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Raychem

Specification	**RT-511**
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RAYCHEM® NT-FR TUBING
Neoprene, Fluid Resistant, Flexible, Heat-Shrinkable

1.0 SCOPE

This specification covers the requirements for one type of highly flexible, electrically insulating, extruded tubing whose diameter will reduce to a predetermined size upon the application of heat in excess of 135°C *(275°F)*.

2.0 APPLICABLE DOCUMENTS

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

2.1 GOVERNMENT-FURNISHED DOCUMENTS

Military

MIL-PRF-5606H	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance, NATO no. H-515.
MIL-PRF-7808L	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, Grade 3 NATO no. O-148, Grade 4 NATO no. O-163.
SAE-AMS-1424	Anti-Icing and Deicing - Defrosting Fluid
MIL-PRF-23699F	Lubricating Oil, Aircraft Turbine Engines, Synthetic Base, NATO no. O-156
MIL-DTL-46162E	Fuel, Diesel, Referee Grade
MIL-PRF-46170D	Hydraulic Fluid, Rust Inhibited, Fire-Resistant, Synthetic Hydrocarbon Base, NATO code no. H-544.
MIL-DTL-83133G	Turbine Fuels, Aviation, Kerosene Types, (NATO F-34) JP-8, (NATO F-35) and JP8+100, (NATO F-37).

Federal

A-A-694D	Sodium Chloride, Technical
A-A-59133B	Cleaning Compound, High Pressure (Steam) Cleaner

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2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

D 257	Standard Test Methods for d-c Resistance or Conductance of Insulating Materials
D 412	Standard Test Methods for Rubber Properties in Tension
D 2240	Standard Test Method of Rubber Property - Durometer Hardness
D 2671	Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use
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.

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 Varembé, CH-1211 Geneva 20, Switzerland or at http://www.iso.org/iso/home.html

3.0 REQUIREMENTS

3.1 MATERIAL

The tubing shall be fabricated from a stabilized, flame resistant, modified neoprene and shall be radiation crosslinked. It shall be homogeneous and essentially free from flaws, defects, pinholes, bubbles, seams, cracks, and inclusions.

3.2 COLOR

The tubing shall be black.

3.3 PROPERTIES

The tubing shall meet the requirements of Table 3.

4.0 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.

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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
Longitudinal Change
Tensile Strength
Tensile Stress
Ultimate Elongation
Heat Shock
Hardness
Flammability
Low Temperature Flexibility

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

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

Size Range
1/8 through 7/8
1 through 3

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 10 minutes in a 175 ± 5°C *(347 ± 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 over the specimens at a velocity of 100 to 200 feet *(30 to 60 m)* per minute.

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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 10 minutes in a 175 ± 5°C *(347 ± 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. 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 Tensile Strength, Tensile Stress, and Ultimate Elongation

Three specimens of tubing shall be tested for tensile strength, tensile stress, and ultimate elongation in accordance with ASTM D 2671. For tubing sizes 3/8 and smaller, the specimens shall be full sections of tubing. For sizes 1/2 and larger, the specimens shall be 1/4-inch *(6.3-mm)* wide strips. The specimens shall have 1-inch *(25-mm)* bench marks, centrally located. The testing machine shall have an initial jaw separation of 1 inch *(25 mm)* for full sections of tubing , and 2 inches *(51 mm)* for strip specimens. The rate of jaw separation shall be 20 ± 2 inches
(500 ± 50 mm) per minute.

4.3.3 Low Temperature Flexibility

Three specimens, each 12 inches *(300 mm)* in length, and a mandrel selected in accordance with Table 2, shall be conditioned at -70 ± 3°C *(-94 ± 5°F)* for 4 hours. For tubing sizes 5/8 or less, the specimens shall be whole sections of tubing recovered on a stranded wire (nearest AWG which is larger than the sleeving maximum inside diameter after unrestricted shrinkage). For tubing sizes larger than 5/8, the specimens shall be 1/4-inch *(6.3-mm)*wide strips cut from tubing which has been recovered in accordance with 4.3. After 4 hours conditioning, and while still at the conditioning temperature, the specimens shall be wrapped around the mandrel for not less than 360° *(6.28 rad)* in 10 ± 2 seconds. The specimens then shall be visually examined for evidence of cracking.

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4.3.4 Heat Shock

Three 6-inch *(150-mm)* specimens of tubing shall be conditioned for 4 hours in a 200 ± 3°C *(392 ± 5°F)* oven. After conditioning, the specimens shall be removed form the oven, cooled to room temperature, and visually examined for evidence of dripping, flowing, or cracking.

