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Raychem  
Tubing

Specification  
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## **ZEROHAL ZH2 and ZH4 Tubing Polyolefin, Flexible, Heat-Shrinkable, Flame Retardant**

### **1. SCOPE**

This specification covers the requirements for halogen-free, flexible electrically insulating, extruded tubing whose diameter will reduce to a predetermined size upon the application of heat in excess of 90°C (194°F). The tubing is essentially free of halogens.

ZH2, a standard wall, 600 V, 125°C, VW-1 rated, UL recognized tubing meeting the requirements of UL 224. ZH2 also meets the requirements of Standard C22.2 No. 198.1 and is CSA certified.

ZH4, a thin wall very flexible, 300 V, 125°C, VW-1 rated, UL recognized tubing meeting the requirements of UL 224. ZH4 also meets the requirements of Standard C22.2 No. 198.1 and is CSA certified with a 150 V rating.

### **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 UNDERWRITERS LABORATORIES, INCORPORATED**

UL Subject 224 Extruded Insulating Tubing

(Copies of UL publications may be obtained from Underwriters Laboratories, Inc., 1285 Walt Whitman Road, Melville, Long Island, New York 11746.)

#### **2.2 CANADIAN STANDARDS ASSOCIATION**

C22.2 No. 198.1 Extruded Insulating Tubing

(Copies of CSA publications may be obtained from Canadian Standards Association, 1897 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.)

#### **2.3 OTHER PUBLICATIONS**

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 [www.iso.ch/iso/en/ISOOnline.frontpage](http://www.iso.ch/iso/en/ISOOnline.frontpage))

#### **American Society for Testing and Materials (ASTM)**

ASTM D 2671 Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use

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

### 3. REQUIREMENTS

#### 3.1 MATERIAL

The tubing shall be essentially halogen free and fabricated from thermally stabilized, flame retarded, modified polyolefin and shall be crosslinked by irradiation. It shall be homogeneous and free from defects, pinholes, bubbles, seams, cracks and inclusions.

#### 3.2 PROPERTIES

The tubing shall meet the requirements of Table 3.

#### 3.3 COLOR

The tubing shall be available in black.

### 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 the following:

Dimensions  
Longitudinal Change  
Tensile Strength  
Ultimate Elongation

#### 4.2 SAMPLING INSTRUCTIONS

##### 4.2.1 Qualification Test Samples

Qualification test samples shall consist of 15 m (*50 feet*) of tubing of the size and color specified. Qualification of the 1 mm size of ZH2 to all properties and the 25 mm size to dimensions and flammability will qualify all sizes of ZH2. Qualification of the 1 mm size of ZH4 to all properties and the 10 mm size to dimensions and flammability will qualify all sizes of ZH4.

##### 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

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 specimen (and measurement gauges, when applicable) shall be conditioned for 4 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 the specimens at a velocity of 30 to 60 m (*100 to 200 feet*) per minute.

#### 4.3.1 Dimensions and Longitudinal Change

Three 152 mm (6 inch) specimens of tubing, as supplied, shall be measured for length, to an accuracy of  $\pm 1$  mm ( $\pm 1/32$  inch), and inside diameter in accordance with ASTM D 2671. The specimens then shall be conditioned for 3 minutes in a  $200 \pm 3^\circ\text{C}$  ( $392 \pm 5^\circ\text{F}$ ) oven, removed from the oven, cooled to  $23 \pm 3^\circ\text{C}$  ( $73 \pm 5^\circ\text{F}$ ), remeasured for length, inside diameter and wall thickness in accordance with ASTM D 2671. The 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 [mm (inches)]  
 L<sub>1</sub> = Length After Conditioning [mm (inches)]

#### 4.3.2 Tensile Strength and Ultimate Elongation

The tensile strength and ultimate elongation of the tubing shall be determined in accordance with ASTM D 2671 using 25 mm (1 inch) bench marks and a 25 mm (1 inch) initial jaw separation. The speed of jaw separation shall be  $500 \pm 50$  mm ( $20 \pm 2$  inches) per minute.

#### 4.3.3 Secant Modulus

The secant modulus of the tubing shall be tested using tubing as supplied in accordance with ASTM D 2671.

#### 4.3.4 Copper Stability

Three 152 mm (6 inch) specimens of tubing shall be slipped over a snug fitting, straight, clean and bare copper conductor. For tubing sizes 1/4 and smaller, a solid conductor shall be used; for tubing sizes 3/8 and larger, a solid or tubular conductor shall be used. The specimens on the conductors shall be conditioned for 24 hours in a desiccator or similar humidity chamber at 90 to 95 percent relative humidity and  $23 \pm 3^\circ\text{C}$  ( $73 \pm 5^\circ\text{F}$ ). Three specimens shall be conditioned for 7 days in a  $158.0 \pm 1.0^\circ\text{C}$  ( $316.4 \pm 1.8^\circ\text{F}$ ) oven. After conditioning, the specimens shall be removed from the oven and cooled to  $23.0 \pm 3.0^\circ\text{C}$  ( $73.0 \pm 5.0^\circ\text{F}$ ). The copper conductor shall then be removed from the tubing, the tubing and conductor shall then be examined. Darkening of the copper due to normal air oxidation shall not be the cause for rejection. The tubing then shall be conditioned at room temperature for 16 to 96 hours and tested for ultimate elongation in accordance with 4.3.2.

