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Specification	**RT-1162**
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HELICAL CONVOLEX® TUBING
HCTE
Ethylene Tetrafluoroethylene, 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-L-2104	Lubricating Oil, Internal Combustion Engine, Heavy Duty
MIL-G-3056	Gasoline, Automotive, Combat
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance
MIL-T-5624	Turbine Fuel, Aviation Grade JP-4, JP-5 and JP5/JP8
MIL-L-7808	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-A-8243	Anti-Icing and Deicing - Defrosting Fluid
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base
MIL-C-43616	Cleaning Compound, Aircraft Surface
MIL-F-46162	Fuel, Diesel, Referee Grade
MIL-L-46167	Lubricating Oil, Internal Combustion Engine, Arctic
MIL-H-46170	Hydraulic Fluid, Rust Inhibited, Fire Resistance Synthetic Hydrocarbon Base
MIL-T-81914	Tubing, Plastic, Flexible, Convoluted, Conduit, General Specification for

Federal

O-S-1926	Sodium Chloride 5% Solution
PC-437	Cleaning compound, High Pressure (Steam Cleaner)
VV-F-800	Fuel Oil, Diesel

2.2 OTHER PUBLICATIONS

American Society for Testing and Materials (ASTM)

ASTM D 638	Standard Test Methods for Tensile Properties of Plastics
ASTM D 792	Standard Test Methods for Specific Gravity and Density of Plastics by Displacement
ASTM D 876	Standard Methods of Testing Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation
ASTM D 910	Standard Specification for Aviation Gasoline
ASTM D 3032	Standard Methods of Testing Hookup Wire Insulation.
ASTM G 21	Recommended Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

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 material shall be modified ethylene tetrafluoroethylene, radiation crosslinked. 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 representative of standard 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
Tensile Strength
Extensibility
Crush Resistance
Flammability
Heat Shock
Longitudinal Change

4.2 SAMPLING INSTRUCTIONS

4.2.1 Qualification Test Samples

Qualification test samples shall consist of sufficient lengths of Sizes 0500 and 1500. These two sizes will qualify all sizes as follows. For Fluid Resistance, one size shall qualify all sizes.

Qualification Size	Qualification Range
0500	Below 1000
1500	1000 and above

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. 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 Tensile Properties (Tensile Strength & Extensibility)

Test three 6-inch *(150-mm)* specimens of tubing, [cut 6 x 1/2 inch *(150 x 12 mm)* strips from tubing larger than Size 0437], in accordance with ASTM D 638, using an initial jaw separation of 3 inches *(76 mm)*, 2-inch *(50-mm)* bench marks and a 2-inch *(50-mm)* per minute rate of jaw separation. Measure the benchmark separation and load at break. Report these values as the extensibility and tensile strength, respectively.

4.3.2 Crush Resistance

Cut three specimens of tubing to provide the number of convolutions specified in Table 1. Place each specimen horizontally between plates larger than 2 inches *(50 mm)* square in a standard tensile testing machine that is arranged to measure and record compressive force. Operate the machine at a compressive speed of 0.2 inches *(5 mm)* per minute. Measure the average force required to reduce the outside diameter of the tubing by 25 percent and report this force as the crush resistance.

4.3.3 Compressive Flexibility

Test three 12-inch *(300-mm)* specimens of tubing in a standard tensile testing machine that is arranged to measure and record the compressive stress of the specimen as it slides freely over an inner supporting mandrel (see Figure 1). Use a mandrel at least 12 inches *(300 mm)* long with an outside diameter of 90 ± 5 percent of the inside diameter of the tubing. Conduct the test at a cross head speed of 0.2 inches *(5.08 mm)* per minute . Compress the tubing to reduce its length by
25 percent and observe the maximum force required for this compression. Report the average value.

