



SPECIFICATION

108-120071

EVSW HEAT SHRINK TUBING

EVSW is a high flame-retarded, semi-electrically insulating and heat-shrinkable tubing available in 2:1 expansion ratio in RAL2003 orange colour suitable for bundling, protecting mid to high voltage (up to 2500 V) wires in Electric and Hybrid Vehicles

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1 SCOPE

This specification covers the requirements for one type of flexible electrical insulating, extruded tubing whose diameter will reduce to a pre-determined size upon applying heat more than 90 °C (194 °F). This tubing has a continuous operating temperature range of -55 °C to +135 °C. EVSW is free of polybrominated biphenyls (PBB) and polybrominated biphenyl oxides (PBBO). EVSW is also a 125 °C, VW-1 rated, UL recognised tubing meeting the requirements of UL 224.

2 REVISION HISTORY

Revision number	Change request	Date	Incorporated By
A	-	16Dec2022	Andre Cardoso
B	-	21 Aug 2023	Matthew Brown

3 RELATED DOCUMENTS

This specification takes precedence over the 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 set herein.

UL Subject 224	UNDERWRITERS LABORATORIES, INCORPORATED UL Subject 224 Extruded Insulating Tubing (Copies of UL publication may be obtained from Underwriters Laboratories, Inc., 1285 Walt Whitman Road, Melville, Long Island, New York 11746.)
C22.2 No. 198.1	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.)
ASTM D882	Standard Test Methods for Tensile Properties of Thin Plastic Sheeting
ASTM D2671	Standard Test Methods for Heat Shrinkable Tubing for Electrical Use
IEC 60212	Standard Conditions for Use Prior to and During Testing of Solid Electrical Insulating Materials
IEC 60243-1	Methods of Test for Electric Strength of Solid Insulating Materials part1 Tests at Power Frequencies
ISO 37	Rubber, vulcanised or thermoplastic – Determination of Tensile Stress-Strain Properties
ISO 62	Determination of Water Absorption
ISO 188	Rubber, vulcanised - Accelerated Ageing or Heat Resistance Tests
ISO 846	Evaluation of the action of micro-organisms
ISO 1183-2	Methods for determining the density and relative density of non-cellular plastics
ISO 1817	Rubber, vulcanized or thermoplastic – Determination of the effect of liquids
RAL Official K5 Booklet	Color reference to RAL2003



4. REQUIREMENTS

4.1 COMPOSITION AND APPEARANCE

The tubing shall be fabricated from thermally stabilized, flame-retardant, modified polyolefin and crosslinked by irradiation. It shall be homogeneous and free from flaws, defects, pinholes, bubbles, seams, cracks, and contaminants. The jacket shall be orange RAL 2003.

4.2 PART SELECTION & PERFORMANCE

The tubing shall meet the requirements of Table 4.

5. QUALITY ASSURANCE PROVISIONS

5.1 CLASSIFICATION OF TESTS

Tests shall be carried out on a sample taken at random from each batch of finished tubing. A batch of tubing is defined as that quantity of tubing extruded at any one time. Testing frequency shall be Qualification, 10th batch or Production Routine as detailed below:

5.1.1 Qualification Tests (Frequency in accordance with the Design Authority)

Qualification tests are those performed on tubing submitted for Qualification as a satisfactory product and shall consist of all tests listed in this, which shall be reviewed every 3 years.

5.1.2 Production routine tests (Every Batch)

Visual examination
Dimensions
Longitudinal change
Tensile Strength
Ultimate elongation
Colour

5.1.3 10th Batch Testing (Every 10th Batch) – ASTM D 2671

Secant modulus at 2% strain
Specific gravity
Flammability (ASTM D 2671 Procedure D)



6 TEST METHODS

Unless otherwise specified, tests shall be performed on specimens fully recovered by conditioning in accordance with 6.1. Prior to all testing, the test specimen (and measurement gauges, when applicable) shall be conditioned for 3 hours at $23 \pm 2 \text{ }^\circ\text{C}$ ($73 \pm 5 \text{ }^\circ\text{F}$) and $50 \pm 5 \%$ 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.

