue paper shall be cause for rejection.

3.3.6 Low Temperature Flexibility: Shall pass the test of 3.3.6.1.

3.3.6.1 Three specimens, each 12 in. (304.8 mm) long, shall be conditioned at -55 C ± 2 (-67 F ± 3.6) for 4 hours. A fixed steel mandrel, selected in accordance with Table I above (see 3.3.4.1), 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 (6.28 rad) about the mandrel in approximately 2 seconds. The specimens shall be free from cracks.

3.3.7 Heat Aging: Shall pass the test of 3.3.7.1.

3.3.7.1 Specimens shall be prepared as in 3.3.1.1 and shall be conditioned for 336 hr in a mechanical convection oven which is at 175 C ± 3 (347 F ± 5.4), with an air velocity of 100 - 200 ft per min. (508 - 1016 mm/s) 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 lower than 150%.

3.3.8 Copper Stability: Shall pass the test of 3.3.8.1.

3.3.8.1 A specimen of each color of tubing, 6 in. (152.4 mm) long, shall be slid over a straight, clean, unplated, uninsulated, solid copper conductor. For sizes 1/4 and smaller, a single copper conductor shall be used; for sizes 3/8 and larger, several copper conductors shall be used, each conductor AWG 18 (0.0403 in.) (1.024 mm) or smaller. The specimens on horizontally suspended conductors shall be conditioned for not less than 24 hr in a humidity chamber at 90 - 95% relative humidity and 25 C ± 3 (77 F ± 5.4). The specimens on horizontally suspended conductors shall then be conditioned for 168 hr in an oven which is at 160 C ± 3 (320 F ± 5.4), in accordance with ASTM D573, cooled to room temperature, and examined. The tubing shall not be brittle, glazed, cracked, severely discolored, or otherwise deteriorated by direct contact with copper. The elongation of the tubing shall be not lower than 200%. The copper shall not be pitted or blackened. Darkening of the copper due to normal air oxidation shall be disregarded.

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3.3.9 Corrosion: Shall pass the test of 3.3.9.1.

3.3.9.1 A specimen 1 in. (25.4 mm) long shall be placed in the bottom of each of two clean 1/2 x 12. in. (12.7 x 304.8 mm) test tubes. A third test tube shall be used for control. A copper-glass mirror about 1/4 in. (6.35 mm) wide x 1 in. (25.4 mm) long shall be suspended 6 - 7 in. (152.4 - 177.8 mm) above the bottom of each tube by fine copper wire attached to a silicone rubber stopper wrapped in aluminum foil. The mirrors shall be vacuum-deposited copper, on one side only, with a thickness equal to 10% ± 5 transmission of normal incident light of 5000 Angstroms (5×10^{-7} m). The coated mirrors shall be stored in vacuum and may be used for test only if no oxide film is present and the copper is not visibly damaged. The three test tubes shall be tightly sealed. The lower 2 in. (50.8 mm) of each tube shall be placed in an oven or oil bath at 175 C ± 3 (347 F ± 5.4) for 16 hours. After cooling, the mirrors shall be examined in a good light against a white background. The copper shall not have been removed from a mirror leaving an area of transparency greater than 5% of the total area. Discoloration of the copper film shall not be considered corrosion.

3.3.10 Color Stability: Shall pass the test of 3.3.10.1.

3.3.10.1 Three specimens, in the expanded form (as supplied), each 4 in. (101.6 mm) long of each color shall be conditioned for 48 hr in a mechanical convection oven which is at 175 C ± 3 (347 F ± 5.4), with an air velocity of 100 - 200 ft per min. (508 - 1016 mm/s) past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and determined to be within the limits of MIL-STD-104.

3.3.11 Solvent Resistance: Shall pass the test of 3.3.11.1.

3.3.11.1 Tubing shall have tensile strength not lower than 1600 psi (11.0 MN/m^2) and dielectric strength not lower than 400 v per mil (15,750 V/mm) after being immersed for 24 hr ± 2 at 23 C ± 3 (73.4 F ± 5.4) in JP-4 Fuel (MIL-T-5624), SAE Phosphate ester fluid No. 1, hydraulic oil (MIL-H-5606), ASTM Fuel B (ASTM D471), and water. Six specimens (a total of 30), each 6 in. (152.4 mm) long, shall be immersed in each of the fluids. The volume of 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.

3.3.12 Fungus Resistance: Shall pass the test of 3.3.12.1.

3.3.12.1 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. At the end of the incubation period, not more than traces of growth on the specimens are permissible. Three specimens, each 3 in. (76.2 mm) long, shall be used for each organism.

