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Raychem
Tubing

SPECIFICATION:
THIS ISSUE:
DATE:
REPLACES:

RT-1112
Issue 5
April 22, 2008
Issue 4

ES2000 TUBING

Environmental Sealing, Polyolefin, Semirigid, Adhesive-Lined

1. SCOPE

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

2. APPLICABLE DOCUMENTS

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

2.1 AMERICAN SOCIETY FOR TESTING AND MATERIAL (ASTM)

ASTM D 471	Oil, IRM 903
ASTM D 471	Fuel C
ASTM D 975	Diesel Fuel No. 2
ASTM D 2671	Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use
ASTM D 3032	Method of Testing Hookup Wire Insulation
ASTM D 3306	Engine Coolant, Type III

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

2.2 SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE J 1128	Low Tension Primary Cable, Standard
SAE J 1703	Brake Fluid

(Copies of SAE publications may be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096).

3. REQUIREMENTS

3.1 DIMENSIONS

The dimensions shall be in accordance with Table 1.

3.2 MATERIALS

The tubing shall consist of two components.

- a) The jacket shall be fabricated from a thermally stabilized, modified semirigid polyolefin and shall be crosslinked by irradiation.
- b) The liner shall be a thermoplastic adhesive which melts and flows at the shrink temperature of the jacket.

The tubing shall be essentially free from flaws, defects, pinholes, bubbles, seams, cracks and inclusions.

3.3 COLOR

Unless otherwise specified, the jacket shall be black and the adhesive liner shall be amber.

3.4 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:

Dimensions
Tensile Strength
Ultimate Elongation
Heat Shock
Longitudinal Change

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

Qualification test samples shall consist of 15 m (50 feet) of tubing of each size.

Qualification of ES2000-No.1 qualifies ES2000-No.1 and ES2000-No.2
Qualification of ES2000-No.3 qualifies ES2000-No.3 and ES2000-No.4

4.2.2 Acceptance Test Samples

Acceptance test samples shall consist of not less than 5 m (16 feet) 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

4.3.1 Material Properties

Unless otherwise specified, perform tests on specimens which have been recovered by heating for 3 minutes in a $200 \pm 5^{\circ}\text{C}$ ($392 \pm 9^{\circ}\text{F}$) oven. Condition the test specimens (and measurement gauges when applicable) for 3 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$). For referee purposes, condition the test specimens at 50 ± 5 percent relative humidity for 3 hours prior to testing. Use mechanical convection type ovens in which air passes the specimens at a velocity of 30 to 60 m (100 to 200 feet) per minute.

4.3.1.1 Dimensions and Longitudinal Change

Measure three 150 mm (6 inch) specimens of tubing, as supplied, for length ± 1 mm ($\pm 1/32$ inch) and inside diameter in accordance with ASTM D 2671. Condition the specimens for 3 minutes in a $200 \pm 5^\circ\text{C}$ ($392 \pm 9^\circ\text{F}$) oven, cool to $23 \pm 3^\circ\text{C}$ ($73 \pm 5^\circ\text{F}$), then re-measure. 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. Calculate the longitudinal change as follows:

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

Where: C = Longitudinal Change [percent]
 L₀ = Length Before Conditioning [inches (mm)]
 L₁ = Length After Conditioning [inches (mm)]

4.3.1.2 Tensile Strength and Ultimate Elongation

Perform the tests in accordance with ASTM D 2671 using 25 mm (1 inch) bench marks, 25 mm (1 inch) initial jaw separation and jaw separation speed of 50 ± 5 mm (2.0 ± 0.2 inches) per minute. Calculate the tensile strength based on the wall thickness of the jacket only.

4.3.1.3 Dynamic Cut-Through

Perform the test in accordance with ASTM D 3032. Recover the specimens on a 4.7 mm (0.187 inch) diameter steel rod and cool to room temperature. Use the optional cutting edge with a flat configuration of 0.127 mm (0.005 inch). The speed shall be 0.2 inches (5.0 mm) per minute.

4.3.1.4 Flammability

Recover five 500 mm (20 inch) lengths of tubing over mandrels with a diameter 75 ± 5 percent of the specified minimum expanded (as supplied) inside diameter of the tubing.