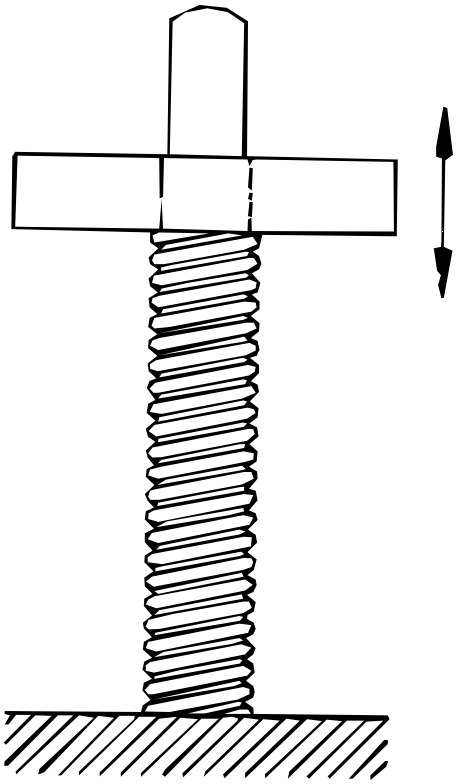


Figure 1

4.3.4 Flexibility

Secure three 12-inch *(300-mm)* specimens of tubing to a flat surface so that each specimen extends 6-inches *(150-mm)* beyond a 90 degree edge. Attach the weight specified in Table 1 to the free end of each specimen, measure the average vertical displacement of the weighted ends and report the average value as the flexibility.

4.3.5 Flex Life

Attach three 24-inch *(600-mm)* specimens of tubing at one end to a mandrel 5 times the outside diameter of the specimen, and at the other end to the load weight specified in Table 1. Wind and unwind the specimens on the mandrel for 10,000 cycles at a rate of 10 cycles per minute. Subject the specimens to the dielectric withstand voltage test described in Section 4.3.9.

4.3.6 Heat Shock and Longitudinal Change

Mark three 6-inch *(150-mm)* specimens of tubing with 4 ± 1/32 inch *(100 ± 1 mm)* benchmarks, centrally located. Suspend the tubing horizontally in an oven by inserting an 8 x 0.125-inch *(200 x 3-mm)* metal mandrel through the tubing and resting the ends of the mandrel on metal blocks. Condition the specimen for 4 hours at 300 ± 5°C *(572 ± 9°F)*. Remove the test assembly from the oven and allow to cool at room temperature for one hour. Inspect the specimens for evidence of dripping, flowing or cracking. Measure the distance between benchmarks, calculate the percentage change in benchmark length and report this value as the longitudinal change.

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

Where: LC = Longitudinal Change [percent]
L_0 = Length Before Conditioning [inches *(mm)*]
L_1 = Length After Conditioning [inches *(mm)*]

4.3.7 Low Temperature Flexibility

Prepare three 24-inch *(600-mm)* specimens of tubing and a test fixture . The test fixture shall consist of two 3.5-inch *(88.9-mm)* diameter mandrels mounted at right angles to a support plate with the distance between them slightly larger [approximately 1/16 inch *(1.59 mm)*] than the outside diameter of the specimens. Condition the specimens and the mandrel assembly for 4 hours at -55 ± 2°C *(-67 ± 4°F)*, keeping the tubing straight and vertical. While at this temperature, place the tubing between the two mandrels, fixed at the lower end and alternately flexed
180 degrees around each mandrel for 5 cycles (Figure 2). A cycle shall consist of 180 degree bend in one direction, 180 degree bend in the other direction and the return to the original or vertical position. Complete the 5 bend cycles within 2 minutes. Examine the specimens for cracking and subject them to the dielectric withstand voltage test described in Section 4.3.9.

