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Specification
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THERMOFIT[®] RNF-150 TUBING

Flexible, Heat-Shrinkable, Flame-Retarded Modified Fluoropolymer

1. SCOPE

This specification covers the requirements for flexible electrical insulating, extruded tubing whose diameter will reduce to a predetermined size upon the application of heat in excess of 150°C (302°F).

Tubing shall be flame retarded and, unless otherwise specified, colors shall be black and white.

2. APPLICABLE DOCUMENTS

This specification takes precedence over documents referenced herein. Unless otherwise specified, the latest issue of reference documents applies. The following documents form a part of this specification to the extent specified herein.

2.1 GOVERNMENT-FURNISHED DOCUMENTS

Military

MIL-G-5572	Gasoline, Aviation, Grades 80/87, 100/130, and 115/145
MIL-PRF-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordinance
MIL-T-83133	Turbine Fuel, Aviation, Grades JP-8
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-STD-104	Limits for Electrical Insulation Color

2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

D 2671	Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use
D 3032	Method of Testing Hookup Wire Insulation

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

Underwriters Laboratories

UL 224	Standard for Extruded Insulating Tubing
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(Copies of UL publications may be obtained from Underwriters Laboratories Inc., 1285 Walt Whitman Road, Melville, Long Island, New York 11746.)

International Organization for Standardization (ISO)

ISO 846 Plastics – Evaluation of the action of Microorganisms

(Copies of ISO publications may be obtained from the International Organization for Standardization, 1, rue de Varembe, CH-1211 Geneva 20, Switzerland or via the ISO website at <http://www.iso.ch/iso/en/ISOOnline.frontpage>)

3. REQUIREMENTS

3.1 MATERIALS

The tubing shall be fabricated from thermally stabilized, modified fluoropolymer and shall be crosslinked by irradiation. It shall be homogeneous and essentially free from flaws, defects, pinholes, bubbles, seams, cracks, and inclusions.

3.2 PROPERTIES

The tubing shall meet the requirements of Table 3.

4. QUALITY ASSURANCE PROVISIONS

4.1 CLASSIFICATION OF TESTS

4.1.1 Qualification Tests

Qualification tests are those performed on tubing submitted for qualification as a satisfactory product and shall consist of all tests listed in this specification.

4.1.2 Acceptance Tests

Acceptance tests are those performed on tubing submitted for acceptance under contract. Acceptance tests shall consist of the following: dimensions, concentricity, longitudinal change, recovery angle, tensile strength, ultimate elongation, secant modulus, flammability, and heat shock.

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

Qualification test samples shall consist of 50 feet (15 m) of tubing. Qualification of any size within each size range specified below shall qualify all sizes within that size range.

Range of Sizes
3/64 through 1/4
3/8 through 1

For Dynamic Cut-Through test, use size 3/16 or over to qualify all sizes. For Fungus Resistance test, any size shall qualify all sizes. Tubing shall be qualified in both black and white.

4.2.2 Acceptance Test Samples

Acceptance test samples shall consist of not less than 16 feet (5 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 TEST PROCEDURES

Unless otherwise specified, tests shall be performed on specimens which have been fully recovered by conditioning for 3 minutes in a $200 \pm 5^{\circ}\text{C}$ ($392 \pm 9^{\circ}\text{F}$) oven. Prior to all testing, the test specimens (and measurement gauges, when applicable) shall be conditioned for 3 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) and 50 ± 5 percent relative humidity. All ovens shall be of the mechanical convection type in which air passes the specimens at a velocity of 100 to 200 feet (30 to 60 m) per minute.

4.3.1 Dimensions and Longitudinal Change

Three 6-inch (150-mm) specimens of tubing, as supplied, shall be measured for length $\pm 1/32$ inch (± 1 mm), and inside diameter in accordance with ASTM D 2671, conditioned for 3 minutes in a $200 \pm 5^{\circ}\text{C}$ ($392 \pm 9^{\circ}\text{F}$) oven, cooled to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) and then remeasured. Prior to and after conditioning, the dimensions of the tubing shall be in accordance with Table 1 and the longitudinal change shall be in accordance with Table 3. The longitudinal change shall be calculated as follows:

$$C = \frac{L_1 - L_0}{L_0} \times 100$$

Where: C = Longitudinal Change [Percent]
 L_0 = Length Before Conditioning [Inches (mm)]
 L_1 = Length After Conditioning [Inches (mm)]

