

 <p>SAE Aerospace An SAE International Group</p>	<p>AEROSPACE MATERIAL SPECIFICATION</p>	<p>SAE AMS 3593A</p>				
		<table> <tr> <td>Issued</td> <td>JUL 1984</td> </tr> <tr> <td>Revised</td> <td>JAN 1991</td> </tr> <tr> <td>Reaffirmed</td> <td>MAR 2003</td> </tr> </table> <p>Superseding AMS 3593</p>	Issued	JUL 1984	Revised	JAN 1991
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**Tubing, Plastic, Electrical Insulation
 Irradiated Polyvinylidene Fluoride, Semi-Rigid, Heat-Shrinkable
 Marker Sleeving Grade
 Low Outgassing**

1. SCOPE:

1.1 Form:

This specification covers an irradiated, thermally-stabilized, flame-resistant, modified-polyvinylidene-fluoride plastic in the form of extra-thin-wall tubing.

1.2 Application:

Primarily for use as a semi-rigid, electrical insulation tubing and marker sleeves in short lengths whose diameter can be reduced to a predetermined size by heating to temperatures of 175 °C (347 °F) or higher.

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.

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2.1 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or
www.astm.org.

ASTM D 471	Rubber Property - Effect of Liquids
ASTM D 910	Aviation Gasolines
ASTM D 2671	Testing Heat-Shrinkable Tubing for Electrical Use
ASTM E 595	Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ASTM G 21	Determining Resistance of Synthetic Polymeric Materials to Fungi

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue,
Philadelphia, PA 19111-5094.

2.2.1 Military Specifications:

MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-L-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-A-8243	Anti-icing and Deicing-Defrosting Fluid

2.2.2 Military Standards:

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

3. TECHNICAL REQUIREMENTS:**3.1 Material:**

Shall be an irradiated, thermally-stabilized, flame-resistant, modified-polyvinylidene fluoride plastic.

3.2 Color:

Shall be opaque white.

3.3 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.

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3.3.1	Recovered Tubing: The following requirements apply to tubing after being shrunk by heating to 200 °C ± 5 (392 °F ± 9) in a convection-current air oven with an air velocity of 100 to 200 feet per minute (0-5 to 1.0 m/second) 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 to 55% relative humidity:	
3.3.1.1	Tensile Strength, minimum Jaw separation rate 2.0 inches per minute (0.85 mm/second)	4000 psi (27.6 MPa)
3.3.1.2	Elongation, minimum	200%
3.3.1.3	Dielectric Strength (short time test), minimum	600 volts/mil (23,622 V/mm)
3.3.1.4	Volume Resistivity, minimum	10 ¹² ohm-cm
3.3.1.5	Flammability, Burning Time Procedure A, maximum (See 8.2)	15 seconds
3.3.1.6	Fungus Resistance	Rating of 1 or less ASTM G 21
3.3.1.7	Heat Aging, 168 hours ± 2 at 225 °C ± 3 (437 °F ± 5)	
3.3.1.7.1	Tensile Strength, minimum	3000 psi (20.7 MPa)
3.3.1.7.2	Elongation, minimum	150%
3.3.1.8	Fluid Resistance	4.5.1
3.3.1.8.1	Tensile Strength, minimum	2000 psi (13.8 MPa)
3.3.1.8.2	Dielectric Strength, minimum	500 volts/mil (19,685 V/mm)
3.3.1.9	Dimensional Change on Heating	
3.3.1.9.1	Diametral	In accordance with Table I
3.3.1.9.2	Longitudinal, maximum	± 10%
3.3.1.10	Vacuum Outgassing	ASTM E 595

