



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

**Raychem**

Specification

**RT-511**

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**THERMOFIT® 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

## 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).

## 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.

#### 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  $175 \pm 5^{\circ}\text{C}$  ( $347 \pm 9^{\circ}\text{F}$ ) 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  $50 \pm 5$  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.

#### 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 ( $\pm 1$  mm) and inside diameter in accordance with ASTM D 2671, conditioned for 10 minutes in a  $175 \pm 5^{\circ}\text{C}$  ( $347 \pm 9^{\circ}\text{F}$ ) 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. Longitudinal change shall be calculated as follows:

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

Where: C = Longitudinal Change [Percent]  
L<sub>0</sub> = Length Before Conditioning [Inches (mm)]  
L<sub>1</sub> = 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  $20 \pm 2$  inches (500  $\pm$  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  $-70 \pm 3^{\circ}\text{C}$  ( $-94 \pm 5^{\circ}\text{F}$ ) 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  $360^{\circ}$  (6.28 rad) in  $10 \pm 2$  seconds. The specimens then shall be visually examined for evidence of cracking.

#### 4.3.4 Heat Shock

Three 6-inch (150-mm) specimens of tubing shall be conditioned for 4 hours in a  $200 \pm 3^{\circ}\text{C}$  ( $392 \pm 5^{\circ}\text{F}$ ) oven. After conditioning, the specimens shall be removed from 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  $121 \pm 3^{\circ}\text{C}$  ( $250 \pm 5^{\circ}\text{F}$ ) 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

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  $25 \pm 3^{\circ}\text{C}$  ( $77 \pm 5^{\circ}\text{F}$ ). The specimens on the mandrels then shall be conditioned for 168 hours in a  $121 \pm 3^{\circ}\text{C}$  ( $250 \pm 5^{\circ}\text{F}$ ) oven. After conditioning, the specimens shall be removed from the oven, cooled to  $23 \pm 3^{\circ}\text{C}$  ( $73 \pm 5^{\circ}\text{F}$ ). The copper mandrels shall then be removed from 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  $150 \pm 3^{\circ}\text{C}$  ( $302 \pm 5^{\circ}\text{F}$ ).

#### 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  $23 \pm 3^{\circ}\text{C}$  ( $73 \pm 5^{\circ}$ ). 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.

**TABLE 1**  
**Tubing Dimensions**

| Size  | AS SUPPLIED     |       | RECOVERED       |       |                |      |         |      |         |      |
|-------|-----------------|-------|-----------------|-------|----------------|------|---------|------|---------|------|
|       | Inside Diameter |       | Inside Diameter |       | Wall Thickness |      |         |      |         |      |
|       | Minimum         |       | Maximum         |       | 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 |