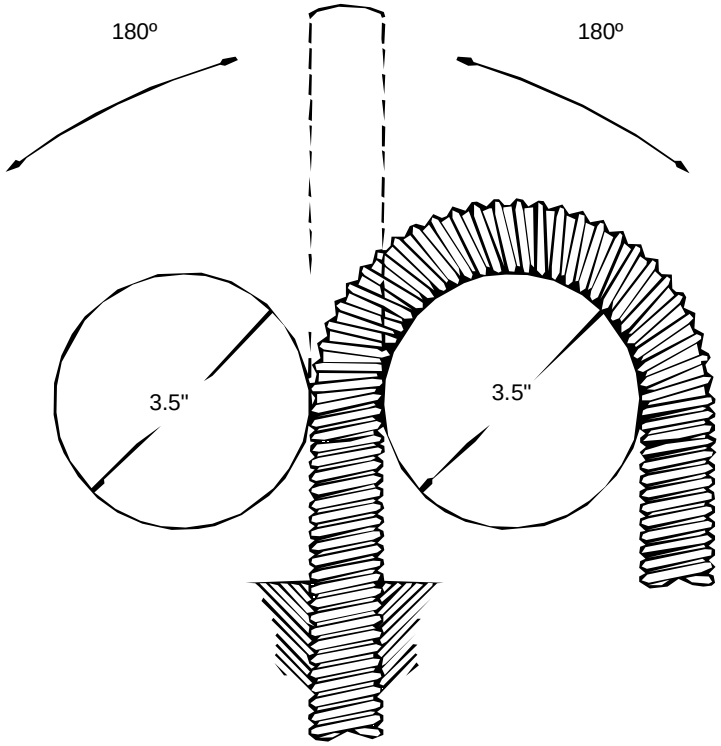


Figure 2

4.3.8 Heat Resistance

Cut three 6-inch *(150-mm)* specimens of tubing, [6 x 1/2 inch *(150 x 12 mm)* strips from tubing larger than Size 0750], lay them on an oven tray and condition them for 168 hours in a 200 ± 5°C *(392 ± 9°F)* mechanical convection oven with an air velocity of 100 to 200 feet *(30 to 60 m)* per minute past the specimens. After conditioning, remove the specimens from the oven and cool to 23 ± 3°C *(73 ± 5°F)* within 1 hour. After cooling, test the specimens for Tensile Strength and extensibility in accordance with Section 4.3.1.

4.3.9 Dielectric Withstand at 12 kV

Insert a non-insulated 20 gauge copper wire through each of three 24-inch *(600-mm)* specimens of tubing. Bend each specimen into a "U" shape and twist the ends of the wire together to hold the specimen in this shape (refer to Figure 3). Fill each specimen with an aqueous solution of 1 percent sodium chloride to within 6 inches *(150 mm)* of the end (the outer surface of the specimens must be kept dry). Immerse the specimens in an aqueous solution of 1 percent sodium chloride so that the ends of the specimens protrudes about 6 inches *(150 mm)* above the liquid surface. The level of the liquid in the specimen shall be above that in the container. After one hour immersion, apply 12 kV AC across the wire in each specimen and an electrode formed by immersing copper wire at the edge of the salt bath. The potential should be applied gradually from 0 to 12 kv over a period of about 30 seconds and then maintained for 1 minute. Observe and report evidence of dielectric breakdown.