Using a Bunsen burner with a 100 mm (4 inch) tube, adjust the burner to achieve a flame with an inner blue cone of approximately 50 mm (2 inches).

Suspend each specimen in a draft free environment in the configuration shown in Figure 1. The time of exposure of the test flame to each specimen is one 30 second application.

Record the time for each specimen to self extinguish after removal of the flame. The result is the average burning time for all five specimens.

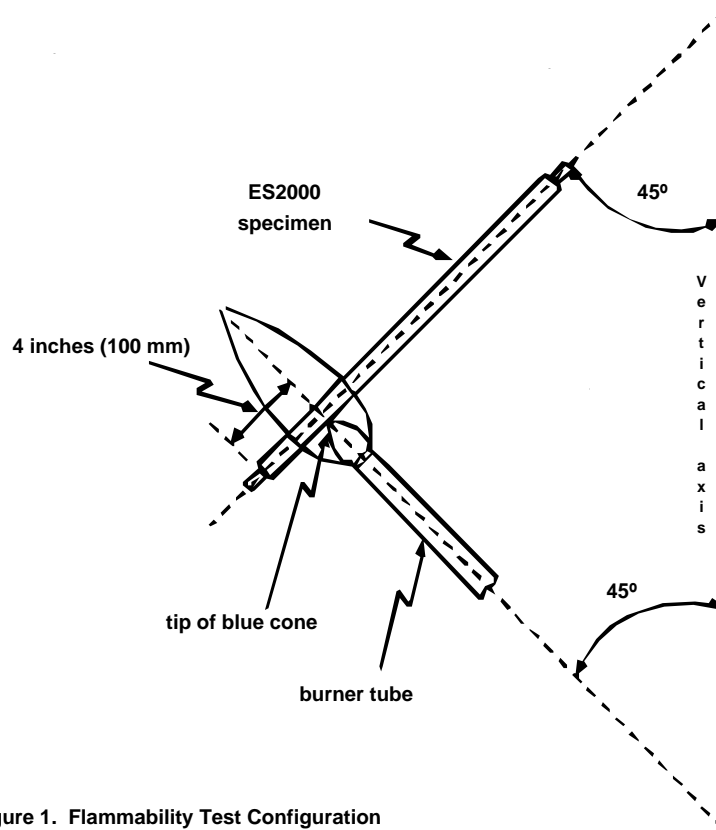


Figure 1. Flammability Test Configuration

4.3.2.1 Specimen Preparation

Where crosslinked polyolefin wire is specified for specimen preparation, use wire conforming to SAE J 1128 SXL. Where polyvinyl chloride wire is specified, use wire conforming to SAE J 1128 GPT. Test three specimens for each property.

4.3.2.1.1 ES2000-No.1

Construct a 2 wire to 2 wire inline splice in any suitable manner (crimped, soldered or welded). Splice two (2) AWG 20 wires to two (2) AWG 20 wires, using wires approximately 30 cm (12 inches) long. The splice area shall have a length of approximately 12.5 mm (0.5 inch) of exposed conductor. Install a 50 mm (2 inch) length of ES2000-No.1 centrally over the splice in an air circulating oven at $150 \pm 3^{\circ}\text{C}$ ($302 \pm 5^{\circ}\text{F}$) for 5 minutes, then cool to room temperature.

4.3.2.1.2 ES2000-No.3

Construct a 2 wire to 7 wire inline splice in any suitable manner (crimped, soldered or welded). Splice two (2) AWG 14 wires to seven (7) AWG 20 wires, using wires approximately 30 cm (12 inches) long. The splice area shall have a length of approximately 12.5 mm (0.5 inch) of exposed conductor. Install a 65 mm (2.5 inch) length of ES2000-No.3 centrally over the splice in an air circulating oven at $150 \pm 3^{\circ}\text{C}$ ($302 \pm 5^{\circ}\text{F}$) for 5 minutes, then cool to room temperature.

4.3.2.2 Current Leakage

Test three specimens each with SXL wire and GPT wire.

Immerse the center section of all specimens in a $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) water bath containing 5 percent sodium chloride by weight. The ends of the specimens should be a minimum of 50.8 mm (2 inches) above the water line.