4.3.2 Concentricity as Supplied

Three 6-inch (150-mm) specimens of tubing, as supplied, shall be measured for minimum and maximum wall thickness. Concentricity shall be calculated as follows:

$$W = \frac{W_{\min}}{W_{\max}} \times 100$$

Where: C = Concentricity [Percent]
 W_{\min} = Minimum Wall Thickness
 W_{\max} = Maximum Wall Thickness

4.3.3 Weight Per Length

A 12-inch $\pm 1/32$ inch ($305\text{-mm} \pm 1$ mm) length of tubing, as supplied, shall be weighed. The weight shall be multiplied by 100 and reported as pounds/100 ft ($kg/100$ m).

4.3.4 Recovery Angle

A length of tubing shall be cut such that the end of the tubing is 90 degrees to the longitudinal axis. The tubing shall be recovered in accordance with Section 4.3, and by means of an optical comparitor or equivalent, the angle between the end and the longitudinal axis shall be measured. The deviation from 90 degrees shall be reported as the recovery angle.

4.3.5 Tensile Strength and Ultimate Elongation

The tensile strength and ultimate elongation of the tubing shall be determined in accordance with ASTM D 2671 using 1-inch (25-mm) bench marks and a 1-inch (25-mm) initial jaw separation. The speed of jaw separation shall be 20 ± 2 inches (500 ± 50 mm) per minute.

4.3.6 Low Temperature Flexibility

For tubing of expanded diameter 1/4 inch (6 mm) or greater, three strip specimens, 1/4 inch (6 mm) wide and 12 inches (300 mm) long, shall be cut from the expanded tubing. For tubing of expanded diameter less than 1/4 inch (6 mm) three tubular specimens, 12 inches (300 mm) long, shall be cut from the expanded tubing. The specimens shall be recovered in accordance with Section 4.3 and conditioned with appropriate mandrels for 4 hours at $-55 \pm 2^{\circ}\text{C}$ ($-67 \pm 4^{\circ}\text{F}$). The mandrel diameter shall be 10 times the specimen thickness, ± 10 percent. For tubular specimens, the specimen thickness shall be equivalent to the outside diameter. While at the specified temperature, and without removing the specimens from the cold chamber, the specimens shall be wrapped 360 degrees around the mandrel in approximately 2 seconds. Any side cracking, caused by flattening of the specimens on the mandrel, shall be disregarded.

4.3.7 Heat Shock

Three 6-inch (150-mm) specimens of tubing shall be conditioned for 4 hours in a $250 \pm 5^{\circ}\text{C}$ ($482 \pm 9^{\circ}\text{F}$) oven. The specimens shall be removed from the oven, cooled to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$), wrapped 180 degrees around a mandrel selected in accordance with Table 2, and then visually examined for evidence of dripping, flowing, or cracking. Any side cracking caused by flattening of the specimen on the mandrel shall not constitute failure.

4.3.8 Dynamic Cut-Through at Temperature

Two 6-inch (150-mm) lengths of size 3/16-inch or over shall each be recovered on a 7-inch (175-mm) length of 3/32-inch (2.38-mm) oil hardened drill rod, by placing in a $200 \pm 5^{\circ}\text{C}$ ($392 \pm 9^{\circ}\text{F}$) mechanical convection oven for 3 minutes. The cut-through tests shall be performed at $135 \pm 3^{\circ}\text{C}$ ($275 \pm 5^{\circ}\text{F}$) in accordance with ASTM D 3032 using the optional cutting edge. Four readings shall be taken on each of the assemblies.

4.3.9 Heat Resistance

Specimens in accordance with Section 4.3.5 shall be conditioned for 336 hours in a $225 \pm 3^{\circ}\text{C}$ ($437 \pm 5^{\circ}\text{F}$) oven. The specimens shall be removed from the oven, cooled to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) and tested for elongation in accordance with Section 4.3.5.

