

**Convolex™ Tubing
Poly(Vinylidene Fluoride), Modified, Radiation-Crosslinked**

1. SCOPE

This specification covers the requirements for one type of convoluted tubing that will provide mechanical protection for electrical wiring systems.

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-T-5438	Tester, Abrasion, Electrical Cable
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-T-23699	Lubrication Oil, Aircraft Turbine Engines, Synthetic Base
MIL-T-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5

Federal

TT-I-735	Isopropyl Alcohol
----------	-------------------

2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

Standard Test Methods for

ASTM D 570	Water Absorption of Plastics
ASTM D 638	Tensile Properties of Plastics
ASTM D 792	Specific Gravity and Density of Plastics by Displacement
ASTM D 876	Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation
ASTM D 2671	Heat Shrinkable Tubing for Electrical Use

(Copies of ASTM publications may be obtained from the American Society for Testing and Materials, 1969 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS

3.1 MATERIAL

The tubing shall be fabricated from an irradiated, thermally stabilized, modified poly(vinylidene fluoride) composition. It shall be homogeneous and essentially free from flaws, defects, pinholes, cracks, and inclusions.

3.2 COLOR

The tubing shall be black.

3.3 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 samples submitted for qualification as satisfactory products 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:

- Visual Examination
- Dimensions
- Breaking Load
- Ultimate Extensibility
- Crush Resistance
- Compressive Flexibility
- Heat Shock

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.

<u>Size Ranges</u>		
9/32	through	1/2
5/8	through	1-5/8

4.2.2 Acceptance Test Samples

Acceptance test samples shall consist of not less than 10 feet (3 m) of tubing selected at random from each lot.

4.2.3 Lot Formation

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 Breaking Load and Ultimate Extensibility

Three specimens 6 inches (150 mm) long shall be cut from sizes 7/16 and smaller. Three strip specimens 6 x 3/16 inch (150 x 5 mm) shall be cut from sizes larger than 7/16. The specimens shall be tested in accordance with ASTM D 638, using an initial jaw separation of 2 inches (50 mm) and a 2 inch (50 mm) per minute rate of jaw separation. The ultimate extensibility (jaw separation) and pounds (N) to break shall be recorded.

4.3.2 Crush Resistance

Three specimens of tubing shall be cut to provide the number of convolutions specified in Table 1. Each specimen shall be placed horizontally between plates large enough to cover the specimens. This assembly shall be positioned in a standard tensile testing machine that is arranged to measure and record compressive force. The machine shall be operated at a compressive speed of 0.2 inch (5 mm) per minute. The crush resistance shall be the average force required to reduce the outside diameter of the tubing by 25 percent.

4.3.3 Compressive Flexibility

Three 12-inch (300 mm) specimens of tubing shall be placed in a standard tensile testing machine that is arranged to measure and record the compressive strength of the tubing as it slides freely over a supporting mandrel. The mandrel shall be at least 12 inches (300 mm) long and shall have an outside diameter equivalent to 90 ± 2 percent of the inside diameter of the tubing. The machine shall be operated at a compressive speed of 0.2 inches (5 mm) per minute. The compressive flexibility shall be the average force required to reduce the length of the tubing by 25 percent.

4.3.4 Flexibility

Three 12-inch (300 mm) specimens of tubing shall be secured to a flat surface so that each specimen extends 6 inches (150 mm) beyond a 90 degree edge. The weight specified in Table 1 shall be attached to the free end of each specimen and the average vertical displacement of the weighted ends shall be the flexibility of the sample.

4.3.5 Flex Life

Three 24-inch (600 mm) specimens of tubing shall be attached at one end to a 3 inch (76 mm) diameter mandrel and at the other end to the load weight specified in Table 1. The specimens then shall be wound and unwound on the mandrel for 10,000 cycles at a rate of 10 cycles per minute. After conditioning, the specimens shall be subjected to the dielectric withstand voltage test of 4.3.10.

4.3.6 Abrasion Resistance

Each of three specimens of tubing shall be cut to provide the number of convolutions specified in Table 1. An abrasion tester similar to that described in MIL-T-5438 shall be modified to conform to the basic essentials of Figure 1. Each specimen shall be drawn onto the mandrel shown in Figure 1 and a small hole shall be cut to allow the weight support rod to be attached. The test assembly then shall be assembled in accordance with Figure 1 and the specimens shall be abraded at a rate of 60 inches (1.5 m) per minute with the length of grade 4/0 tape specified in Table 1. After conditioning, the specimen shall be removed from the test assembly and visually examined for holes.