6.1 Preparation of Test specimens

Unless otherwise specified, tests shall be carried out on specimens of tubing recovered by conditioning in a fan-assisted air circulating oven at $200 \pm 5 \text{ }^\circ\text{C}$ for 6 ± 1 minutes and allowed to cool in the air to ambient temperature. Unless otherwise specified, all tests shall be made under standard ambient conditions according to IEC Publication 212. In cases of dispute, the tests shall be carried out at a temperature of $23 \pm 2 \text{ }^\circ\text{C}$ and $50 \pm 5\%$ relative humidity.

6.2 Colour Measurement

A RAL Official K5 Booklet in Glossy shall be used with the Page related to RAL2003. The samples are measured by pressing the colourimeter on representative cut pieces of recovered tubing in 3 places and the average DeltaL, delta-a, delta-b and compared DeltaE to the RAL2003 using the equation 1, according to COLORIMETRY — PART 4: CIE 1976 L*A*B* COLOUR SPACE - ISO/CIE 11664-4:2019(E).

$$\Delta E_{ab}^* = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (\text{Equation 1})$$

The value of DeltaE is reported.

6.3 Dimensional

Three 150-mm (6-inch) specimens of tubing, as supplied, shall be measured for length, to an accuracy of $\pm 1 \text{ mm}$ ($\pm 1/32 \text{ inch}$), and inside diameter in accordance with ASTM D 2671. The specimens then shall be conditioned for 3 minutes in a $200 \pm 3 \text{ }^\circ\text{C}$ ($392 \pm 5^\circ\text{F}$) oven, removed from the oven, cooled to $23 \pm 2 \text{ }^\circ\text{C}$ ($73 \pm 5 \text{ }^\circ\text{F}$), re-measured for length, inside diameter, and wall thickness in accordance with ASTM D 2671.



6.4 Longitudinal Change

The longitudinal change (Recovered tube sample) shall be calculated as follows in accordance with UL 224 and the following equation:

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

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

The longitudinal change, “C” shall be expressed as a percentage of the original length. In addition, the minimum and maximum recovered wall thickness shall be determined. For ASTM D 2671 the longitudinal change is calculated as for UL224, however the sample to be tested are in the Expanded State

6.5 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) benchmarks and a 50-mm (2-inch) initial jaw separation. The jaw separation speed shall be 500 ± 50 mm (20 ± 2-inches) per minute.

6.6 Secant Modulus at 2% Strain

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

6.7 Copper Stability

Three 150-mm (6-inch) specimens of tubing shall be slipped over a snug fitting, straight, clean, 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 ± 2 °C (73 ± 5 °F).

Three specimens shall be conditioned for 7 days in 158 ± 1 °C (316 ± 2 °F) oven. After conditioning, the specimens shall be removed from the oven and cooled to 23 ± 2 °C (73 ± 5 °F).

The copper conductor then shall be removed from the tubing, and the tubing and conductor shall then be examined. Darkening of the copper due to normal air oxidation shall not be a 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 6.5.



6.8 Specific Gravity

The test shall be carried out in accordance with Method A of ISO 1183

6.9 Electrical Testing

Dielectric Strength shall be tested in accordance with ASTM D2671 and additionally a test shall be carried out as per Table 4 requirements.

Dielectric Withstand at 2 500 V (1 hour) shall be tested in accordance to IEC 60243-1 and following conditions in Table 4 requirements.

Volume Resistivity testing shall be carried out in accordance to ASTM D2671 and following conditions in Table 4 requirements.

6.10 Heat Shock

The test shall be as specified in ASTM D2671.

The specimens shall be conditioned as specified in Table 4 in a fan-assisted air circulating oven.

Use the following Mandrel diameter for bend tests – Table 1.