4.3.10 Copper Stability

Three 6-inch (150-mm) specimens of tubing shall be slid over a snug-fitting, straight, clean, bare copper conductor. For tubing sizes 1/4 and smaller, a solid conductor shall be used; for tubing sizes 3/8 and larger, a solid or tubular conductor shall be used. The specimens on the conductors shall be conditioned for 24 hours in a desiccator or similar humidity chamber at 90 to 95 percent relative humidity and $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$). The specimens on the conductors then shall be conditioned for 168 hours in a $180 \pm 3^{\circ}\text{C}$ ($356 \pm 5^{\circ}\text{F}$) oven. After conditioning, the specimens shall be removed from the oven and cooled to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$). The copper conductor then shall be removed from the tubing, and the tubing and conductor shall be examined. Darkening of the copper due to normal air oxidation shall not be cause for rejection. The tubing shall be tested for elongation in accordance with 4.3.5.

4.3.11 Corrosive Effect

4.3.11.1 Copper Mirror Corrosion

The tubing shall be tested for copper mirror corrosion in accordance with ASTM D 2671, Procedure A, for 16 hours at $160 \pm 3^{\circ}\text{C}$ ($320 \pm 5^{\circ}\text{F}$). For tubing sizes 1/8 and larger, specimens shall consist of 1/4 x 1 inch ($6 \times 25 \text{ mm}$) strips cut longitudinally. Evidence of corrosion shall be the removal of copper from a mirror, leaving an area of transparency greater than 5 percent of its total area.

4.3.11.2 Corrosion in Contact with Copper

The tubing shall be tested for corrosion in contact with copper for 16 hours at $175 \pm 3^{\circ}\text{C}$ ($347 \pm 5^{\circ}\text{F}$) in accordance with ASTM D 2671, Procedure B.

4.3.12 Fluid Resistance

Six 6-inch (150-mm) specimens of tubing, prepared and measured in accordance with ASTM D 2671 solvent resistance, shall be completely immersed in each listed fluid for 24 ± 2 hours at $50 \pm 3^{\circ}\text{C}$ ($122 \pm 5^{\circ}\text{F}$). The volume of the fluid shall be not less than 20 times that of the specimens. After immersion, the specimens shall be lightly wiped and air-dried for 30 to 60 minutes at room temperature. Three specimens then shall be tested for dielectric strength and the other three for tensile strength.

4.4 REJECTION AND RETEST

Failure of any sample of tubing to conform to any one of the requirements of this specification shall be cause for rejection of the lot represented. Tubing which has been rejected may be replaced or reworked to correct the defects and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and action taken to correct the defects shall be furnished to the inspector.

5. PREPARATION FOR DELIVERY

5.1 FORM

The tubing shall be supplied on spools, unless otherwise specified.

5.2 PACKAGING

Packaging shall be in accordance with good commercial practice. The shipping container shall not be less than 125-pound-test fiberboard.

5.3 MARKING

Each container of tubing shall be permanently and legibly marked with the size, quantity, manufacturer's identification, specification number, color, lot number and date of manufacturing.

TABLE 1
INSIDE DIAMETERS AND WALL THICKNESSES OF TUBING

Size	Expanded As Supplied		Recovered Dimension -- After Heating								Weight, As Supplied Maximum	
	Inside Diameter Minimum		Inside Diameter Maximum		Wall Thickness						lbs/ 100 ft.	kg/ 100 m
					Minimum		Maximum		Nominal			
	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.		
3/64	0.046	1.17	0.023	0.58	0.008	0.20	0.012	0.30	0.010	0.25	0.10	0.15
1/16	0.063	1.60	0.031	0.79	0.008	0.20	0.012	0.30	0.010	0.25	0.13	0.19
3/32	0.093	2.36	0.046	1.17	0.008	0.20	0.012	0.30	0.010	0.25	0.17	0.25
1/8	0.125	3.18	0.062	1.60	0.008	0.20	0.012	0.30	0.010	0.25	0.22	0.33
3/16	0.187	4.75	0.093	2.36	0.008	0.20	0.012	0.30	0.010	0.25	0.31	0.46
1/4	0.250	6.35	0.125	3.18	0.009	0.23	0.015	0.38	0.012	0.30	0.40	0.60
3/8	0.375	9.53	0.187	4.75	0.009	0.23	0.015	0.38	0.012	0.30	0.73	1.09
1/2	0.500	12.70	0.250	6.35	0.009	0.23	0.015	0.38	0.012	0.30	0.96	1.43
3/4	0.750	19.05	0.375	9.53	0.014	0.35	0.020	0.51	0.017	0.43	1.92	2.85
1	1.000	25.40	0.500	12.70	0.016	0.40	0.022	0.56	0.019	0.48	2.78	4.14

