

THERMOFIT® ZEROHAL™ ZHTM TUBING
Elastomeric, Halogen-Free, Flame-Retarded, Flexible, Heat-Shrinkable

1. SCOPE

This specification covers the requirements for one type of highly flexible, electrical insulating, extruded tubing whose diameter will reduce to a predetermined size upon the application of heat in excess of 121°C (250°F).

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-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engines, Synthetic Base
MIL-C-24643	Cable and Cord, Electrical, Low Smoke, for Shipboard Use, General Specification for

2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

D 412	Standard Test Methods for Rubber Properties in Tension
D 2671	Standard Methods of Testing Heat-Shrinkable Tubing for Electrical Use
D 2863	Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics (Oxygen Index)
D 3487	Specification for Mineral Insulating Oil Used in Electrical Apparatus
E 662	Test Method for Specific Optical Density of Smoke Generated by Solid Materials

(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 fabricated from a stabilized, flame retarded, halogen-free, modified polyolefin 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, unless otherwise specified.

3.3 PROPERTIES

The tubing shall meet all the requirements of Table 2.

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
Secant Modulus
Dielectric Strength.

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

Qualification test samples shall consist of 50 feet (15 m) of tubing and a molded slab 6 x 6 x 0.118 ± 0.02 inches (150 x 150 x 3 ± 0.5 mm). The molded slab shall be fabricated from the same lot of material and subjected to the same degree of crosslinking as the tubing. Qualification of any size will qualify all sizes.

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 5 minutes in a $150 \pm 2^\circ\text{C}$ ($302 \pm 4^\circ\text{F}$) 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 ± 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 (± 1 mm) and inside diameter in accordance with ASTM D 2671, conditioned for 10 minutes in a $200 \pm 2^\circ\text{C}$ ($392 \pm 4^\circ\text{F}$) 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 2. Longitudinal change shall be calculated 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)]

4.3.2 Tensile Strength and Ultimate Elongation

Tubing shall be tested for tensile strength and ultimate elongation in accordance with ASTM D 2671. For tubing size No. 12/6 and smaller, the specimens shall be full sections of tubing. For size No. 18/9 and larger, the specimens shall be cut with Die D of ASTM D 412. 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 (50 mm) for die cut specimens. The rate of jaw separation shall be $5 \pm .5$ inches (125 ± 12.5 mm) per minute.

4.3.3 Low Temperature Flexibility

Three specimens, each 12 inches (300 mm) in length, shall be conditioned, with the appropriate mandrels at $-25 \pm 3^\circ\text{C}$ ($-13 \pm 5^\circ\text{F}$) for 4 hours. For tubing sizes No. 5/2.5 or smaller, the specimens shall be whole sections of recovered tubing. For tubing sizes 8/4 and larger, the specimens shall be 1/4-inch (6.3-mm) wide strips cut from tubing which has been recovered in accordance with 4.3. The mandrel diameter shall be 40 times, $\pm 10\%$ the specimen thickness. For tubular specimens, the specimen thickness shall be taken as the outside diameter. While at the specified temperature, and still in the cold chamber, the specimens shall be wrapped around the mandrel not less than 360 degrees in 10 ± 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 $225 \pm 3^{\circ}\text{C}$ ($437 \pm 5^{\circ}\text{F}$) 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 $150 \pm 2^{\circ}\text{C}$ ($302 \pm 4^{\circ}\text{F}$) oven. After conditioning, the specimens shall be removed from the oven, cooled to room temperature, and tested for tensile strength and ultimate elongation in accordance with 4.3.2.

4.3.6 Limiting Oxygen Index

Test three specimens in accordance with ASTM D 2863, 0.26 ± 0.02 inches (6.5 ± 0.5 mm) wide; 0.118 ± 0.02 inches (3.0 ± 0.5 mm) thick; 2-3/4 to 6 inches (70 to 150 mm) long cut from a molded slab 6 x 6 x 0.118 ± 0.02 inches (150 x 150 x 3.0 ± 0.5 mm). The molded slabs shall be made from the same lot of material and subjected to the same degree of crosslinking as the tubing.

4.3.7 Oxygen Index at Elevated Temperature

Determine the oxygen index using the apparatus described in ASTM D 2863 with the exception of a special double wall glass chimney replacing the standard chimney. The specimens shall be in accordance with section 4.3.6. This chimney must be equipped with a heating element and temperature controller capable of maintaining the temperature of the gas atmosphere in the chimney to $\pm 2^{\circ}\text{C}$ ($\pm 4^{\circ}\text{F}$).