Measure the leakage current between the conductors in the specimens and the water bath after 24 hours of immersion. The applied voltage for the measurement shall be 50 volts dc. After environmental exposure (sections 4.3.2.3 through 4.3.2.7) the immersion period shall be 4 hours.

4.3.2.3 Flex Test

While at room temperature, wrap 3 specimens made with SXL wire and 3 specimens made with GPT wire around 50.8 mm (2 inch) mandrels, using the following procedure. Attach one end of the specimen to the mandrel and the other end to a weight (see Table 2). Rotate the mandrel sufficiently to cause the splice area to wrap around the mandrel, and the wires on the opposite side of the splice to contact the mandrel. Rotate the mandrel in the opposite direction until the splice is again wrapped around the mandrel. This shall be one cycle. Test each sample for five cycles. Measure the current leakage in accordance with section 4.3.2.2.

4.3.2.4 Thermal Shock

Suspend vertically 3 specimens made with SXL wire in a circulating air oven for 30 minutes at $130 \pm 5^{\circ}\text{C}$ ($266 \pm 9^{\circ}\text{F}$) and 3 specimens made with GPT wire for 30 minutes at $105 \pm 5^{\circ}\text{C}$ ($221 \pm 9^{\circ}\text{F}$). Remove the specimens from the oven and within 2 minutes immerse them in a 5 percent sodium chloride solution by weight at $5 \pm 5^{\circ}\text{C}$ ($41 \pm 9^{\circ}\text{F}$). Remove them from the bath within 30 minutes. This shall be one cycle. Test the samples for 5 cycles and measure the current leakage in accordance with section 4.3.2.2.

4.3.2.5 Low Temperature Flexibility

4.3.2.5.1 SXL Wire

Condition 3 specimens in a cold chamber for 4 hours at $-30 \pm 3^{\circ}\text{C}$ ($-22 \pm 5^{\circ}\text{F}$). While at this temperature, wrap the specimens around a 10 cm (4 inch) mandrel. Attach one end of the specimen to the mandrel and the other end to a weight (see Table 2). Rotate the mandrel sufficiently to cause the splice area to wrap around the mandrel, and the wires on the opposite side of the splice to contact the mandrel. Then rotate the mandrel in the opposite direction until the splice is again wrapped around the mandrel. This shall be one cycle. Test each specimen for five cycles. Upon completion of the fifth cycle, test the specimens for dielectric withstand.

Dielectric Withstand

Immerse the center section of all specimens in a $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) water bath containing 5 percent sodium chloride by weight. The ends of the specimens should be a minimum of 50.8 mm (2 inches) above the water line. The specimens shall remain immersed in the bath for two hours prior to testing. Raise the voltage on the immersed specimens to 1,000 volts ac and hold for 1 minute, then inspect for insulation rupture.

4.3.2.5.2 GPT Wire

Fix one end of each of 3 specimens to a 10 cm (4 inch) diameter mandrel at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$). Attach the weight specified in Table 2 to the free end of each specimen, then wrap around the mandrel. Remove the weight, fix the free end of the specimens to the mandrels and place in a $-30 \pm 3^{\circ}\text{C}$ ($-22 \pm 5^{\circ}\text{F}$) cold chamber for 4 hours. Remove the mandrels with the wrapped specimens from the cold chamber and condition at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) for 4 hours. Remove the specimens from the mandrels and test for dielectric withstand in accordance with section 4.3.2.5.1.

4.3.2.6 Heat Aging

Suspend the specimens vertically for 168 hours in a circulating air oven.

SXL wire	Heat age at $130 \pm 5^{\circ}\text{C}$ ($266 \pm 9^{\circ}\text{F}$)
GPT wire	Heat age at $105 \pm 5^{\circ}\text{C}$ ($221 \pm 9^{\circ}\text{F}$)

Remove the specimens from the oven and within 2 minutes, immerse in a 5 percent sodium chloride solution by weight at room temperature. Measure current leakage in accordance with section 4.3.2.2.