#### 4.3.5 Dielectric Withstand, Breakdown and Strength

The dielectric strength of the tubing shall be measured under oil in accordance with ASTM D 2671. Five 152 mm (6 inch) specimens of tubing shall be recovered over a metal mandrel by conditioning for 3 minutes in a  $200 \pm 3^\circ\text{C}$  ( $392 \pm 5^\circ\text{F}$ ) oven. The mandrel diameter shall be slightly larger than the fully recovered inside diameter of the tubing being tested. The metal mandrel shall serve as one electrode and a 25 mm (1 inch) wide strip of metal foil wrapped around the outside of the tubing as the other electrode. The test voltage shall be applied at a rate of rise of 500 volts per second. Thickness measurements for calculating dielectric strength shall be made adjacent to the point of breakdown. Specimens for dielectric withstand shall be held for 60 seconds at 2500 volts.

#### 4.3.6 Corrosive Effect

Three specimens of tubing shall be tested for copper contact corrosion in accordance with ASTM D 2671, Procedure B. Three specimens shall be conditioned for 7 days in a  $158.0 \pm 1.0^\circ\text{C}$  ( $316.4 \pm 1.8^\circ\text{F}$ ) oven. After conditioning, the specimens shall be visually examined for evidence of corrosion.

4.3.7 **Material Halogen Content**

Determine the halogen content (fluorine, chlorine and bromine) of the tubing by any suitable elemental analysis technique capable of measuring each halogen to +/- 50 ppm or all three halogens together to +/- 100 ppm.

4.4 **REJECTION AND RETEST**

Failure of any samples 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 the rejection and the action taken to correct the defect shall be furnished to the inspector.

**5. PREPARATION FOR DELIVERY**

5.1 **FORM**

The tubing shall be supplied on spools, 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, specification number, product designation and lot number.

**TABLE 1**  
**ZH2 TUBING DIMENSIONS,**  
**METRIC**

Size	As Supplied (mm)		As Recovered (mm)	
	Inside Diameter	Wall Thickness	Inside Diameter	Wall Thickness
		Nominal	Maximum	Minimum
0.8/0.4	1.2 ± 0.2	0.2	0.4	0.33
1.0/0.5	1.5 ± 0.2	0.2	0.5	0.33
1.5/0.75	2.1 ± 0.2	0.2	0.75	0.36
2.0/1.0	2.6 ± 0.2	0.25	1.0	0.43
2.5/1.25	3.1 ± 0.2	0.25	1.25	0.43
3.0/1.5	3.6 ± 0.2	0.25	1.5	0.43
3.5/1.75	4.1 ± 0.3	0.25	1.75	0.43
4.0/2.0	4.6 ± 0.3	0.25	2.0	0.43
5.0/2.5	5.6 ± 0.3	0.3	2.5	0.56
6.0/3.0	6.6 ± 0.3	0.3	3.0	0.56
7.0/3.5	7.6 ± 0.3	0.3	3.5	0.56
8.0/4.0	8.6 ± 0.3	0.3	4.0	0.56
9.0/4.5	9.6 ± 0.3	0.3	4.5	0.56
10.0/5.0	10.4 ± 0.3	0.3	5.0	0.56
11.0/5.5	11.4 ± 0.3	0.3	5.5	0.56
12.0/6.0	12.7 ± 0.3	0.3	6.0	0.56
13.0/6.5	13.5 ± 0.3	0.35	6.5	0.66
14.0/7.0	14.4 ± 0.4	0.35	7.0	0.68
15.0/7.5	15.7 ± 0.4	0.35	7.5	0.68
16.0/8.0	16.9 ± 0.4	0.35	8.0	0.68
18.0/9.0	19.0 ± 0.4	0.4	9.0	0.76
20.0/10.0	21.4 ± 0.4	0.4	10.0	0.76
22.0/11.0	23.2 ± 0.4	0.45	11.0	0.89
25.0/12.5	26.8 ± 0.4	0.45	12.5	0.89
27.0/12.5	28.2 ± 0.5	0.45	12.5	0.89
28.0/14.0	30.0 ± 0.5	0.45	14.0	0.89
30.0/15.0	32.1 ± 0.5	0.45	15.0	0.89

