



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 220°C (428°F). 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 Ordnance |
| 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.)

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 via the ISO website at <http://www.iso.ch/iso/en/ISOOnline.frontpage>)

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

1/16 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 $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) 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, Dimensional Recovery, Longitudinal Change and Concentricity

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

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

Where: LC = Longitudinal Change [Percent]
 L₀ = Length Before Conditioning [Inches (mm)]
 L₁ = 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]
 M₁ = Minimum Thickness [Inches (mm)]
 M₂ = 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 $-65 \pm 3^{\circ}\text{C}$ ($-85 \pm 5^{\circ}\text{F}$) 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 $300 \pm 5^{\circ}\text{C}$ ($572 \pm 9^{\circ}\text{F}$) oven. Remove the specimens from the oven, cool to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$), 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 $250 \pm 3^{\circ}\text{C}$ ($482 \pm 5^{\circ}\text{F}$) oven. After conditioning, 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 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 $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$), followed by 16 hours in a $200 \pm 3^{\circ}\text{C}$ ($392 \pm 5^{\circ}\text{F}$) oven. After conditioning, remove the specimens from the oven and cool to $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$). 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 $200 \pm 3^{\circ}\text{C}$ ($392 \pm 5^{\circ}\text{F}$). 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.

4.4 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 |
| 1/16 | .0625 | 1.58 | .0313 | 0.795 | .010 | .25 | .014 | .36 | .012 | .30 |
| 1/8 | .125 | 3.18 | .0625 | 1.57 | .010 | .25 | .016 | .41 | .012 | .30 |
| 3/16 | .187 | 4.75 | .0935 | 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 |
| 1/16 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 (<i>mm</i>) | 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 (<i>MPa</i>) | 4000 minimum (<i>27.6</i>) | Section 4.3.2 |
| Ultimate Elongation | Percent | 200 minimum | ASTM D 2671 |
| 2% Secant Modulus (Expanded) | Psi (<i>MPa</i>) | 50,000 maximum (<i>345</i>) | ASTM D 2671 |
| Specific Gravity | --- | 2.0 maximum | ASTM D 792 |
| Low Temperature Flexibility 4 hours at $-65 \pm 3^{\circ}\text{C}$ ($-85 \pm 5^{\circ}\text{F}$) | --- | No cracking | Section 4.3.3 |
| Heat Shock 4 hours at $300 \pm 5^{\circ}\text{C}$ ($572 \pm 9^{\circ}\text{F}$) | --- | No dripping, flowing or cracking | Section 4.3.4 |
| Heat Resistance 336 hours at $250 \pm 3^{\circ}\text{C}$ ($482 \pm 5^{\circ}\text{F}$) Followed by test for Ultimate Elongation | --- | --- | Section 4.3.5 |
| | Percent | 150 minimum | Section 4.3.2 ASTM D 2671 |
| Vacuum Outgassing TML (Total Mass Loss) VCM (Volatile Condensable Material) | Percent Percent | 1.0 maximum 0.1 maximum | NASA Specification SP-R-0022A |
| Copper Stability 16 hours at $200 \pm 3^{\circ}\text{C}$ ($392 \pm 5^{\circ}\text{F}$) Followed by test for Ultimate Elongation | --- | No brittleness, glazing or severe discoloration of tubing. No pitting or blackening of copper. | Section 4.3.6 |
| | Percent | 150 minimum | Section 4.3.2 ASTM D 2671 |
| ELECTRICAL | | | |
| Dielectric Strength | Volts/mil | 200 minimum | ASTM D 2671 |
| CHEMICAL | | | |
| Copper Mirror Corrosion 16 hours at $200 \pm 3^{\circ}\text{C}$ ($392 \pm 5^{\circ}\text{F}$) | 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 $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) ASTM D 4814 Gasoline, Automotive Combat 24 hours at $50 \pm 3^{\circ}\text{C}$ ($122 \pm 5^{\circ}\text{F}$) 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 |
| Water Absorption 24 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) | Percent | 0.5 maximum | ASTM D 2671 |

TABLE 3
Requirements (continued)

| PROPERTY | UNIT | REQUIREMENT | TEST METHOD |
|--|-------------------|---------------------|---------------|
| CHEMICAL (continued) Fungus Resistance Followed by tests for: Tensile Strength Ultimate Elongation Dielectric Strength | --- | Rating less than 1 | ASTM G 21 |
| | | or | |
| | --- | | ISO 846 B |
| | psi (MPa) | 2000 minimum (13.8) | ASTM D 2671 |
| | Percent | 300 minimum | Section 4.3.2 |
| | Volts/mil (kV/mm) | 300 minimum (11.8) | ASTM D 2671 |
| Fluid Resistance 24 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) Gasoline, Aviation Grade 100 (ASTM D 910) Coolanol 25* Followed by tests for: Tensile Strength Ultimate Elongation | --- | --- | Section 4.3.8 |
| | Psi (MPa) | 3500 minimum (24.1) | Section 4.3.2 |
| | Percent | 150 minimum | ASTM D 2671 |
| Fluid Resistance 24 hours at $50 \pm 3^{\circ}\text{C}$ ($122 \pm 5^{\circ}\text{F}$) 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: Tensile Strength Ultimate Elongation | --- | --- | Section 4.3.8 |
| | Psi (MPa) | 3500 minimum (24.1) | Section 4.3.2 |
| | Percent | 150 minimum | ASTM D 2671 |
| Fluid Resistance 24 hours at $75 \pm 3^{\circ}\text{C}$ ($167 \pm 5^{\circ}\text{F}$) Hydraulic Fluid (MIL-PRF-5606) Lubricating Oil (MIL-PRF-2104) Lubricating Oil (MIL-PRF-7808) Followed by tests for: Tensile Strength Ultimate Elongation | --- | --- | Section 4.3.8 |
| | Psi (MPa) | 3500 minimum (24.1) | Section 4.3.2 |
| | Percent | 150 minimum | ASTM D 2671 |

*Trademark Solutia, Inc.

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