4.3.2.7 Fluid Immersion

4.3.2.7.1 Immerse 3 specimens of each wire type for 1 hour at $100 \pm 3^{\circ}\text{C}$ ($212 \pm 5^{\circ}\text{F}$) in each of the following fluids:

Oil, IRM 903 (ASTM D 471)
Automatic Transmission Fluid (Dextron III/Mercon)
Engine Coolant, Type III (ASTM D 3306)

4.3.2.7.2 Immerse 3 specimens of each wire type for 24 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) in each of the following fluids:

Diesel Fuel, Grade No. 2 (ASTM D 975)
Windshield Washer Fluid, PRESTONE
Fuel C, ASTM D 471 (SXL wire only)

4.3.2.7.3 Immerse 3 specimens of each wire type for 10 seconds in each of the following fluids at intervals of 30 minutes for 16 hours at $23 \pm 3^{\circ}\text{C}$ ($73 \pm 5^{\circ}\text{F}$) to simulate a splash environment:

Engine Cleaner, GUNK*
Brake Fluid, SAE J 1703

Allow the specimens to drain between immersions.

*Trademark of the Radiator Specialty Co., Charlotte, NC

4.3.2.7.4 Visually inspect all fluid immersion specimens for splice insulation integrity. Calculate the percent swell of the minimum outside dimension of the specimen. Immediately measure current leakage in accordance with section 4.3.2.2.

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 defect and then 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 in cut pieces, unless otherwise specified.

5.2 PACKAGING

Packaging shall be in accordance with good commercial practice.

5.3 MARKING

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

TABLE 1
ES2000 Tubing Dimensions

Size	As Supplied		As Recovered							
	Minimum Expanded I.D. Including Core		Maximum Recovered I.D. Including Core		Minimum Recovered Jacket Wall		Minimum Recovered Adhesive Wall		Minimum Recovered Total Wall	
	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
-No.1	0.225	5.72	0.050	1.27	0.025	0.64	0.022	0.56	0.047	1.20
-No.2	0.293	7.44	0.065	1.65	0.030	0.76	0.030	0.76	0.060	1.52
-No.3	0.427	10.85	0.095	2.41	0.035	0.89	0.040	1.02	0.075	1.91
-No.4	0.700	17.78	0.175	4.45	0.041	1.04	0.054	1.37	0.095	2.41

TABLE 2
Weights for Flex Test Procedure
(Section 4.3.2.3)

Size	Weight
-No.1	5 pounds (2.27 kg)
-No.3	10 pounds (4.54 kg)

TABLE 3
Requirements

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
Material Properties			
Dimensions	inch (mm)	In accordance with Table 1	ASTM D 2671 Section 4.3.1.1
Longitudinal Change	percent	+0, -10	
Tensile Strength	psi (MPa)	1,500 (10.3) minimum	ASTM D 2671
Ultimate Elongation	percent	250 minimum	Section 4.3.1.2
2% Secant Modulus* (expanded)	psi (MPa)	20,000 (137) minimum	ASTM D 2671
Heat Shock 4 hours at 225 ± 3°C (437 ± 5°F)	--	No dripping, flowing or cracking of outer jacket	ASTM D 2671
Dynamic Cut Through	pounds (kg)	30 (13.6) minimum	ASTM D 3032 Section 4.3.1.3
Volume Resistivity	ohm-cm	1.0 x 10 ¹² minimum	ASTM D 2671
Flammability		Self-extinguishing within 30 seconds	Section 4.3.1.4
Splice Performance Properties			
Current Leakage (original sample)	microamps	0.25 maximum	Section 4.3.2.2
Room Temperature Flex Test	--	--	Section 4.3.2.3
Current Leakage	microamps	0.25 maximum	Section 4.3.2.2
Thermal Shock	--	--	Section 4.3.2.4
Current Leakage	microamps	0.25 maximum	Section 4.3.2.2
Low Temperature Flexibility	--	--	Section 4.3.2.5
Dielectric Withstand 1 minute at 1,000 volts	--	No breakdown	Section 4.3.2.5.1
Heat Aging	--	--	Section 4.3.2.6
Current Leakage	microamps	0.25 maximum	Section 4.3.2.2
Fluid Immersion	--	--	Section 4.3.2.7
Current Leakage	microamps	0.25 maximum	Section 4.3.2.2
Swell	percent	50 maximum	Section 4.3.2.7.4

*Calculate based on wall thickness of jacket only.