4.3.5 Heat Resistance

Three specimens of tubing prepared and measured in accordance with 4.3.2, shall be conditioned for 168 hours in a 121 ± 3°C *(250 ± 5°F)* oven. After conditioning, the specimens shall be removed from the oven, cooled to 23± 3°C *(73 ± 5°F)*, and tested for tensile strength and ultimate elongation in accordance with 4.3.2.

4.3.6 Copper Stability

Three 6-inch *(150-mm)* specimens of tubing shall be slid over snug fitting, straight, clean, bare copper mandrels, either solid or tubular. The specimens on the mandrels shall be conditioned for 24 hours in a desiccator or similar humidity chamber at 90 to 95 percent relative humidity and 25 ± 3°C *(77 ± 5°F)*. The specimens on the mandrels then shall be conditioned for 168 hours in a 121 ± 3°C *(250 ± 5°F)* oven. After conditioning, the specimens shall be removed form the oven, cooled to 23 ± 3°C *(73 ± 5°F)*. The copper mandrels shall then be removed form the tubing and the tubing and copper mandrels 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 4.3.2.

4.3.7 Dielectric Strength

The dielectric strength shall be determined in accordance with the ASTM D 2671 procedure for dielectric breakdown. When dielectric breakdown occurs, the thickness measurements for calculating dielectric strength shall be made adjacent to the point of breakdown and the dielectric strength shall be calculated in volts per mil.

4.3.8 Corrosive Effect

The tubing shall be tested for copper mirror corrosion in accordance with ASTM D 2671, Method A. The specimens shall be conditioned for 16 hours at 150 ± 3°C *(302 ± 5°F)*.

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4.3.9 Fluid Resistance

Six specimens, three 6-inch tubing specimens and three tensile specimens prepared and measured in accordance with 4.3.2, shall be immersed for 24 hours in each of the test fluids listed in Table 3 at the temperature specified. The volume of the fluid shall not be less than 20 times that of the specimens. After conditioning, all the specimens shall be lightly wiped and air dried for 30 to 60 minutes at 23 ± 3°C *(73 ± 5°)*. The three specimens intended for the tensile strength and elongation tests shall then be tested in accordance with 4.3.2. The other three specimens shall be weighed before and after immersion and the weight change calculated as a percentage.

4.4 REJECTION AND RETEST

Failure of any sample of tubing to comply with 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 defect and then resubmitted for acceptance. Before resubmitting, full particulars concerning the rejection and the action taken to correct the defect shall be furnished to the inspector.

5.0 PREPARATION FOR DELIVERY

5.1 PACKAGING

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

5.2 MARKING

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

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TABLE 1
Tubing Dimensions

Size	AS SUPPLIED		RECOVERED							
	Inside Diameter Minimum		Inside Diameter Maximum		Wall Thickness					
					Minimum		Maximum		Nominal	
	in.	*mm.*	in.	*mm.*	in.	*mm.*	in.	*mm.*	in.	*mm.*
1/8	.125	*3.18*	.061	*1.55*	.019	*0.48*	.035	*0.91*	.027	*0.69*
3/16	.187	*4.75*	.100	*2.54*	.023	*0.58*	.043	*1.09*	.033	*0.83*
1/4	.250	*6.35*	.143	*3.63*	.025	*0.63*	.045	*1.14*	.035	*0.88*
3/8	.375	*9.52*	.214	*5.45*	.030	*0.76*	.050	*1.27*	.040	*1.01*
1/2	.500	*12.70*	.286	*7.25*	.033	*0.83*	.063	*1.60*	.048	*1.21*
5/8	.625	*15.87*	.357	*9.06*	.037	*0.93*	.067	*1.70*	.052	*1.32*
3/4	.750	*19.05*	.428	*10.88*	.042	*1.06*	.072	*1.82*	.057	*1.44*
7/8	.875	*22.22*	.500	*12.70*	.050	*1.27*	.080	*2.03*	.065	*1.65*
1	1.000	*25.40*	.570	*14.48*	.050	*1.27*	.090	*2.28*	.070	*1.77*
1-1/4	1.250	*31.75*	.714	*18.13*	.067	*1.70*	.107	*2.71*	.087	*2.20*
1-1/2	1.500	*38.10*	.857	*21.76*	.075	*1.90*	.115	*2.92*	.095	*2.41*
1-3/4	1.750	*44.45*	1.000	*25.40*	.087	*2.20*	.127	*3.22*	.107	*2.71*
2	2.000	*50.80*	1.140	*28.96*	.090	*2.28*	.130	*3.30*	.110	*2.79*
3	3.000	*76.20*	1.710	*43.54*	.105	*2.65*	.145	*3.67*	.125	*3.18*

TABLE 2
Mandrel Dimensions for Bend Testing

Tubing Size	Mandrel Diameter	
	in.	*mm.*
1/8 through 1/2	3/8	*9.5*
5/8 through 1	5/8	*15.9*
1-1/4 through 2	7/8	*22.2*
3	1-1/8	*28.6*