TABLE 2
MANDREL DIMENSIONS
for Heat Shock

Tubing	Mandrel Dimensions	
	in.	mm.
3/64 to 3/16 inclusive	5/16	7.9
1/4 to 1 inclusive	3/4	19.1

TABLE 3
REQUIREMENTS

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
PHYSICAL			
Dimensions	Inches (<i>mm</i>)	In accordance with Table 1	Section 4.3.1
Longitudinal Change	Percent	+0, -10	ASTM D 2671
Concentricity as Supplied	Percent	70% minimum	Section 4.3.2
Weight per Length as Supplied	lbs/100 ft (<i>kg/100 m</i>) maximum	In accordance with Table 1	Section 4.3.3
Recovery Angle	Degrees	5 maximum	Section 4.3.4
Tensile Strength	psi (<i>MPa</i>)	4000 minimum (27.6)	Section 4.3.5
Ultimate Elongation	Percent	300 minimum	ASTM D 2671
Secant Modulus	psi (<i>MPa</i>)	25,000-100,000 (172-690)	ASTM D 2671
Low Temperature Flexibility 4 hours at -55°C (-67°F)	---	No cracking	Section 4.3.6
Heat Shock 4 hours at 250°C (482°F)	---	No dripping, flowing, or cracking	Section 4.3.7
Dynamic Cut-Through 135°C (275°F)	lbs	5 minimum (2.3)	Section 4.3.8 ASTM D 3032
Heat Resistance 336 hours at 225°C (437°F) Followed by test for: Ultimate Elongation	---	---	Section 4.3.9
	Percent	250 minimum	Section 4.3.5 ASTM D 2671
Copper Stability 168 hours at 180°C (356°F) Followed by test for: Ultimate Elongation	---	No brittleness, glazing or severe discoloration of tubing. No pitting or blackening of copper.	Section 4.3.10
	Percent	250 minimum	Section 4.3.5 ASTM D 2671
Color	---	MIL-STD-104, Class I	MIL-STD-104
ELECTRICAL			
Dielectric Strength	Volts per mil (<i>volts per mm</i>)	500 minimum (19,680)	ASTM D 2671
Volume Resistivity	ohm-cm	10 ¹¹ minimum	ASTM D 2671
CHEMICAL			
Corrosive Effect	---	Noncorrosive	Section 4.3.11 ASTM D 2671
Copper Mirror Corrosion 16 hours at 160°C (320°F)	---	Copper removal, 5% maximum	Section 4.3.11.1 ASTM D 2671 Procedure A
Copper Contact Corrosion 16 hours at 175°C (347°F)	---	No blackening or pitting of copper	Section 4.3.11.2 ASTM D 2671 Procedure B
Flammability	---	1) 25% maximum flag burn 2) No burning of cotton 3) No flaming or glowing longer than 60 seconds.	UL 224, VW-1 ASTM D 2671 Procedure C

TABLE 3
REQUIREMENTS (continued)

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
CHEMICAL (continued) Fungus Resistance Followed by tests for: Tensile Strength Ultimate Elongation Dielectric Strength	psi (<i>Mpa</i>) percent Volts per mil (<i>volts per mm</i>)	4000 minimum (<i>27.6</i>) 300 minimum 500 minimum (<i>19,680</i>)	ISO 846 Method B Section 4.3.5 ASTM D 2671 ASTM D 2671
Water Absorption 24 hours at 23°C (<i>73°F</i>)	Percent	0.5 maximum	ASTM D 2671
Fluid Resistance 24 hours at 50°C (<i>122°F</i>) JP-8 Fuel (MIL-T-83133) Hydraulic Fluid (MIL-PRF-5606) Aviation Gasoline (100/130) (MIL-G-5572) Water Lubricating Oil (MIL-L-23699) Followed by tests for: Dielectric Strength	---	---	Section 4.3.12 ASTM 2671
Dielectric Strength	Volts per mil (<i>volts per mm</i>)	400 minimum (<i>15,760</i>)	ASTM D 2671
Tensile Strength	psi (<i>MPa</i>)	2000 minimum (<i>13.8</i>)	Section 4.3.5 ASTM D 2671