Tyco Electronics Corporation
300 Constitution Drive
Menlo Park, CA 94025 USA

Raychem

Specification	**RT-555**
This Issue:	Issue 6
Date:	November 28, 2006
Replaces:	Issue 5

Raychem RT-555 TUBING
Modified Fluoropolymer, Radiation Crosslinked, Flexible, Abrasion Resistant, Flame Retardant, Heat Shrinkable

1. SCOPE

This specification covers the requirements for one type of flexible, electrical insulating extruded tubing whose diameter will reduce to a predetermined size upon the application of heat in excess of 220ºC *(428ºF)*. The tubing is suitable for use in wire harness systems requiring high fluid resistance.

2. APPLICABLE DOCUMENTS

This specification takes precedence over documents referenced 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-372	Cleaning Compound, Solvent
SAE-AMS1424	Fluid, Deicing/Anti-Icing, Aircraft, SAE Type 1
MIL-PRF-2104	Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service
MIL-PRF-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-PRF-46167	Lubricating Oil, Internal Combustion Engine, Arctic
MIL-PRF-46170	Hydraulic Fluid, Rust Inhibited, Fire-resistance, Synthetic Hydrocarbon Base
MIL-PRF-5606	Hydraulic Fluid, Petroleum Base, Aircraft; Missile and Ordinance
MIL-PRF-2104	Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service
MIL-PRF-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-DTL-83133	Turbine Fuels, Aviation Kerosene Types, Nato F-34(JP-8), Nato F-35, JP-8 + 100

Federal

A-A-52557	Fuel Oil, Diesel for Posts, Camps and Stations
A-A-59133	Cleaning Compound, High Pressure (Steam) Cleaner (formerly P-C-437)

Ordnance Drawings

10873919	Electrolyte

2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

ASTM D 412	Standard Test Methods for Vulcanized Rubber & Thermoplastic Elastomers
ASTM D 792	Specific Gravity & Density of Plastics by Displacement, Tests for
ASTM D 910	Standard Specification for Aviation Gasoline
ASTM D 2671	Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use
ASTM D 4814	Standard Specification for Automotive Spark-Ignition Fuel
ASTM 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.)

NASA
SP-R-0022 General Specification, Vacuum Stability Requirements of Polymeric Material for Spacecraft Applications

3. REQUIREMENTS

3.1 MATERIAL

The product shall consist of a heat shrinkable, crosslinked, thermally stabilized, flame-retardant modified fluoropolymer material. The product shall be homogeneous and essentially free from flaws, defects, pinholes, bubbles, cracks and inclusions.

3.2 COLOR

The tubing shall be black unless otherwise specified.

3.3 PROPERTIES

The tubing shall meet the requirements of Tables 1 and 3.

4. QUALITY ASSURANCE PROVISIONS

4.1 CLASSIFICATION OF TESTS

4.1.1 Qualification Tests

Qualification tests are those performed on product 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 product submitted for acceptance under contract. Acceptance tests shall consist of the following:

Visual
Dimensions
Longitudinal Change
Tensile Strength
Ultimate Elongation
Heat Shock

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

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

Size Ranges
1/8 through 3/4
1" through 2"

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.

4.2 TEST PROCEDURES

Unless otherwise specified, tests shall be performed on specimens which have been fully recovered by conditioning in accordance with 4.3.1. Prior to all testing, the test specimens (and measurement gauges, when applicable) shall be conditioned for 3 hours at 23 ± 3ºC *(73 ± 5ºF)* 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, Dimensional Recovery, Longitudinal Change and Concentricity

Measure three 6-inch *(150 mm)* specimens of tubing, as supplied, for length ± 1/32 inch *(± 1 mm)* and inside diameter in accordance with ASTM D 2671. Recover these specimens fully by conditioning for 3 minutes in a 250 ± 5ºC *(482± 9ºF)* oven. Remove the specimens from the oven, allow to cool to 23 ± 3ºC *(73 ± 5ºF)* and re-measure. Calculate longitudinal change as follows:

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

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

Measure the wall thickness of three 6-inch *(150-mm)* long specimens, as supplied, in accordance with ASTM D 2671. Calculate concentricity as follows:

$$C = \frac{M_1}{M_2} \times 100$$

Where: C = Concentricity [Percent]
M_1 = Minimum Thickness [Inches *(mm)*]
M_2 = Maximum Thickness [Inches *(mm)*]

4.3.2 Tensile Strength and Ultimate Elongation

Test three specimens of tubing for tensile strength and ultimate elongation in accordance with ASTM D 2671. For tubing sizes 3/8 and smaller, use full sections of tubing. For sizes 1/2 and larger, cut the specimens with Die D, ASTM D 412. Apply 1-inch *(25-mm)* centrally located benchmarks to the specimens. Use an initial machine jaw separation of 1 inch *(25 mm)* for full sections of tubing and 2 inches *(51 mm)* for die cut specimens. Test at a rate of jaw separation of 2.0 ± 0.2 inches *(50 ± 5 mm)* per minute.