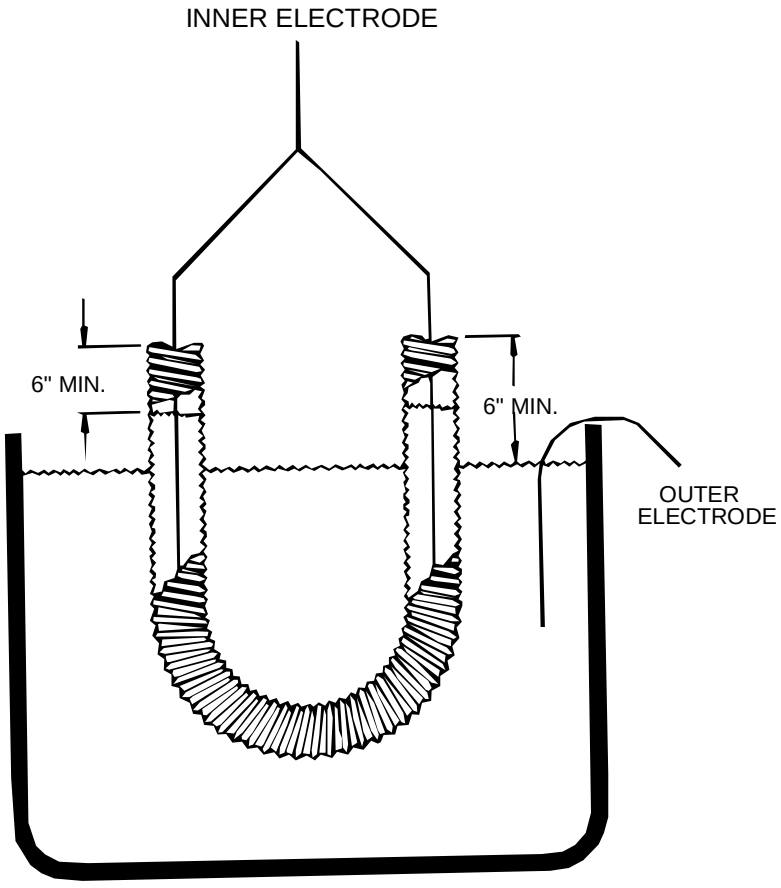


Figure 3

4.3.10 Fluid Resistance

Prepare six specimens, three 6-inch *(150-mm)* tubing specimens and three tensile specimens prepared and measured in accordance with Section 4.3.1, and immerse for the time and temperature specified for each of the test fluids listed in Table 3. The volume of the fluid shall not be less than 20 times that of the specimens. Before and after immersion, rinse the specimens in methyl ethyl ketone to remove surface contamination and fluid residues. After immersion and rinsing, wipe the specimens lightly and air dry for 30 to 60 minutes at 23 ± 3°C *(73 ± 5°F)*. Test the three specimens intended for the Tensile Strength and extensibility tests in accordance with Section 4.3.1. Weigh the other three specimens before and after immersion and calculate the weight change as a percentage. Report the average of the three values.

4.3.11 Flammability

Perform flammability in accordance with ASTM D 876, except that the bottom of the chamber shall be within 9 inches *(229 mm)* of the point of flame impingement and covered with surgical cotton. Observe any ignition of the cotton from dripping or falling particles.

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 the rejection and the action taken to correct the defect shall be furnished to the inspector.