3.3.13 Restricted Shrinkage: Shall pass the test of 3.3.13.1.

3.3.13.1 A specimen in the expanded form (as supplied) shall be shrunk onto a clean metallic mandrel of the configuration and size shown in Fig. 1. The tubing on the mandrel shall then be conditioned for 30 min. in an oven which is at 175 C ± 5 (347 F ± 9), in accordance with ASTM D573. When cooled to room temperature, the tubing shall be examined visually and shall then be subjected to the following voltage withstand test. The tubing shall snugly fit the mandrel and shall not be cracked. The test potential shall be applied between the mandrel and a metal foil electrode wrapped around the largest diameter of the tubing, in accordance with ASTM D876. The test potential shall then be applied in accordance with the short-time test of ASTM D149 using a 500 v per sec rate of rise. The specimen shall withstand 2000 v for 1 minute.

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3.3.14	Specific Gravity, max	1.35	ASTM D792, Method A
3.3.15	Water Absorption in 24 hr, max	0.50%	ASTM D570
3.3.16	Dielectric Strength, short time test, min	500v per mil (19,680 V/mm)	ASTM D876
3.3.17	Volume Resistivity, min	10^{14} ohm-cm	ASTM D257

3.4 Dimensions After Shrinkage:

3.4.1 Diametral: Three specimens in the expanded form (as supplied), each 6 in. (152.4 mm) long, shall be measured for length and inside diameter. The specimens shall be conditioned for 3 min. in a mechanical convection oven which is at 200 C ± 5 (392 F ± 9), with an air velocity of 100 - 200 ft per min. (508 - 1016 mm/s) past the specimens. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and remeasured. 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.

3.4.2 Longitudinal: In reaching its recovered dimensions, the tubing shall not exhibit a longitudinal change greater than + 1%, - 5%, computed as follows:

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

3.5 Marking: Prior to or after shrinkage, tubing shall be capable of having numbers or characters printed on it with conventional tubing marking techniques.

3.6 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.

3.7 Standard Sizes and Tolerances: Unless otherwise specified, tubing shall be supplied in lengths of 48 in., +1, -0 (1219 mm + 25.4, -0), and in the standard sizes and tolerances shown in Table II. Tolerances apply at 23 - 30 C (73.4 - 86 F).

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor shall supply all samples and shall be responsible for performing all required tests. Results of such tests performed shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to assure that material conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Routine Control Tests: Tests to determine conformance to tensile strength (3.3.1), elongation (3.3.2), secant modulus (3.3.3), heat shock (3.3.4), flammability (3.3.5), diametral change (3.4.1), and longitudinal change (3.4.2) requirements are classified as routine control tests.

4.2.2 Periodic Control Tests: Tests to determine conformance to low temperature flexibility (3.3.6), heat aging (3.3.7), copper stability (3.3.8), corrosion (3.3.9), color stability (3.3.10), solvent resistance (3.3.11), fungus resistance (3.3.12), restricted shrinkage (3.3.13), specific gravity (3.3.14), water absorption (3.3.15), dielectric strength (3.3.16), and volume resistivity (3.3.17) requirements are classified as qualification and/or periodic control tests.

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TABLE II

Color	Size	Expanded (As Supplied) ID, Inches min	Recovered Dimensions (After Heating) ID, Inches max	Nominal Wall Thickness Inch	Wall Thickness Tolerance Inch plus and minus
Yellow	3/64	0.046	0.023	0.020	0.003
White	1/16	0.063	0.031	0.020	0.003
Blue	3/32	0.093	0.046	0.020	0.003
Red	1/8	0.125	0.062	0.020	0.003
Green	3/16	0.187	0.093	0.025	0.003
Gray	1/4	0.250	0.125	0.025	0.003
Brown	3/8	0.375	0.187	0.030	0.003
White	1/2	0.500	0.250	0.030	0.003

TABLE II (SI)

Color	Size	Expanded (As Supplied) ID, Millimeters min	Recovered Dimensions (After Heating) ID, Millimeters max	Nominal Wall Thickness Millimeters	Wall Thickness Tolerance Millimeter plus and minus
Yellow	3/64	1.168	0.584	0.508	0.0762
White	1/16	1.602	0.787	0.508	0.0762
Blue	3/32	2.362	1.168	0.508	0.0762
Red	1/8	3.175	1.575	0.508	0.0762
Green	3/16	4.750	2.362	0.635	0.0762
Gray	1/4	6.350	3.175	0.635	0.0762
Brown	3/8	9.525	4.750	0.762	0.0762
White	1/2	12.700	6.350	0.762	0.0762

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4.3 Sampling:

4.3.1 Routine Control Test Samples: Shall consist of not less than 16 ft (4.88 m) of tubing selected at random from each lot. A lot shall consist of all tubing of the same size from the same production run and offered for inspection at the same time.

4.3.2 Periodic Control Test Samples: Shall consist of 50 ft (15.25 m) of tubing of each size and color. Certain sizes will qualify additional sizes, as shown below:

Range of Sizes	Qualification Size
3/64 - 1/4, incl	1/4
3/8 - 1/2, incl	1/2

4.4 Reports:

4.4.1 The vendor of the product shall furnish with each shipment three copies of a report showing the results of routine control tests made on the lot and a statement that the product conforms to all other technical requirements of this specification. This report shall include the purchase order number, material specification number and its revision letter, vendor's compound number, lot number, size, color, and quantity.