Table 1 – Mandrel diameters utilised for heat shock and low temperature flexibility in accordance with method detailed in ASTM D2671

Inside diameter of tubing (maximum recovered, for heat shrink tubing)		Mandrel diameter,	
mm	(in)	mm	(in)
0.50-3.20	(0.020-0.125)	7.90±0.05	(5/16±0.002)
3.30-6.40	(0.126-0.250)	9.50±0.08	(3/8±0.003)
6.50-25.40	(0.251-1.000)	11.10±0.10	(7/16±0.004)
25.50-50.80	(1.001-2.000)	22.20±0.13	(7/8±0.005)

6.11 Heat Ageing

The test method shall be as specified in ISO 188.

The following tests that should be done after heat aging: Visual assessment (Section 4.1); and the following tests of Section 6: Tensile Strength; Ultimate Elongation; Flexibility; Dielectric Withstand; Dielectric Strength; and Dielectric Breakdown.



6.12 Long-Term Heat Ageing

Samples shall be prepared as in section 6.5 for Tensile Strength and Ultimate Elongation. The specimens shall be conditioned in a fan-assisted air circulating oven. The test method shall be as specified in ISO 188 for 3000 ± 2 h at 125 ± 3 °C.

After long-term heat, ageing samples shall be tested as previously in section 6.4 for Tensile Strength and Ultimate Elongation.

6.13 Low-Temperature Flexibility

Two test methods shall be made in as specified in Procedure C of ASTM D2671 and UL224.

- For ASTM D2671 please proceed with the following:

Samples shall be prepared using Table 1 – Mandrel diameters for heat shock and low temperature flexibility, to decide the mandrels that have to be used for this test. Note that, the tubing shall be tested in the “recovered” state and that mandrel diameter shall be $20 \times$ specimen thickness ± 10 %.

The specimens and mandrels shall be conditioned as specified in Table 4.

- For UL224 please proceed with the following:

Samples shall be prepared using Table 2 – Mandrel diameters for low temperature flexibility following UL224.

The specimens and mandrels shall be conditioned as specified in Table 4.

Table 2 - Mandrel diameters for low temperature flexibility following UL224

Inside diameter of tubing (maximum recovered, for heat shrink tubing)		Mandrel diameter,	
mm	(in)	mm	(in)
0.50-3.20	(0.020-0.125)	7.90±0.05	(5/16±0.002)
3.30-6.40	(0.126-0.250)	9.50±0.08	(3/8±0.003)
6.50-25.40	(0.251-1.000)	11.10±0.10	(7/16±0.004)
25.50-50.80	(1.001-2.000)	22.20±0.13	(7/8±0.005)
50.90-76.20	(2.001-3.000)	25.40±0.13	(1±0.005)

6.14 Flammability

The test method shall be as specified in UL 224 conducted internally at TE when required, and additionally at UL 224 external when required to maintain the certification. The test shall be carried out on all sizes and as required by UL 224.



6.15 Water Absorption

The test method shall be as specified in Method 1 of ISO 62.

For tubing of recovered bore greater than 8mm, three disc specimens of diameter 25 ± 1 mm shall be cut from the tubing. For tubing of recovered bore less than or equal to 8 mm, three tubular specimens 50 mm long shall be cut from the tubing.

6.16 Water impact on Electrical Performance

Water Absorption shall be as specified in Method 1 of ISO 62, this preparation should be followed by Dielectric Strength and Dielectric Withstand. Please note that the specimens for dielectric withstand shall be held for 1 hour at 2500 volts and then they should be continued for obtaining the Dielectric Strength test.

The dielectric strength of the tubing shall be measured under oil in accordance with ASTM D 2671. Five 150-mm specimens of tubing shall be recovered over a metal mandrel by conditioning for 3 minutes in a 200 ± 3 °C 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 25mm wide strip of lead 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 the dielectric strength shall be made adjacent to the point of breakdown

6.17 Fluid Resistance

The test method shall be as specified in ISO 1817.