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3.3.1.10.1 Total Mass Loss (TML), maximum	1.0%	
3.3.1.10.2 Volatile Condensable Material (VCM), maximum	0.1%	
3.3.2 Expanded Tubing: The following requirements apply to tubing in the expanded (as-received) condition. Heating for the tests of 3.3.2.2 and 3.3.2.3 shall be performed in an oven as specified in 3.3.1.		
3.3.2.1 Secant Modulus at 2% Strain, minimum	80,000 psi (552 MPa)	
3.3.2.2 Heat Shock, 4 hours \pm 0.25 at 275 °C \pm 5 (527 °F \pm 9)	No dripping, flowing, or cracking	
3.3.2.3 Restricted Shrinkage, Procedure C, after 30 minutes \pm 1 at 175 °C \pm 5 (347 °F \pm 9)	No cracks; withstand 2000 volts for 1 minute	
3.3.2.4 Specific Gravity, maximum	1.90	
3.3.2.5 Low-Temperature Flexibility 4 hours \pm 0.25 at -55 °C \pm 2 (-67 °F \pm 4)	No cracks	4.5.3
3.3.2.6 Water Absorption, maximum 24 hours \pm 0.25 at 25 °C \pm 2 (77 °F \pm 4)	2.0%	
3.4 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.		
3.5 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 48 inches, + 1, -0 (1219 mm, +25, -0), and in the standard sizes and to the tolerances shown in Table I. Tolerances apply at 23 to 30 °C (73 to 86 °F). Measurements shall be made in accordance with ASTM D 2671.		

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

TABLE I

Size	Expanded (As Supplied)		Recovered Dimensions (After Heating)	
	ID, Inches min	ID, Inches max	Nominal Wall Thickness Inch	Wall Thickness Tolerance Inch plus and minus
3/64	0.046	0.023	0.010	0.002
1/16	0.063	0.031	0.010	0.002
3/32	0.093	0.046	0.010	0.002
1/8	0.125	0.062	0.010	0.002
3/16	0.187	0.093	0.010	0.002
¼	0.250	0.125	0.012	0.003
3/8	0.375	0.187	0.012	0.003
½	0.500	0.250	0.012	0.003
¾	0.750	0.375	0.017	0.003
1	1.000	0.500	0.019	0.003
1½	1.500	0.750	0.019	0.003
2	2.000	1.000	0.020	0.003

TABLE I (SI)

Size	Expanded (As Supplied)		Recovered Dimensions (After Heating)	
	ID, Millimeters min	ID, Millimeters max	Nominal Wall Thickness Millimeters	Wall Thickness Tolerance Millimeters plus and minus
3/64	1.17	0.58	0.25	0.05
1/16	1.60	0.79	0.25	0.05
3/32	2.36	1.17	0.25	0.05
1/8	3.18	1.57	0.25	0.05
3/16	4.75	2.36	0.25	0.05
¼	6.35	3.18	0.30	0.08
3/8	9.52	4.75	0.30	0.08
½	12.70	6.35	0.30	0.08
¾	19.05	9.52	0.43	0.08
1	25.40	12.70	0.48	0.08
1½	38.10	19.05	0.48	0.08
2	50.80	25.40	0.51	0.08

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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, 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 tensile strength (3.3.1.1), elongation (3.3.1.2), dimensional change on heating (3.3.1.9), heat shock (3.3.2.2), and sizes and tolerances (3.6) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests for dielectric strength (3.3.1.3), volume resistivity (3.3.1.4), flammability (3.3.1.5), fungus resistance (3.3.1.6), heat aging (3.3.1.7), fluid resistance (3.3.1.8), vacuum outgassing (3.3.1.10), secant modulus (3.3.2.1), restricted shrinkage (3.3.2.3), specific gravity (3.3.2.4), low-temperature flexibility (3.3.2.5), water absorption (3.3.2.6), and marking (3.4) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

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 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:

Shall be in accordance with ASTM D 2671 and the following; a lot shall be all tubing of the same size from the same production run presented for vendor's inspection at one time. 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. A lot may be packaged in small quantities and delivered under the basic lot approval provided lot identification is maintained.

4.3.1 For Acceptance Tests: Not less than 16 feet (4.9 m) of tubing from each lot.

4.3.1.2 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.

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4.3.2 For Periodic Tests: Not less than 48 feet (14.6 m) of tubing of each size or size range. Any size within a size range may be chosen to demonstrate conformance to that size range.

Range of Sizes

3/64 - 3/16, incl
 1/4 - 2, incl

4.3.3 For 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 use ingredients, manufacturing procedures, processes, and methods of inspection on production tubing which are essentially the same as those used on the approved sample tubing. If necessary to make any change in ingredients, in type of equipment for processing, or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in ingredients and/or processing and, when requested, sample tubing. Tubing made by the revised procedure shall not be shipped prior to receipt of reapproval.