**TABLE 3**  
**Requirements**

| PROPERTY                                                                                | UNIT                                     | REQUIREMENT                                                                        | TEST METHOD                  |
|-----------------------------------------------------------------------------------------|------------------------------------------|------------------------------------------------------------------------------------|------------------------------|
| <b>PHYSICAL</b>                                                                         |                                          |                                                                                    |                              |
| Dimensions                                                                              | Inches ( <i>mm</i> )                     | In accordance with Table 1                                                         | Section 4.3.1                |
| Longitudinal Change                                                                     | Percent                                  | +1, -8                                                                             | ASTM D 2671                  |
| Tensile Strength                                                                        | psi ( <i>MPa</i> )                       | 1500 minimum ( <i>10.3</i> )                                                       | Section 4.3.2<br>ASTM D 2671 |
| Tensile Stress<br>at 100 percent elongation                                             | psi ( <i>MPa</i> )                       | 1500 maximum( <i>10.3</i> )                                                        |                              |
| Ultimate Elongation                                                                     | Percent                                  | 250 minimum                                                                        |                              |
| Specific Gravity                                                                        | ---                                      | 1.5 maximum                                                                        | ASTM D 2671                  |
| Hardness                                                                                | Shore A                                  | 80 ± 5                                                                             | ASTM D 2240                  |
| Low Temperature Flexibility<br>4 hours at -70 ± 3°C (-94 ± 5°F)                         | ---                                      | No cracking                                                                        | Section 4.3.3                |
| Heat Shock<br>4 hours at 200 ± 3°C (392 ± 5°F)                                          | ---                                      | No dripping, flowing or cracking                                                   | Section 4.3.4                |
| Heat Resistance (Aging)<br>168 hours at 121 ± 3°C (250 ± 5°F)<br>Followed by tests for: | ---                                      | ---                                                                                | Section 4.3.5                |
| Tensile Strength                                                                        | psi ( <i>MPa</i> )                       | 1200 minimum ( <i>8.3</i> )                                                        | Section 4.3.2                |
| Ultimate Elongation                                                                     | Percent                                  | 175 minimum                                                                        | ASTM D 2671                  |
| Copper Stability<br>168 hours at 121 ± 3°C (250 ± 5°F)<br>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                |
| <b>ELECTRICAL</b>                                                                       |                                          |                                                                                    |                              |
| Dielectric Strength                                                                     | Volts/mil<br>( <i>Volts/mm</i> )         | 300 minimum ( <i>11,800</i> )                                                      | Section 4.3.7<br>ASTM D 2671 |
| Volume Resistivity                                                                      | ohm-cm                                   | 10 <sup>11</sup> minimum                                                           | ASTM D 257                   |
| <b>CHEMICAL</b>                                                                         |                                          |                                                                                    |                              |
| Corrosive Effect<br>16 hours at 150 ± 3°C (302°± 5°F)                                   | ---                                      | Noncorrosive                                                                       | Section 4.3.8<br>ASTM D 2671 |
| Flammability                                                                            | Seconds                                  | Self-extinguishing within 15 seconds                                               | ASTM D 2671<br>Procedure A   |
| Fungus Resistance<br>Followed by tests for:                                             |                                          |                                                                                    | ISO 846 Method B             |
| Tensile Strength                                                                        | psi ( <i>Mpa</i> )                       | 1500 minimum ( <i>10.3</i> )                                                       | Section 4.3.2                |
| Ultimate Elongation                                                                     | percent                                  | 250 minimum                                                                        | ASTM D 2671                  |
| Dielectric Strength                                                                     | Volts per mil<br>( <i>volts per mm</i> ) | 300 minimum ( <i>11,800</i> )                                                      | ASTM D 2671                  |

**TABLE 3**  
**Requirements**  
 (continued)

| PROPERTY                                                                   | UNIT      | REQUIREMENT                                            | TEST METHOD   |
|----------------------------------------------------------------------------|-----------|--------------------------------------------------------|---------------|
| <b>CHEMICAL</b> (continued)                                                |           |                                                        |               |
| Fluid Resistance                                                           | ---       | ---                                                    | Section 4.3.9 |
| 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:                                                     |           |                                                        |               |
| 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                                                           | ---       | ---                                                    | Section 4.3.9 |
| 24 hours at $25 \pm 3^{\circ}\text{C}$ ( $77 \pm 5^{\circ}\text{F}$ ) in:  |           |                                                        |               |
| JP-8 Fuel (MIL-DTL-83133)                                                  |           |                                                        |               |
| Lubricating Oil (MIL-PRF-7808)                                             |           |                                                        |               |
| Diesel Fuel (MIL-DTL-46162)                                                |           |                                                        |               |
| Followed by tests for:                                                     |           |                                                        |               |
| 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                                                           | ---       | ---                                                    | Section 4.3.9 |
| 24 hours at $71 \pm 3^{\circ}\text{C}$ ( $160 \pm 5^{\circ}\text{F}$ ) in: |           |                                                        |               |
| Hydraulic Fluid (MIL-PRF-46170)                                            |           |                                                        |               |
| Followed by tests for:                                                     |           |                                                        |               |
| 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<br>1 through 3: 15 maximum | Section 4.3.9 |
| Fluid Resistance                                                           | ---       | ---                                                    | Section 4.3.9 |
| 24 hours at $25 \pm 3^{\circ}\text{C}$ ( $77 \pm 5^{\circ}\text{F}$ ) in:  |           |                                                        |               |
| Hydraulic Fluid (MIL-PRF-5606)                                             |           |                                                        |               |
| Followed by tests for:                                                     |           |                                                        |               |
| 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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### Офис по работе с юридическими лицами:

105318, г.Москва, ул.Щербаковская д.3, офис 1107, 1118, ДЦ «Щербаковский»

Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

E-mail: [info@moschip.ru](mailto:info@moschip.ru)

Skype отдела продаж:

moschip.ru

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