Five tensile test specimens prepared as in section 6.1 shall be completely immersed in each of the fluids for the times and temperatures specified in Table 4. The volume of the fluid shall not be less than 20 times that of the specimen. After immersion lightly wipe the specimens and allow them to air dry at 23 ± 2 °C for $1h \pm 15$ mins. The Tensile Strength, Ultimate Elongation and Dielectric Strength of each specimen shall be tested in accordance with information of session 6.5 and 6. , respectively. The test shall be repeated on the remaining specified fluids.

Fluids to be tested:

- Engine Oil; ISO 1817 Oil No.1 (IRM 901)
- Automatic Transmission Fluid ATF; Dexron VI™
- Diesel Fuel; 90% ISO 1817, Oil No.3 (IRM 903) + 10% p-xylene
- Brake Fluid; DOT 4
- Petrol without oxygen compounds; ISO 1817 Liquid C1
- Screen Wash; 50 % iso-propanol/ 50 % Distilled H2O by volume
- Multi-purpose detergent (carwash); 1% Teepol + 99% Distilled H2O by volume
- Battery Acid; H2SO4 +H2O (SG 1.25)
- Engine Coolant; 50 % Ethylene Glycol + 50 % Distilled H2O by volume



6.18 Fungus Resistance

The test method shall be as specified in Method B of ISO 846.
The specimens shall be conditioned for 56 days and tested for Tensile Strength, Ultimate Elongation and Dielectric Strength in accordance with section 6.3.

7 REJECTION AND RETEST

Failure of any tubing samples to conform to any of the requirements of this specification shall cause 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.

8 PACKAGING

Packaging shall be in accordance with good commercial practice. Each package shall bear an identification label showing material quantity, product description, size, colour and batch number.
Additional information shall be supplied as specified in the contract or order.

EV SINGLE WALL TUBING



TABLE 3
Tubing Dimensions

2:1 Ratio											
Size		Inside Diameter as Supplied (Min) - D		Inside Diameter after recovery (Max) - d		Wall thickness after recovery (W)					
						Minimum		Maximum		Nominal	
mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.
10/5	3/8	10.00	0.394	4.50	0.177	0.56	0.022	0.72	0.028	0.64	0.025
12.7/6.4	1/2	12.70	0.500	6.40	0.252	0.56	0.022	0.72	0.028	0.64	0.025
20/9.5	3/4	20.00	0.787	9.50	0.374	0.68	0.027	0.84	0.033	0.76	0.030
26/12.7	1	26.00	1.024	12.70	0.500	0.76	0.030	1.01	0.040	0.88	0.035
40/19	1-1/2	40.00	1.575	19.00	0.748	0.86	0.034	1.17	0.046	1.01	0.040
50/25	2	50.00	1.969	25.00	0.984	0.96	0.038	1.32	0.052	1.14	0.045

Tubing of special expanded or recovered dimensions may be supplied as specified in the contract or order.



TABLE 4
Requirements

PROPERTY	TEST METHOD	REQUIREMENT
Visual examination		As per section 4.1
Colour	Colourimeter Colorimetry — PART 4: CIE 1976 L*A*B* COLOUR SPACE ISO/CIE 11664- 4:2019(E)	RAL 2003 (to be measured on RAL2003 of K5 Booklets plaques and used for comparison) DeltaE ≤ 12
Dimensions	ASTM D2671	As per section 6.3 and Table 3
Longitudinal Change (Recovered)	UL 224	± 3 %
Longitudinal Change (Expanded)	ASTM D 2671	+1 to -5%
Concentricity (Expanded)	ASTM D 2671	70% minimum (60% for tube sizes 1" or greater)
Tensile Strength	ASTM D2671	10.3 MPa (1500 psi) minimum
Ultimate Elongation	ASTM D2671	200% minimum
Secant Modulus @ 2 % strain (expanded)	ASTM D 2671	172 MPa maximum (2.5 x 10 ⁴ psi)
Specific Gravity	ISO 1183	1.4 maximum
Heat Shock 4 h ± 15 m at 250 ± 5 °C	ASTM D2671	No dripping, cracking, use mandrel diameters for bend tests in Table 1
Heat Ageing 168 ± 2 h at 158 ± 3 °C Followed by tests for:	ISO 188	
Visual assessment	Section 4.1	No dripping, no cracking or flowing of the outer wall
Tensile Strength	ASTM D2671	Larger than 70% retention (of unaged specimens)
Ultimate Elongation	ASTM D2671	100% minimum
Flexibility	UL224	No Cracking
Dielectric Withstand at 2500V	IEC 60243-1	1 hour minimum
Dielectric Strength	ASTM D 2671	19.7 kV/mm minimum (500 Volts/mil)
Dielectric Breakdown	ASTM D 2671	50% Volts min of unaged specimen
Long Term Heat Aging 3000 ± 2 h at 125 ± 3 °C Followed by tests:	ISO 188	
Tensile Strength	ASTM D 2671	5.0 MPa minimum
Ultimate Elongation	ASTM D 2671	100% minimum