**TABLE 2**  
**ZH4 TUBING DIMENSIONS,**  
**METRIC**

Size	As Supplied (mm)		As Recovered (mm)	
	Inside Diameter	Wall Thickness	Inside Diameter	Wall Thickness
		Nominal	Maximum	Minimum
0.4/0.2	0.7 ± 0.2	0.1	0.22	0.187
0.6/0.3	0.95 ± 0.25	0.1	0.3	0.187
0.8/0.4	1.2 ± 0.25	0.1	0.4	0.25
1.0/0.5	1.4 ± 0.25	0.1	0.5	0.25
1.5/0.75	1.9 ± 0.25	0.1	0.75	0.25
2.0/1.0	2.3 ± 0.25	0.1	1.0	0.25
2.5/1.25	2.8 ± 0.25	0.15	1.25	0.25
3.0/1.5	3.3 ± 0.25	0.15	1.5	0.25
3.5/1.75	3.8 ± 0.25	0.15	1.75	0.25
4.0/2.0	4.4 ± 0.25	0.15	2.0	0.25
5.0/2.5	5.5 ± 0.25	0.15	2.5	0.25
6.0/3.0	6.5 ± 0.4	0.15	3.0	0.28
7.0/3.5	7.5 ± 0.4	0.15	3.5	0.28
8.0/4.0	8.5 ± 0.4	0.15	4.0	0.28
9.0/4.5	9.5 ± 0.4	0.15	4.5	0.28
10.0/5.0	10.5 ± 0.5	0.15	5.0	0.28

**TABLE 3**  
**Requirements**

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
<b>PHYSICAL</b>			
Dimensions	mm ( <i>inches</i> )	In accordance with Tables 1& 2	Section 4.3.1
Dimensional Recovery			ASTM D 2671
Longitudinal Change			Section 4.3.1
ZH2 - ASTM D 2671	Percent	+1, -5	ASTM D 2671
ZH4 - ASTM D 2671	Percent	+1, -15	ASTM D 2671
UL 224	Percent	+3, -3	UL 224
Eccentricity (Recovered)	Percent	30 maximum	ASTM D 2671
Tensile Strength	MPa ( <i>psi</i> )	10.3 ( <i>1500</i> ) minimum	Section 4.3.2
Ultimate Elongation	Percent	200 minimum	ASTM D 2671
Secant Modulus (expanded), 2%	MPa ( <i>psi</i> )	172 ( $2.5 \times 10^4$ ) maximum	ASTM D 2671
Low Temperature Flexibility 1 hour at -30°C (-22°F)	--	No cracking	UL 224
Heat Shock 4 hours at 250°C (482°F)	--	No cracking	UL 224
Heat Aging 7 days at 158°C (316°F) Followed by tests for:	--	--	UL 224
Tensile Strength	MPa ( <i>psi</i> )	70% minimum of unaged specimens	Section 4.3.2 UL 224
Ultimate Elongation	Percent	100 minimum	
Dielectric Withstand at 2500 V	Seconds	60 minimum	
Dielectric Breakdown	Volts	50% minimum of unaged specimen	Section 4.3.5 ASTM D 2671
Dielectric Strength	kV/mm ( <i>Volts/mil</i> )	19.7 ( <i>500</i> ) minimum	
Copper Stability 7 days at 158°C (316°F) Followed by test for		No brittleness, glazing, cracking or severe discoloration of tubing. No pitting or blackening of copper.	Section 4.3.4 ASTM D 2671
Ultimate Elongation	Percent	100 minimum	Section 4.3.2
Restricted Shrinkage	--	Pass	UL 224
<b>ELECTRICAL</b>			
Dielectric Withstand at 2500 V	Seconds	60 minimum	UL 224
Dielectric Strength	kV/mm ( <i>Volts/mil</i> )	19.7 ( <i>500</i> ) minimum	Section 4.3.5
Volume Resistivity	Ohm-cm	$1 \times 10^{14}$ minimum	ASTM D 2671

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

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
<b>CHEMICAL</b> (continued)			
Corrosive Effect 7 days at 158°C (316°F)	--	No Corrosion	Section 4.3.6 ASTM D 2671
Halogen Content	Percent ( <i>ppm</i> )	0.1 (1000) maximum	Section 4.3.7
Flammability	--	Pass	UL 224, VW-1
Water Absorption (Recovered) 24 hours at 23°C (73°F)	Percent	0.75 maximum	ASTM D 2671
Fungus Resistance			ISO 846 Method B
Followed by tests for:			
Tensile Strength	MPa ( <i>psi</i> )	10.3 (1500) minimum	Section 4.3.2
Ultimate Elongation	percent	200 minimum	ASTM D 2671
Dielectric Strength	kV/mm ( <i>Volts/mil</i> )	19.7 (500) minimum	ASTM D 2671



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