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TABLE 3
Requirements

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
PHYSICAL			
Dimensions	Inches *(mm)*	In accordance with Table 1	Section 4.3.1
Longitudinal Change	Percent	+1, -5	ASTM D 2671
Tensile Strength	psi *(MPa)*	1500 minimum *(10.3)*	
Tensile Stress at 100 percent elongation	psi *(MPa)*	1500 maximum*(10.3)*	Section 4.3.2 ASTM D 2671
Ultimate Elongation	Percent	250 minimum	
Specific Gravity	---	1.5 maximum	ASTM D 2671
Hardness	Shore A	80 ± 5	ASTM D 2240
Low Temperature Flexibility 4 hours at -70 ± 3°C *(-94 ± 5°F)*	---	No cracking	Section 4.3.3
Heat Shock 4 hours at 200 ± 3°C *(392 ± 5°F)*	---	No dripping, flowing or cracking	Section 4.3.4
Heat Resistance (Aging) 168 hours at 121 ± 3°C *(250 ± 5°F)* Followed by tests for:	---	---	Section 4.3.5
Tensile Strength	psi *(MPa)*	1200 minimum *(8.3)*	Section 4.3.2
Ultimate Elongation	Percent	175 minimum	ASTM D 2671
Copper Stability 168 hours at 121 ± 3°C *(250 ± 5°F)* Followed by test for:	---	No brittleness, glazing or cracking of tubing; no pitting or blackening of copper.	Section 4.3.6
Ultimate Elongation	Percent	175 minimum	Section 4.3.2
ELECTRICAL			
Dielectric Strength	Volts/mil *(Volts/mm)*	300 minimum *(11,800)*	Section 4.3.7 ASTM D 2671
Volume Resistivity	ohm-cm	10^{11} minimum	ASTM D 257
CHEMICAL			
Corrosive Effect 16 hours at 150 ± 3°C *(302°± 5°F)*	---	Noncorrosive	Section 4.3.8 ASTM D 2671
Flammability	Seconds	Self-extinguishing within 15 seconds	ASTM D 2671 Procedure A
Fungus Resistance	---	---	ISO 846 Method B
Followed by tests for:			
Tensile Strength	psi *(MPa)*	1500 *(10.3)* minimum	Section 4.3.2
Ultimate Elongation	percent	225 minimum	ASTM D 2671
Dielectric Strength	volts/mil (*kV/mm*)	300 *(11.8)* minimum	ASTM D 2671
		Or	
Fungus Resistance	---	Rating of 1 or less	ASTM G21

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TABLE 3
Requirements
(continued)

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
CHEMICAL (continued) Fluid Resistance Lubricating Oil (MIL-PRF-23699) Hydraulic Fluid (MIL-PRF-46170) Isopropyl Alcohol De-Icing Fluid (SAE-AMS-1424) Water Cleaning Fluid (A-A-59133) Followed by tests for:	---	---	Section 4.3.9
Tensile Strength	psi *(MPa)*	1000 minimum *(6.9)*	Section 4.3.2
Ultimate Elongation	Percent	250 minimum	
Weight Increase	Percent	5 maximum	Section 4.3.9
Fluid Resistance 24 hours at 25 ± 3°C *(77 ± 5°F)* in: JP-8 Fuel (MIL-DTL-83133) Lubricating Oil (MIL-PRF-7808) Diesel Fuel (MIL-DTL-46162) Followed by tests for:	---	---	Section 4.3.9
Tensile Strength	psi *(MPa)*	1000 minimum *(6.9)*	Section 4.3.2
Ultimate Elongation	Percent	250 minimum	
Weight Increase	Percent	20 maximum	Section 4.3.9
Fluid Resistance 24 hours at 71 ± 3°C *(160 ± 5°F)* in: Hydraulic Fluid (MIL-PRF-46170) Followed by tests for:	---	---	Section 4.3.9
Tensile Strength	psi *(MPa)*	1000 minimum *(6.9)*	Section 4.3.2
Ultimate Elongation	Percent	250 minimum	
Weight Increase	Percent	1/8 through 7/8: 25 maximum 1 through 3: 15 maximum	Section 4.3.9
Fluid Resistance 24 hours at 25 ± 3°C *(77 ± 5°F)* in: Hydraulic Fluid (MIL-PRF-5606) Followed by tests for:	---	---	Section 4.3.9
Tensile Strength	psi *(MPa)*	1000 minimum *(6.9)*	Section 4.3.2
Ultimate Elongation	Percent	250 minimum	
Weight Increase	Percent	15 maximum	Section 4.3.9

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