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Specification	**RT-220**
This Issue:	Issue 3
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THERMOFIT® RT-220 TUBING
Flexible, Heat-Shrinkable, Flame-Retarded Modified Fluoropolymer - Low Outgassing

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 shall be black or 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-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
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
E 595	Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
G 21	Standard Recommended Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

(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

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

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, size 3/16 shall qualify all sizes. For Fungus Resistance test, any size shall qualify all sizes.

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 ± 5°C *(392 ± 9°F)* oven. Prior to all testing, the test specimens (and measurement gauges, when applicable) shall be conditioned for 3 hours at 23 ± 3°C *(73 ± 5°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 ± 1/32 inch *(± 1 mm)*, and inside diameter in accordance with ASTM D 2671, conditioned for 3 minutes in a 200 ± 5°C *(392 ± 9°F)* oven, cooled to 23 ± 3°C *(73 ± 5°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
L_1 = Length After Conditioning

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:

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

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

4.3.3 Weight Per Length

A 12 ± 1/32 inch *(305 ± 0.8 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 ± 2°C *(-67 ± 4°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 ± 5°C *(482 ± 9°F)* oven. The specimens shall be removed from the oven, cooled to 23 ± 3°C *(73 ± 5°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 tubing 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 ± 5°C *(392 ± 9°F)* mechanical convection oven for 3 minutes. The cut-through tests shall be performed at 135 ± 3°C *(275 ± 5°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 ± 3°C *(437 ± 5°F)* oven. The specimens shall be removed from the oven, cooled to 23 ± 3°C *(73 ± 5°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 ± 3°C *(73 ± 5°F)*. The specimens on the conductors then shall be conditioned for 168 hours in a 180 ± 3°C *(356 ± 5°F)* oven. After conditioning, the specimens shall be removed from the oven and cooled to 23 ± 3°C *(73 ± 5°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 ± 3°C *(320 ± 5°F)*. For tubing sizes 1/8 and larger, specimens shall consist of 1/4 x 1 inch *(6 x 25 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 ± 3°C *(347 ± 5°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 ± 3°C *(122 ± 5°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.

4.3.13 Vacuum Outgassing

Three 0.5 ± .05 gram specimens shall be recovered for 3 minutes at 200°C and then tested for percent total weight loss and percent volatile condensable materials. The conditions for testing are: exposure time, 24 hours; sample temperature 125 ± 3°C; condensing surface temperature, 18 ± 3°C; and pressure, not greater than 1×10^{-5} torr. The vacuum shall be provided by a diffusion pump, liquid nitrogen trap vacuum system. The apparatus shall consist of a glass sample chamber, refluxing liquid heat source and a polished stainless steel plate in close contact with a copper cold finger cooled internally by circulating water. The axis of the exit of the sample chamber shall be perpendicular to and approximately 15-mm from the cooled condensing plate. A Cahn RG micro balance or equivalent shall be used for weighing. The specimen shall be weighed before and after conditioning and total weight loss calculated and the condensing plate shall be weighed before and after to calculate percent volatile condensable material.

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 Dia. Minimum		Inside Dia. Maximum		Wall Thickness							
					Minimum		Maximum		Nominal		lbs/ 100 ft	*kg/ 100 m*
	in.	*mm.*	in.	*mm.*	in.	*mm.*	in.	*mm.*	in.	*mm.*		
3/64	0.046	*1.17*	0.023	*0.58*	0.007	*0.18*	0.012	*0.30*	0.009	*0.23*	0.10	*0.15*
1/16	0.063	*1.60*	0.031	*0.79*	0.007	*0.18*	0.012	*0.30*	0.009	*0.23*	0.13	*0.19*
3/32	0.093	*2.36*	0.046	*1.17*	0.007	*0.18*	0.012	*0.30*	0.009	*0.23*	0.17	*0.25*
1/8	0.125	*3.18*	0.062	*1.60*	0.007	*0.18*	0.012	*0.30*	0.009	*0.23*	0.22	*0.33*
3/16	0.187	*4.75*	0.093	*2.36*	0.007	*0.18*	0.012	*0.30*	0.009	*0.23*	0.31	*0.46*
1/4	0.250	*6.35*	0.125	*3.18*	0.008	*0.20*	0.015	*0.38*	0.011	*0.28*	0.40	*0.60*
3/8	0.375	*9.53*	0.187	*4.75*	0.008	*0.20*	0.015	*0.38*	0.011	*0.28*	0.73	*1.09*
1/2	0.500	*12.70*	0.250	*6.35*	0.008	*0.20*	0.015	*0.38*	0.011	*0.28*	0.96	*1.43*
3/4	0.750	*19.05*	0.375	*9.53*	0.013	*0.33*	0.020	*0.51*	0.016	*0.41*	1.92	*2.85*
1	1.000	*25.40*	0.500	*12.70*	0.015	*0.38*	0.022	*0.56*	0.018	*0.46*	2.78	*4.14*

TABLE 2
Mandrel Dimensions for Heat Shock

Tubing				Mandrel Diameter	
				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 *(mm)*	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 *(kg/100 m)* maximum	In accordance with Table 1	Section 4.3.3
Recovery Angle	Degrees	5 maximum	Section 4.3.4
Tensile Strength	psi *(MPa)*	4000 minimum *(27.6)*	Section 4.3.5
Ultimate Elongation	Percent	300 minimum	ASTM D 2671
Secant Modulus	psi *(MPa)*	50,000 maximum *(345)*	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 at 135°C *(275°F)*	lbs *(kg)*	5 minimum *(2.3)*	Section 4.3.8 ASTM D 3032
Heat Resistance 336 hours at 225°C *(437°F)* Followed by test for:	---	---	Section 4.3.9
Ultimate Elongation	Percent	250 minimum	Section 4.3.5 ASTM D 2671
Copper Stability 168 hours at 180°C *(356°F)* Followed by test for	---	No brittleness, glazing or severe discoloration of tubing. No pitting or blackening of copper.	Section 4.3.10
Ultimate Elongation	Percent	250 minimum	Section 4.3.5 ASTM D 2671
Color	---	MIL-STD-104, Class I	MIL-STD-104
ELECTRICAL			
Dielectric Strength	Volts/ mil *(volts /mm)*	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	--- 	Rating of 1 or less	ASTM G 21
Water Absorption 24 hours at 23°C *(73°F)*	Percent	0.5 maximum	ASTM D 2671
Fluid Resistance 24 hours at 50°C *(122°F)* JP-4 Fuel (MIL-T-5624) Hydraulic Fluid (MIL-H-5606) Aviation Gasoline (100/130) (MIL-G-5572) Water Trichloroethane Lubricating Oil MIL-L-23699 Followed by tests for:	--- 	---	Section 4.3.12 ASTM D 2671
Dielectric Strength	Volts/mil *(volts /mm)*	400 minimum *(15,760)*	ASTM D 2671
Tensile Strength	psi *(MPa)*	2000 minimum *(13.8)*	Section 4.3.5 ASTM D 2671
Vacuum Outgassing TML (Total Mass Loss)	Percent	1.0 maximum	Section 4.3.13
VCM (Volatile Condensable Materials)	Percent	0.1 maximum	ASTM E 595

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- Поставка образцов и прототипов;
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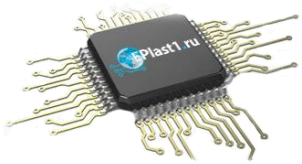

Как с нами связаться

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