4.3.7 Low Temperature Flexibility

Three specimens of tubing of sufficient length to be wound totally around a cylindrical metal mandrel of 10 times the outside diameter of the tubing shall be conditioned for 4 hours at $-55 \pm 2^\circ\text{C}$ ($-67 \pm 4^\circ\text{F}$). While still at the conditioning temperature the specimens shall be wrapped 360° around the mandrel in approximately 30 seconds. The specimens shall be visually examined for cracking, unwrapped from the mandrel, and subjected to the dielectric withstand voltage test of 4.3.10.

4.3.8 Heat Shock

Three 6-inch (150 mm) specimens of tubing shall be suspended vertically for 4 hours in a $250 \pm 5^\circ\text{C}$ ($482 \pm 9^\circ\text{F}$) oven. After conditioning, the specimens shall be cooled to room temperature and visually examined for evidence of splitting, cracking, dripping or flowing.

4.3.9 Heat Aging

Three specimens 6 inches (150 mm) long shall be cut from sizes 7/16 and smaller. Three strip specimens 6 x 3/16 inch (150 x 5 mm) shall be cut from sizes larger than 7/16. The specimens shall be laid on an oven tray and conditioned for 168 hours in a $175 \pm 5^\circ\text{C}$ ($347 \pm 9^\circ\text{F}$) mechanical convection oven with an air velocity of 100 to 200 feet (30 to 60 m) per minute past the specimens. After conditioning, the specimens shall be removed from the oven and cooled to $25 \pm 3^\circ\text{C}$ ($77 \pm 5^\circ\text{F}$) within 1 hour. After cooling, the specimens shall be tested for breaking load and ultimate extensibility in accordance with 4.3.1.

4.3.10 Dielectric Withstand Voltage

A bare wire shall be inserted through each length of three 24-inch (600 mm) specimens of tubing. Each specimen then shall be bent into a "U" form and its ends fastened together. A one percent solution of salt water at room temperature shall be poured inside each specimen to within 6 inches (150 mm) of its ends (the outer surface of the specimens must be kept dry). The specimens then shall be placed to within 6 inches (150 mm) of their ends in a container filled with a one percent salt water solution. The solution inside the specimens shall serve as an inner electrode and shall be above the surface of the solution in the container; the solution in the container shall serve as an outer electrode. The specimens shall remain immersed for one hour, after which a potential of 5 kilovolts shall be applied between the electrodes. The potential shall be gradually increased from zero to 5 kilovolts within approximately 30 seconds and shall be held at the voltage for one minute.

4.3.11 Solvent Resistance

For tubing of sizes 7/16 and smaller, tubular specimens 6 inches (150 mm) long shall be tested. For tubing sizes larger than 7/16, strip specimens 6 x 3/16-inch (150 x 5 mm) shall be tested. Five specimens shall be immersed in each solvent listed in Table 3 for 24 ± 2 hours at $23 \pm 3^\circ\text{C}$ ($73 \pm 5^\circ\text{F}$). The volume of the fluid shall be not less than 20 times that of the specimen. After immersion, the specimen shall be lightly wiped and air-dried for one hour at room temperature. The specimen then shall be tested for breaking load and ultimate extensibility in accordance with 4.3.1.

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 LENGTHS

Unless otherwise specified, the tubing shall be supplied in the following lengths:

<u>Size</u>		<u>Spooled Length</u>	
9/32	through 7/16	200 ft	(60 m)
1/2	through 1-5/8	100 ft	(30 m)

The minimum acceptable length supplied shall be five feet (1.5 m). The maximum number of lengths per spool shall be four.

5.2 PACKAGING

Unless otherwise specified, the tubing shall be supplied coiled on spools or reels and shall be packaged in accordance with good commercial practice.

5.3 MARKING

Each spool or reel of tubing shall be permanently and legibly marked with the size, color, quantity, manufacturer's identification, specification number, and lot number.