4.3.3 Low Temperature Flexibility

Condition three specimens, each 12 inches *(300 mm)* in length, and a mandrel selected in accordance with Table 2, at -65 ± 3ºC *(-85 ± 5ºF)* for 4 hours. For tubing sizes 3/4 or less, use whole sections of tubing recovered on a stranded wire (nearest AWG which is larger than the tubing maximum inside diameter after unrestricted shrinkage). For tubing sizes larger than 3/4, use 1/4-inch *(6.3-mm)* wide strips cut from tubing which has been recovered in accordance with 4.3.1. After 4 hours conditioning, and while still at the conditioning temperature, wrap the specimens consisting of whole sections of tubing around the mandrel for not less than 180 degrees in 10 ± 2 seconds. Wrap strip specimens around the mandrel for not less than 360 degrees in 10 ± 2 seconds. Examine the specimens visually for evidence of cracking.

4.3.4 Heat Shock

Condition three 6-inch *(150-mm)* specimens of tubing for 4 hours in a 300 ± 5ºC *(572 ± 9ºF)* oven. Remove the specimens from the oven, cool to 23 ± 3ºC *(73 ± 5ºF)*, wrap 360 degrees around a mandrel selected in accordance with Table 2 and then visually examine for evidence of dripping, flowing or cracking. Any side cracking caused by flattening of the specimen on the mandrel shall not constitute failure.

4.3.5 Heat Resistance

Condition three 6-inch *(150-mm)* specimens prepared in accordance with 4.3.2 for 336 hours in a 250 ± 3ºC *(482 ± 5ºF)* oven. After conditioning, the specimens shall be removed from the oven, cooled to 23 ± 3ºC *(73 ± 5ºF)* and tested for tensile strength and ultimate elongation in accordance with 4.3.2.

4.3.6 Copper Stability

Slide three 6-inch *(150-mm)* specimens of tubing over a snug-fitting, straight, clean, bare solid or tubular copper conductor. Condition the specimens on the conductors for 24 hours in an appropriate humidity chamber at 90 to 95 percent relative humidity and 23 ± 3ºC *(73 ± 5ºF)*, followed by 16 hours in a 200 ± 3ºC *(392 ± 5ºF)* oven. After conditioning, remove the specimens from the oven and cool to 23 ± 3ºC *(73 ± 5ºF)*. Remove the copper conductor from the tubing and examine the tubing and conductor. Darkening of the copper due to normal air oxidation shall not be cause for rejection. Test the tubing for ultimate elongation in accordance with 4.3.2.

4.3.7 Corrosive Effect

Test the tubing for copper mirror corrosion in accordance with ASTM D 2671, Procedure A, for 16 hours at 200 ± 3ºC *(392 ± 5ºF)*. Use specimens of 1/4 x 1 inch *(6 x 25 mm)* strips cut longitudinally from the tubing. Evidence of corrosion shall be the removal of copper from the mirror, leaving an area of transparency greater than 8 percent of its total area.

4.3.8 Fluid Resistance

Immerse three 6-inch *(150-mm)* specimens of tubing, prepared and measured in accordance with 4.3.2, completely in each listed fluid for the time and temperature specified in Table 3. Use a volume of fluid not less than 20 times that of the specimens. After immersion, lightly wipe the specimens and air-dry for 30 to 60 minutes at room temperature. Test the specimens from each fluid for tensile strength and ultimate elongation in accordance with 4.3.2.

4.3.9 Flammability After Fluid Exposure

Flammability tests shall be performed in accordance with ASTM D 2671 Procedure C on a 22-inch *(559-mm)* length of the tubing that has been fully immersed for 24 hours with ends open in fluids specified in Table 3. The outside of the tubing shall be wiped to remove excess fluid and mounted in the apparatus. The inside of the tubing shall be allowed to drain for 5 minutes before flame is applied.

4.3.10 Radiation Resistance

Three specimens prepared in accordance with Section 4.3.2 shall be subjected to gamma radiation for a total dosage of 10 Mrad at a rate of less than 0.5 Mrad per hour. The specimens shall be measured for tensile strength and ultimate elongation in accordance with Section 4.3.2.

4.4 REJECTION AND RETEST

Failure of any sample to conform to any one of the requirements of the specification shall be cause for rejection of the lot represented. Product 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. PREPARATION FOR DELIVERY

5.1 PACKAGING

Packaging shall be in accordance with good commercial practice.