PROPERTY	TEST METHOD	REQUIREMENT
Low Temperature Flexibility 4 h ± 15 m at -55 ± 2 °C	ASTM D2671	No cracking
1 h at -30 °C (-22 °F)	UL 224	No cracking
Electrical 1) Dielectric Withstand at 2500 V	IEC 60243-1	1 hour minimum
2) Dielectric Strength	UL 224	19.7 kV/mm minimum (500 Volts/mil)
3) Volume Resistivity	ASTM D 2671	1.0 x 10 ¹⁴ Ohm.cm minimum
Flammability	UL 224, VW-1 ASTM D2671 Procedure D	PASS Duration of burning 60s maximum, no burning or charring of indicator
Abrasion Resistance	ISO 6722-1	750 cycles minimum
Copper Stability 7 days at 158 °C (316 °F) Followed by a test for: Visual inspection	ASTM D 2671	No brittleness, glazing, cracking, or severe discoloration of tubing. No pitting or blackening of copper.
Ultimate Elongation		100 % minimum
Copper Mirror Corrosion 16h ± 2h at 150 ± 3 °C	ASTM D2671	No corrosion of mirrors
Water Absorption 24 ± 2h at 23 ± 2 °C	ISO 62	0.5% maximum
Water Impact on Electrical Performance Dielectric Withstand at 2 500 V	IEC 60243-1	1 hour minimum
Dielectric Strength	ASTM D2671	19.7 kV/mm (500 Volts/mil) minimum



PROPERTY	TEST METHOD	REQUIREMENT
<p>Fluid Resistance 24 ± 2h immersion at 23 ± 2 °C</p> <p>After immersion in all fluids listed below, results shall all be above-set values.</p> <ul style="list-style-type: none"> • Engine Oil; ISO 1817 Oil No.1 (IRM 901) • Automatic Transmission Fluid ATF; Dexron VI™ • Diesel Fuel; 90% ISO 1817, Oil Number 3, 10% p-xylene • Brake Fluid; DOT 4 • Petrol without oxygen compounds; ISO 1817 Liquid C*1 • Screen Wash; 50 % iso-propanol/50% Distilled H2O by volume • Multi-purpose detergent (carwash); 1% Teepol + 99% Distilled H2O by volume • Battery Acid; H2SO4 +H2O (SG 1.25) • Engine Coolant; 50 % Ethylene Glycol + 50 % Distilled H2O by volume <p>Followed by tests: Tensile Strength Ultimate Elongation Dielectric Strength</p>	<p>ISO 1817 ASTM D2671</p>	<p>5.0 MPa minimum 175 % minimum 19.7 kV/mm (500 Volts/mil) minimum</p>
<p>Fungus Resistance Followed by tests:</p> <ul style="list-style-type: none"> - Tensile Strength - Ultimate Elongation - Dielectric Strength 	<p>ISO 846</p>	<p>10.3 MPa minimum 200% minimum 19.7 kV/mm (500 Volts/mil) minimum</p>