4.5 Test Methods:

4.5.1 Fluid Resistance: Shall be determined in accordance with ASTM D 2671 on specimens immersed for 24 hours ± 2 at 23 °C ± 3 (73 °F ± 5) in MIL-T-5624 JP-4 fuel, SAE phosphate ester test fluid No. 1A, MIL-L-7808 lubricating oil, MIL-H-5606 hydraulic oil, ASTM service fluid No. 101 (See ASTM D 471), ASTM D 910 aviation gasoline 100/130, MIL-A-8243 anti-icing fluid, and salt water (5% salt), using separate specimens for each fluid.

4.5.2 Bending After Heat Shock: Specimens from the heat shock test of 3.3.2.2 shall be bent 180 degrees around the applicable mandrel of Table II. Any side-cracking, caused by flattening of the specimens on the mandrel, shall be disregarded.

TABLE II

MANDREL DIMENSIONS

Tubing Size	Diameter of Mandrel	
	Inches	Millimeters
3/64 through 3/16	5/16	7.9
1/4 through 2	3/4	19.0

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4.5.3 Low-Temperature Flexibility: For tubing of expanded size of 1/4 inch or greater, three strip specimens 0.250 inch \pm 0.010 (6.35 mm \pm 0.25) wide and 12 inches (305 mm) long shall be cut from the expanded tubing. For tubing of expanded diameter less than 1/4 inch (6.35 mm), three tubular specimens 12 inches (305 mm) long shall be cut from the expanded tubing. The specimens shall be recovered in accordance with 3.3.1 and conditioned in accordance with 3.3.2.5. Mandrel diameter shall be 10 times specimen thickness, \pm 10%. For tubular specimens, the specimen thickness shall be taken as the outside diameter, determined in accordance with ASTM D 2671. After the conditioning period and while at the specified low temperature, and without removing the specimens from the chamber, bend the specimens around the mandrel for not less than one complete wrap (360 degrees) at a uniform speed of about 4 seconds per wrap. Any side cracking, caused by flattening of the specimens on the mandrel, shall be disregarded.

4.6 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 3593A, manufacturer's identification, size, and quantity.

4.7 Resampling and Retesting:

If the average results of specimens tested for any requirement fails to meet the specified value, disposition of the tubing may be based on the results of testing three additional specimens for each original specimen failing to meet the specified average requirement. Failure of the average of the original specimens plus the retest specimens to meet any specified requirement shall be cause for rejection of the tubing represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification:

Each package of tubing shall be permanently and legibly marked with not less than AMS 3593A, size, quantity, purchase order number, lot number, manufacturer's identification, and date of manufacture.

5.2 Packaging:

5.2.1 Packaging shall be accomplished to ensure that the tubing, during shipment and storage, will not be permanently distorted and will be protected against damage from exposure to weather or any other normal hazard. Packaging of marker sleeves shall be as agreed upon by purchaser and vendor. Standard packages shall each contain the following quantities.

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Size	Quantity	
	Feet	Meters
3/64, 1/16, 3/32, 1/8, 3/16, 1/4, 3/8	1000	305
1/2	800	244
3/4	500	152
1	300	91
1 1/2	200	61
2	100	30

5.2.1.1 Packaging of special sizes and lengths shall be as agreed upon by purchaser and vendor.

5.2.2 Packages of tubing shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the tubing to ensure carrier acceptance and safe delivery.

5.2.3 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-794, Commercial Level, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Tubing not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Marginal Indicia:

The change bar (I) is used to indicate technical changes from the previous issue of this specification.

8.2 The flammability test is intended for comparative evaluation of products and is not to be construed as an indication of characteristics of the tubing under actual fire conditions.

8.3 Dimensions and properties in inch/pound units and the Celsius temperatures are primary; dimensions and properties in SI units and the Fahrenheit temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

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8.4 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Size of tubing desired
Quantity of tubing desired
Level A packaging, if required (See 5.2-3).

8.5 Tubing meeting the requirements of this specification has been classified under Federal Supply Classification (FSC) 5970.

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