TABLE 1
Performance Details

Size	Specimen Size (Convolutions)	Test Load, ± 3%						Requirement*			
	Crush and Abrasion Resistance	Flexibility		Flex Life		Abrasion Resistance		Compressive Flexibility, maximum		Abrasion Resistance inches (mm) of tape, minimum [†]	
		Lbs	(N)	Lbs	(kg)	Lbs	(N)	Lbs	(N)	in	(mm)
9/32	8	0.25	(1.1)	0.50	(0.23)	2.00	(9)	14	(63.5)	25	(635)
3/8	8	0.50	(2.2)	0.75	(0.34)	3.00	(13)	14	(63.5)	25	(635)
7/16	7	0.75	(3.3)	1.00	(0.45)	4.00	(18)	18	(80)	50	(1270)
1/2	7	1.00	(4.4)	1.00	(0.45)	4.00	(18)	18	(80)	50	(1270)
5/8	7	1.50	(6.7)	1.00	(0.45)	4.00	(18)	20	(89)	50	(1270)
3/4	7	2.00	(8.9)	2.00	(0.91)	4.00	(18)	25	(111)	75	(1905)
7/8	7	2.00	(8.9)	2.00	(0.91)	4.00	(18)	25	(111)	75	(1905)
1	7	2.00	(8.9)	2.00	(0.91)	4.00	(18)	25	(111)	75	(1905)
1-1/4	7	2.25	(10.0)	2.00	(0.91)	4.00	(18)	40	(178)	75	(1905)
1-5/8	7	2.50	(11.1)	2.00	(0.91)	4.00	(18)	40	(178)	75	(1905)

*See Table 3 for complete tubing requirements.

[†]No holes

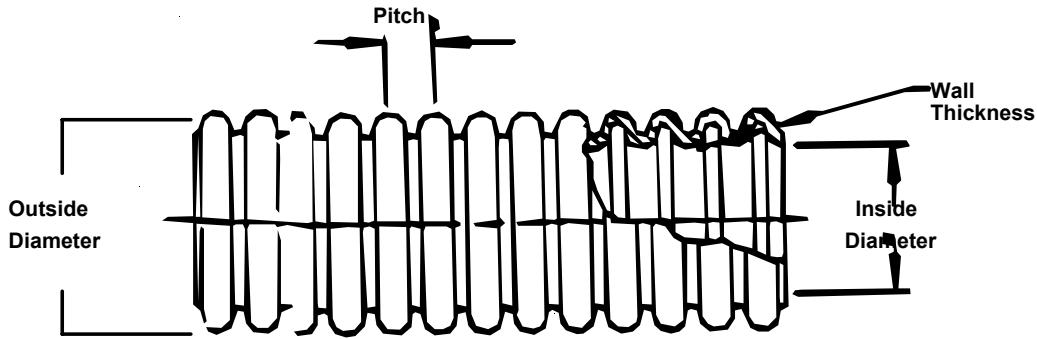
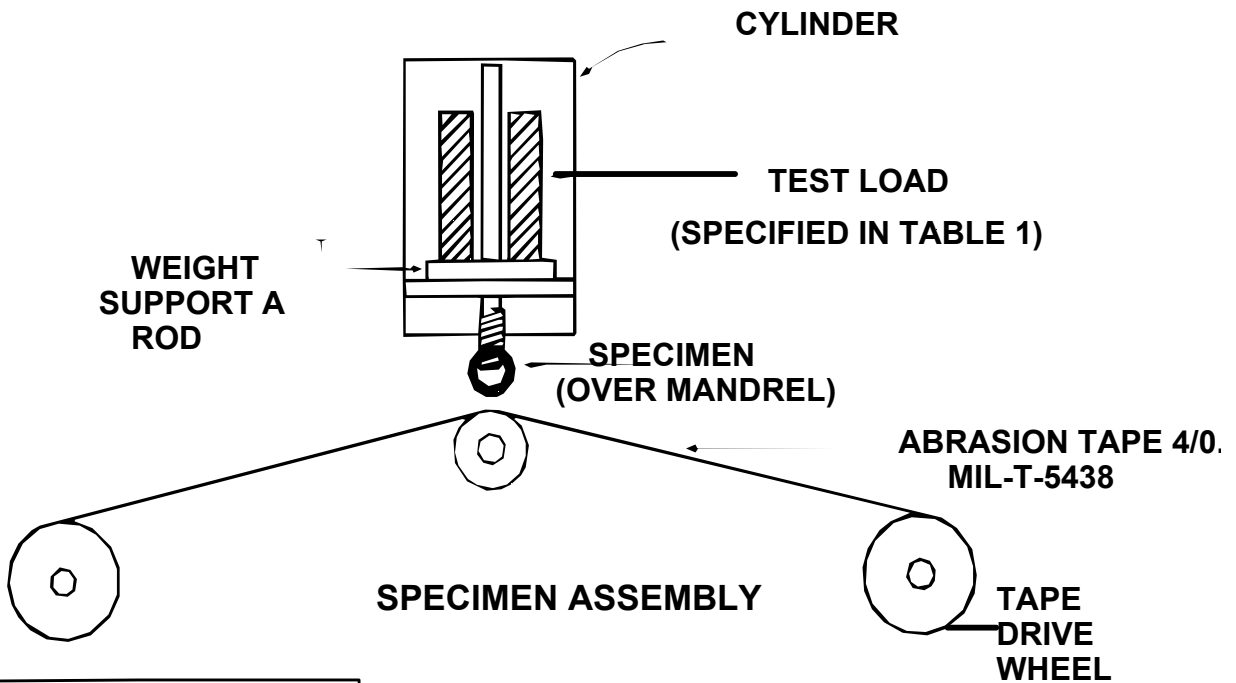
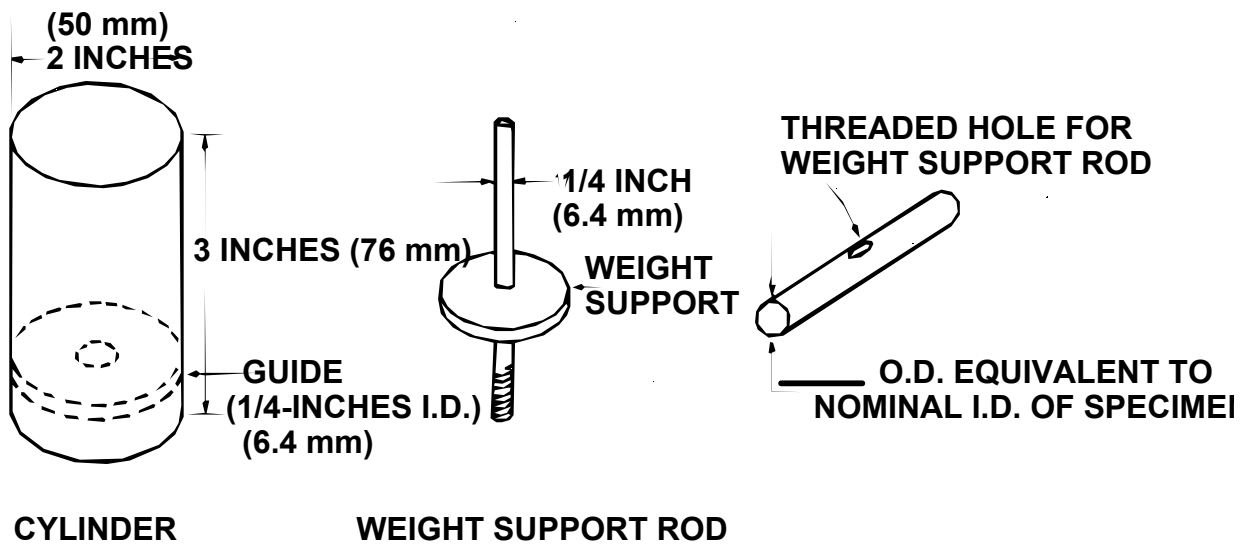