5.2 MARKING

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

TABLE 1
Inside Diameters and Wall Thicknesses of Tubing

Size No.	As Supplied		Recovered Dimensions							
	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	.062	1.57	.010	.25	.016	.41	.012	.30
3/16	.187	4.75	.093	2.36	.011	.28	.018	.46	.014	.36
1/4	.250	6.35	.125	3.18	.013	.33	.020	.51	.016	.41
3/8	.375	9.53	.187	4.75	.016	.41	.023	.58	.019	.48
1/2	.500	12.70	.250	6.35	.016	.41	.023	.58	.019	.48
5/8	.625	15.88	.313	7.95	.019	.48	.026	.66	.022	.56
3/4	.750	19.05	.375	9.53	.024	.61	.031	.79	.027	.69
1	1.000	25.40	.500	12.70	.028	.71	.035	.89	.031	.79
1-1/4	1.250	31.75	.625	15.88	.030	.76	.037	.94	.033	.84
1-1/2	1.500	38.10	.750	19.05	.034	.86	.041	1.04	.037	.94
2	2.000	50.80	1.000	25.40	.037	.94	.044	1.12	.040	1.02

TABLE 2
Mandrel Dimensions for Low Temperature Flexibility and Heat Shock Testing

Tubing Size	Mandrel Diameter	
	in	*mm*
1/8 through 3/8	5/16	*7.9*
1/2 through 2	7/16	*11.1*

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	60% minimum	
Tensile Strength	Psi *(MPa)*	4000 minimum *(27.6)*	Section 4.3.2
Ultimate Elongation	Percent	200 minimum	ASTM D 2671
2% Secant Modulus (Expanded)	Psi *(MPa)*	50,000 maximum *(345)*	ASTM D 2671
Specific Gravity	---	2.0 maximum	ASTM D 792
Low Temperature Flexibility 4 hours at -65 ± 3ºC *(-85 ± 5ºF)*	---	No cracking	Section 4.3.3
Heat Shock 4 hours at 300 ± 5ºC *(572 ± 9ºF)*	---	No dripping, flowing or cracking	Section 4.3.4
Heat Resistance 336 hours at 250 ± 3ºC *(482 ± 5ºF)*	---	---	Section 4.3.5
Followed by test for Ultimate Elongation	Percent	150 minimum	Section 4.3.2 ASTM D 2671
Vacuum Outgassing TML (Total Mass Loss) VCM (Volatile Condensible Material)	 Percent Percent	 1.0 maximum 0.1 maximum	NASA Specification SP-R-0022A
Copper Stability 16 hours at 200 ± 3ºC *(392 ± 5ºF)*	---	No brittleness, glazing or severe discoloration of tubing. No pitting or blackening of copper.	Section 4.3.6
Followed by test for Ultimate Elongation	Percent	150 minimum	Section 4.3.2 ASTM D 2671
ELECTRICAL Dielectric Strength	 Volts/mil	 200 minimum	 ASTM D 2671
Radiation Resistance Followed by tests for: Tensile Strength Ultimate Elongation	 Psi *(MPa)* Percent	 3500 minimum *(24.1)* 150 minimum	Section 4.3.10
CHEMICAL Copper Mirror Corrosion 16 hours at 200 ± 3ºC *(392 ± 5ºF)*	 Percent	 Copper removal 8% maximum	Section 4.3.7 ASTM D 2671 Procedure A
Flammability	---	1) 25% maximum flag burn 2) No burning of cotton 3) No flaming or glowing longer than 60 seconds	ASTM D 2671 Procedure C
After fluid immersion 24 hours at 23 ± 3ºC *(73 ± 5ºF)* ASTM D 4814 Gasoline, Automotive Combat 24 hours at 50 ± 3ºC *(122 ± 5ºF)* A-A-52557 Fuel Oil, Diesel MIL-DTL-83133 Turbine Fuel, Aviation, Grade JP-8	---	1) 25% maximum flag burn 2) No burning of cotton 3) No flaming or glowing longer than 60 seconds	Section 4.3.9 ASTM D 2671, Procedure C
Fungus Resistance	---	Rating of 1 or less	ASTM G 21
Water Absorption 24 hours at 23 ± 3ºC *(73 ± 5ºF)*	Percent	0.5 maximum	ASTM D 2671

TABLE 3
Requirements (continued)

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
CHEMICAL (continued) Fluid Resistance 24 hours at 23 ± 3ºC *(73 ± 5ºF)* Gasoline, Aviation Grade 100 (ASTM D 910) Coolanol 25* Followed by tests for:	---	---	Section 4.3.8
Tensile Strength	Psi *(MPa)*	3500 minimum *(24.1)*	Section 4.3.2
Ultimate Elongation	Percent	150 minimum	ASTM D 2671
Fluid Resistance 24 hours at 50 ± 3ºC *(122 ± 5ºF)* JP-8 (MIL-DTL-83133) Deicing Fluid (SAE-AMS 1424) Cleaning Compound (MIL-PRF-372) 5% Salt Solution Fuel Oil, Diesel (A-A-52557) Followed by tests for:	---	---	Section 4.3.8
Tensile Strength	Psi *(MPa)*	3500 minimum *(24.1)*	Section 4.3.2
Ultimate Elongation	Percent	150 minimum	ASTM D 2671
Fluid Resistance 24 hours at 75 ± 3ºC *(167 ± 5ºF)* Hydraulic Fluid (MIL-PRF-5606) Lubricating Oil (MIL-PRF-2104) Lubricating Oil (MIL-PRF-7808) Followed by tests for:	---	---	Section 4.3.8
Tensile Strength	Psi *(MPa)*	3500 minimum *(24.1)*	Section 4.3.2
Ultimate Elongation	Percent	150 minimum	ASTM D 2671

*Trademark Solutia, Inc.