5. PREPARATION FOR DELIVERY

5.1 PACKAGING

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

5.2 MARKING

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

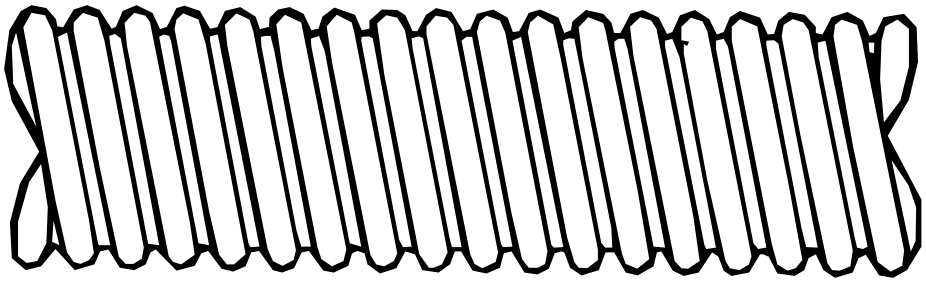
TABLE 1
Size-Dependent Test Criteria

Size Designation	Specimen Size (number of convolutions)	Test Load, LBS *(kg)*, ± 3%		Requirement*	
	Crush Resistance	Flexibility	Flex Life	Crush Resistance Room Temperature LBS *(kg)*, Minimum	Compressive Flexibility LBS *(kg)*, Maximum
0187	8	0.25 *(0.11)*	0.50 *(0.23)*	12 *(5.45)*	14 *(6.36)*
0281	8	0.50 *(0.23)*	0.75 *(0.34)*	12 *(5.45)*	14 *(6.36)*
0312	8	0.75 *(0.34)*	1.00 *(0.45)*	12 *(5.45)*	14 *(6.36)*
0375	8	0.75 *(0.34)*	1.00 *(0.45)*	10 *(4.55)*	14 *(6.36)*
0437	8	0.87 *(0.40)*	1.00 *(0.45)*	10 *(4.55)*	18 *(8.17)*
0500	7	1.00 *(0.45)*	1.00 *(0.45)*	10 *(4.55)*	18 *(8.17)*
0625	7	1.50 *(0.68)*	1.00 *(0.45)*	7 *(3.18)*	20 *(9.08)*
0750	6	2.00 *(0.91)*	2.00 *(0.91)*	7 *(3.18)*	25 *(11.35)*
0875	5	2.00 *(0.91)*	2.00 *(0.91)*	7 *(3.18)*	25 *(11.35)*
1000	5	2.00 *(0.91)*	2.00 *(0.91)*	7 *(3.18)*	25 *(11.35)*
1250	4	3.50 *(1.59)*	2.00 *(0.91)*	7 *(3.18)*	40 *(18.16)*
1500	4	3.50 *(1.59)*	2.00 *(0.91)*	7 *(3.18)*	40 *(18.16)*
1625	4	3.75 *(1.59)*	2.00 *(0.91)*	7 *(3.18)*	40 *(18.16)*
1750	4	4.00 *(1.82)*	2.00 *(0.91)*	7 *(3.18)*	40 *(18.16)*
2000	4	4.00 *(1.82)*	2.00 *(0.91)*	7 *(3.18)*	40 *(18.16)*

*See Table 3 for complete tubing requirements.

TABLE 2
Dimensions
Inches (Millimeters)

CONSTRUCTION DETAILS



Helical (right hand)

Size No. Designation	Maximum Inside Diameter	Minimum Inside Diameter	Maximum Outside Diameter	Maximum Wall Thickness	Convolutions ± 1 Per Inch (25 mm)	Maximum Weight	
						lbs/100 ft.	kg/100 m
0187	.187 *(4.75)*	.181 *(4.60)*	.320 *(8.13)*	.018 *(.46)*	8	1.2	*(1.8)*
0281	.281 *(7.14)*	.273 *(6.93)*	.414 *(10.52)*	.018 *(.46)*	8	1.5	*(2.2)*
0312	.312 *(7.92)*	.306 *(7.77)*	.450 *(11.43)*	.018 *(.46)*	8	1.8	*(2.7)*
0375	.375 *(9.53)*	.364 *(9.25)*	.510 *(12.96)*	.018 *(.46)*	8	2.0	*(3.0)*
0437	.437 *(11.1)*	.427 *(10.85)*	.571 *(14.50)*	.018 *(.46)*	8	2.5	*(3.7)*
0500	.500 *(12.70)*	.485 *(12.32)*	.650 *(16.51)*	.023 *(.58)*	7	3.5	*(5.2)*
0625	.625 *(15.88)*	.608 *(15.44)*	.780 *(19.81)*	.023 *(.58)*	7	4.3	*(6.4)*
0750	.750 *(19.05)*	.730 *(17.90)*	.930 *(23.62)*	.023 *(.58)*	6	5.0	*(7.4)*
0875	.875 *(22.23)*	.860 *(21.84)*	1.073 *(27.25)*	.023 *(.58)*	5	6.5	*(9.6)*
1000	1.000 *(25.40)*	.975 *(24.77)*	1.226 *(31.14)*	.023 *(.58)*	5	7.6	*(11.20*
1250	1.250 *(31.75)*	1.210 *(30.74)*	1.539 *(35.30)*	.023 *(.58)*	4	8.8	*(13.0)*
1500	1.500 *(38.1)*	1.437 *(36.50)*	1.832 *(46.53)*	.023 *(.58)*	4	11.4	*(16.9)*
1625	1.625 *(41.28)*	1.562 *(39.67)*	1.975 *(50.17)*	.023 *(.58)*	4	11.8	*(17.7)*
1750	1.750 *(44.45)*	1.688 *(42.67)*	2.082 *(52.88)*	.023 *(.58)*	4	12.8	*(19.2)*
2000	2.000 *(50.80)*	1.937 *(49.20)*	2.332 *(59.23)*	.023 *(.58)*	4	14.2	*(21.3)*