TABLE 2
Dimensions

Size	Inside Diameter		Outside Diameter	Pitch	Wall Thickness
	in.	mm.	in (mm)	in (mm)	in (mm)
9/32	+0.00	+0.00	0.394 ± 0.031	0.130 ± 0.024	0.013 ± 0.008
	0.28	7.1	(10.0 ± 0.8)	(3.3 ± 0.6)	(0.33 ± 0.20)
3/8	+0.00	+0.00	0.496 ± 0.031	0.130 ± 0.024	0.013 ± 0.008
	0.37	9.4	(12.6 ± 0.8)	(3.3 ± 0.6)	(0.33 ± 0.20)
7/16	+0.00	+0.00	0.575 ± 0.031	0.150 ± 0.023	0.015 ± 0.008
	0.44	11.2	(14.6 ± 0.8)	(3.8 ± 0.7)	(0.38 ± 0.20)
1/2	+0.00	+0.00	0.630 ± 0.031	0.150 ± 0.028	0.015 ± 0.008
	0.50	12.7	(16.0 ± 0.8)	(3.8 ± 0.7)	(0.38 ± 0.20)
5/8	+0.00	+0.00	0.748 ± 0.031	0.150 ± 0.028	0.015 ± 0.008
	0.62	15.8	(19.0 ± 0.8)	(3.8 ± 0.7)	(0.38 ± 0.20)
3/4	+0.00	+0.00	0.909 ± 0.031	0.165 ± 0.028	0.015 ± 0.008
	0.75	19.1	(23.1 ± 0.8)	(4.2 ± 0.7)	(0.38 ± 0.20)
7/8	+0.00	+0.00	1.040 ± 0.039	0.165 ± 0.028	0.015 ± 0.008
	0.87	22.1	(26.4 ± 1.0)	(4.2 ± 0.7)	(0.38 ± 0.20)
1	+0.00	+0.00	1.161 ± 0.039	0.150 ± 0.028	0.015 ± 0.008
	1.00	25.4	(29.5 ± 1.0)	(3.8 ± 0.7)	(0.38 ± 0.20)
1-1/4	+0.00	+0.00	1.402 ± 0.039	0.150 ± 0.028	0.018 ± 0.008
	1.25	31.8	(35.6 ± 1.0)	(3.8 ± 0.7)	(0.46 ± 0.20)
1-5/8	+0.00	+0.00	1.811 ± 0.039	0.150 ± 0.028	0.020 ± 0.008
	1.65	41.4	(46.0 ± 1.0)	(3.8 ± 0.7)	(0.51 ± 0.20)

FIGURE 1



NOTE: DETECTOR ROLLER
MUST BE REMOVED
FROM ABRASION
TESTER

FIGURE 1
APPARATUS,
ABRASION-RESISTANCE TEST

TABLE 3
Requirements

PROPERTY	UNIT	REQUIREMENT	TEST METHOD
PHYSICAL			
Visual Examination	---	In accordance with Section 3.1	---
Dimensions	Inches (<i>mm</i>)	In accordance with Table 2	ASTM D 876
Breaking Load	Pounds (<i>N</i>) to-break	5 minimum (23)	Section 4.3.1 ASTM D 638
Ultimate Extensibility	Percent	100 minimum	
Specific Gravity	---	1.8 maximum	ASTM D 792
Crush Resistance	Pounds (<i>N</i>)	7 minimum (31)	Section 4.3.2
Compressive Flexibility	Pounds (<i>N</i>)	In accordance with Table 1	Section 4.3.3
Flexibility	Inches (<i>mm</i>)	3 minimum (76)	Section 4.3.4
Flex Life	---	---	Section 4.3.5
10,000 cycles			
Followed by test for:			
Dielectric Withstand Voltage	---	No breakdown	Section 4.3.10
Abrasion Resistance	Inches (<i>mm</i>) of Tape	In accordance with Table 1	Section 4.3.6
Low Temperature Flexibility	---	No visible cracks	Section 4.3.7
4 hours at -55°C (-67°F)			
Followed by test for:			
Dielectric Withstand Voltage	---	No breakdown	Section 4.3.10
Heat Shock	---	No dripping or flowing	Section 4.3.8
4 hours at 250°C (482°F)			
Heat Aging	---	---	Section 4.3.9
168 hours at 175°C (347°F)			
Followed by tests for:			
Breaking Load	Pounds (<i>N</i>) to-break	5 minimum (23)	Section 4.3.1 ASTM D 638
Ultimate Extensibility	Percent	75 minimum	
ELECTRICAL			
Dielectric Withstand Voltage	---	No breakdown	Section 4.3.10
5 kV for 1 minute			
CHEMICAL			
Corrosive Effect Copper Mirror	---	Non-Corrosive	ASTM D 2671.Procedure A 1/4 x 1-inch strip
16 hours at 175°C (347°F)			
Flammability	Seconds	Duration of burning 15 maximum	ASTM D 876
Water Absorption	Percent	0.5 maximum	ASTM D 570
CHEMICAL (continued)			
Solvent Resistance	---	---	Section 4.3.12
24 hours at 25°C (77°F) in:			
JP-4 Fuel (MIL-T-5624)			
Skydrol* 500			
Hydraulic Fluid (MIL-H-5606)			
Aviation Gasoline (100/130)			
Salt Water (5% salt)			
Lube Oil 0-149 or			
MIL-L-23699			
Anti-Icing Fluid (TT-I-735)			
Followed by tests for:			
Breaking Load	Pounds (<i>N</i>) to-break	3 minimum (13)	Section 4.3.1 ASTM D 638
Ultimate Extensibility	Percent	100%	

*Trademark of the Monsanto Company