With the gas supply regulated to 21% oxygen content, determine the temperature, within 10°C (18°F), at which the specimen will burn 3 minutes or 2 inches (50 mm), whichever occurs first, using the endpoint criteria of D 2863. Report this temperature as the oxygen index at elevated temperature.

4.3.8 Fluid Resistance

Three specimens prepared in accordance with 4.3.2, shall be completely immersed in each of the fluids listed in the applicable section of Table 2 for 24 hours at the specified temperature. The volume of the fluid shall be not less than 20 times that of the specimens. After conditioning, the specimens shall be lightly wiped and then air dried for 30 to 60 minutes at room temperature. The specimens then shall be tested for tensile strength and ultimate elongation in accordance with 4.3.2.

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 submitted 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

Unless otherwise specified, the tubing shall be supplied on spools.

5.2 PACKAGING

Packaging shall be in accordance with good commercial practice. The shipping container shall be not less than 125 pound-test fiberboard.

5.3 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		As Recovered							
	Inside Diameter Minimum		Inside Diameter Maximum		Wall Thickness					
					Minimum		Maximum		Nominal	
	in.	mm.	in.	mm.	in.	mm.	in.	mm.	in.	mm.
3/1.5	.118	3.0	.059	1.5	.024	0.60	.032	0.80	.028	0.70
5/2.5	.197	5.0	.098	2.5	.025	0.63	.035	0.87	.030	0.75
8/4	.315	8.0	.157	4.0	.025	0.65	.037	0.95	.031	0.80
12/6	.472	12.0	.236	6.0	.029	0.75	.041	1.05	.035	0.90
18/9	.709	18.0	.354	9.0	.032	0.82	.046	1.18	.039	1.00
24/12	.945	24.0	.472	12.0	.035	0.90	.051	1.30	.043	1.10
40/20	1.575	40.0	.787	20.0	.042	1.07	.060	1.53	.051	1.30
60/30	2.362	60.0	1.181	30.0	.048	1.22	.070	1.78	.059	1.50

TABLE 2
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 to -10	ASTM D 2671
Tensile Strength	psi (<i>MPa</i>)	1150 (8) minimum	Section 4.3.2
Ultimate Elongation	Percent	200 min.	ASTM D 2671
Secant Modulus at 2% Strain	psi (<i>MPa</i>)	19,000 (130) maximum	ASTM D 2671
Specific Gravity	---	1.5 maximum	ASTM D 2671
Low Temperature Flexibility 4 hours at -25°C (-13°F)	---	No cracking	Section 4.3.3
Heat Shock 4 hours at 225°C (437°F)	---	No dripping, flowing or cracking	Section 4.3.4
Heat Resistance 168 hours at 150°C (302°F) Followed by tests for:	---	---	Section 4.3.5
Tensile Strength	psi (<i>MPa</i>)	1150 (8) minimum	
Ultimate Elongation	Percent	100 minimum	
ELECTRICAL			
Dielectric Strength	V/mil (<i>kV/m</i>)	375 (15) minimum	ASTM D 2671
Volume Resistivity	ohm-cm	10 ¹² minimum	ASTM D 2671
CHEMICAL			
Water Absorption 24 hours at 23°C (73°F)	Percent	0.75 maximum	ASTM D 2671
24 hours at 70°C (158°F)	Percent	3.5 maximum	
Limiting Oxygen Index	Percent	29 minimum	Section 4.3.6 ASTM D 2863
Oxygen Index at Elevated Temperature	°C	250 minimum	Section 4.3.7
Flammability	---	No burning of indicator	ASTM D 2671
Average time of burning			
Sizes No. 3/1.5 through No. 12/6	seconds	60 maximum	Procedure B
Sizes No. 18/9 through No. 60/30	seconds	30 maximum	Procedure A
Smoke Density, Ds 4 minutes, flaming mode	---	70 maximum	ASTM E 662
Acid Gas Generation HCl Equivalent	Percent	1.5 maximum	MIL-C-24643

TABLE 2
Requirements
(continued)

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
CHEMICAL (continued)			
Fluid Resistance	---	---	Section 4.3.8
24 hours at 23°C (73°F) in:			
Hydraulic Fluid (MIL-H-5606)			
JP-4 Fuel (MIL-T-5624)			
*Skydrol 500			
Diesel Fuel (VV-F-800)			
Water			
24 hours at 50°C (122°F) in:			
Lube Oil (MIL-L-23699)			
Insulating Oil (ASTM D 3487)			
24 hr. at 100°C (212°F) in:			
ASTM #2 Oil			
Followed by tests for:			
Tensile Strength	psi (MPa)	725 (5) minimum	
Ultimate Elongation	Percent	150 minimum	

*TM Monsanto Co.