TABLE 3
Requirements

PROPERTY	UNIT	REQUIREMENTS	TEST METHOD
PHYSICAL			
Dimensions	Inches *(mm)*	In accordance with Table 2	ASTM D 876
Tensile Strength	psi. (*MPa)*	2000 *(13.8)* minimum	Section 4.3.1
Extensibility	Percent	150 minimum	ASTM D 638
Specific Gravity	---	1.8 maximum	ASTM D 792
Crush Resistance	Lbs. *(kg)*	In accordance with Table 1	Section 4.3.2
Compressive Flexibility	Lbs. *(kg)*	In accordance with Table 1	Section 4.3.3
Flexibility	Inches *(mm)*	3 *(76.2)* minimum	Section 4.3.4
Flex Life 10,000 cycles Followed by test for:	---	---	Section 4.3.5
Dielectric Withstand (12 kV)	---	No breakdown	Section 4.3.9
Low Temperature Flexibility 4 hours at -55°C *(-67°F)* for 5 cycles Followed by test for:	---	No visible cracks	Section 4.3.7
Dielectric Withstand (12 kV)	---	No breakdown	Section 4.3.9
Heat Shock at 300°C *(572°F)*	---	No dripping, flowing or cracking	Section 4.3.6
Followed by test for:		20 maximum	
Longitudinal Change	Percent		Section 4.3.6
Heat Aging 168 hours at 200°C *(392°F)* Followed by tests for:	---	---	Section 4.3.8
Tensile Strength	psi. (*MPa)*	2000 *(13.8)* minimum	Section 4.3.1
Ultimate Extensibility	Percent	100 minimum	ASTM D 638
ELECTRICAL			
Dielectric Withstand (12 kV)	---	No breakdown	Section 4.3.9
CHEMICAL			
Flammability Duration of Burning	Seconds	15, maximum No dripping or flowing; no burning or charring of indicator; no flaming of cotton.	Section 4.3.11
Fluid Resistance 24 hours at 23°C *(73°F)* Gasoline, Automotive (MIL-G-3056) Gasoline, Aviation, Grade 100 (ASTM D 910) (MIL-T-81533) Coolanol 25* Followed by tests for:	---	---	Section 4.3.10
Tensile Strength	psi. (*MPa)*	2000 *(13.8)* minimum	Section 4.3.1
Ultimate Extensibility	Percent	100 minimum	ASTM D 638
Weight Change	Percent	3 maximum	

TABLE 3
Requirements
(continued)

PROPERTY	UNIT	REQUIREMENTS	TEST METHOD
CHEMICAL (continued) Fluid Resistance 24 hours at 50°C *(122°F)* JP-4, JP-5 and JP5/JP8(MIL-T-5624) Fuel, Diesel, Referee Grade (MIL-F-46162) Deicing Fluid (MIL-A-8243) Cleaning Compound (MIL-C-43616) 5% Salt Solution (O-S-1926) Cleaning Compound (PC-437) Fuel Oil, Diesel (VV-F-800) Followed by tests for:	---	---	Section 4.3.10
Tensile Strength	psi. (*MPa)*	2000 *(13.8)* minimum	Section 4.3.1 ASTM D 638
Ultimate Extensibility	Percent	100 minimum	
Weight Change	Percent	3 maximum	
Fluid Resistance 24 hours at 75°C *(167°F)* Hydraulic Fluid (MIL-H-5606) Skydrol* 500 Lubricating Oil (MIL-L-7808) Lubricating Oil (MIL-L-23699) Followed by tests for:	---	---	Section 4.3.10
Tensile Strength	psi. (*MPa)*	2000 *(13.8)* minimum	Section 4.3.1 ASTM D 638
Ultimate Extensibility	Percent	100 minimum	
Weight Change	Percent	3 maximum	

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