

DEPARTMENT OF THE NAVY
 STRATEGIC SYSTEMS PROGRAMS
 ARLINGTON, VA 22202-3930

SSP WS16035B
 09 SEPT 08

SUPERSEDING
 WS16035A
 13 MAY 2004

**WEAPON
 SPECIFICATION**

TYPE
 MATERIAL SPECIFICATION
 TITLE
 TUBING, HEAT SHRINKABLE, POLYOLEFIN

CONTRACT NO. N0003000C0100

CAGE Code 10001

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THIS SPECIFICATION CONSISTS OF 14 PAGES

RECORD OF REVISIONS

REV LTR	CHANGE DATE	APPROVED STRATEGIC MISSILE PROGRAMS	DATE	CUSTOMER APPROVAL	DATE
A	13 May 2004	David Lee	17 May 2004	Paul Maier	7 June 2004
B	18 Sept. 2008	Tom VanCleave	Oct. 2008	Michael Wu	Nov. 2008

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MATERIAL SPECIFICATION

TUBING, HEAT SHRINKABLE, POLYOLEFIN.

1.0 SCOPE

1.1 Scope. This specification establishes requirements for flexible, electrically insulating, 2 to 1 shrink ratio tubing, the diameter of which can be reduced to a predetermined size upon the application of heat.

2.0 APPLICABLE DOCUMENTS

2.1 Government Furnished Documents. The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

O-A-51	Acetone, Technical
O-E-760	Ethyl Alcohol (Ethanol), Denatured Alcohol, and Proprietary Solvent

Military

MIL-I-631	Insulation, Electrical, Synthetic - Resin
MIL-I-7444	Insulation, Electrical, Sleeving, Flexible

Department of the Navy

WS 6788	Hydraulic Fluid, Petroleum Base, Missile Use
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STANDARDS

Military

MIL-STD-104	Limits for Electric Insulation Color
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(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

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2.2 Other Publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids shall apply.

American Society for Testing and Materials

D257	DC Resistance or Conductance of Insulating Materials
D412	Tension Testing of Vulcanized Rubber
D518	Surface Cracking Resistance of Stretched Rubber Compounds
D624	Tear Resistance of Vulcanized Rubber
D792	Specific Gravity and Density of Plastics by Displacement
D876	Testing Nonrigid Vinyl Chloride Polymer Tubing
D882	Tensile Properties of Thin Plastic Sheet
D1149	Accelerated Ozone Cracking of Vulcanized Rubber
D1499	Operating Light and Water Exposure Apparatus (Carbon-Arc type) for Exposure of Plastics
D2671	Standard Test Methods for Heat -- Shrinkable Tubing for Electrical Use
G23	Operating Light and Water Exposure Apparatus (Carbon-Arc Type) for Exposure of Nonmetallic Materials

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

ISO Specifications

ISO 846	Plastics -- Evaluation of the Action of Microorganisms
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3.0 REQUIREMENTS

3.1 Materials. Materials specified herein shall be manufactured from irradiated, thermally stabilized modified polyolefin which, when compound with other ingredients¹, will result in compositions that conform to the requirements of this specification. Once qualification has been granted, the manufacturer shall not change material formulation or processing technique without obtaining written approval; requalification may be required.

3.2 Dimensions

3.2.1 Inside Diameter and Wall Thickness. Unless otherwise specified on the engineering drawing, the inside diameter, wall thickness and tolerance of the 2 to 1 tubing in its expanded (as supplied) form and after its complete recovery, subsequent to the application of heat, shall be in accordance with Table I.

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TABLE I. INSIDE DIAMETERS AND WALL THICKNESSES OF 2 TO 1 TUBING

Size	Expanded Inside Dia. (inches) Minimum	Recovered Dimensions (After Heating)			
		Inside Dia. (inches) Maximum	Wall Thickness (inches)		
			Minimum	Maximum	Nominal
3/64	0.046	0.023	0.013	0.019	0.016
1/16	0.063	0.031	0.014	0.020	0.017
3/32	0.093	0.046	0.017	0.023	0.020
1/8	0.125	0.062	0.017	0.023	0.020
3/16	0.187	0.093	0.007	0.026	0.022
1/4	0.250	0.125	0.022	0.031	0.027
3/8	0.375	0.187	0.022	0.031	0.027
1/2	0.500	0.250	0.022	0.031	0.027
3/4	0.750	0.375	0.022	0.036	0.029
1	1.000	0.500	0.030	0.040	0.035
1-1/2	1.500	0.750	0.034	0.046	0.040
2	2.000	1.000	0.038	0.052	0.045
3	3.000	1.500	0.042	0.058	0.050
4	4.000	2.000	0.046	0.064	0.055

3.2.2 Length. Unless otherwise specified in the contract or purchase order, the tubing shall be supplied in lengths of 48 +1, -0 inches.

3.3 Color. The color of the tubing shall be black, white, blue, or red, as specified (See 6.2). Tubing shall conform to the requirements of MIL-STD-104 before and after exposure to the conditions in 4.6.3.1.

3.4 Physical and Electrical Properties. The physical and electrical properties of the material shall conform to the requirements of Table II and to those listed below in the paragraphs that follow.

3.5 Flammability. The material (recovered) shall not burn for a distance of more than six inches and shall be self extinguishing when tested in accordance with 4.6.14

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TABLE II. MATERIAL PROPERTIES

PROPERTY	UNITS	TUBING CONDITION	REQUIREMENT	TEST
<u>Physical</u>				
Longitudinal Change	percent	recovered	-10% to +5%	4.6.2
Secant Modulus	psi	recovered	2.5×10^4 Max.	4.6.4
Tensile strength	psi	recovered	1500 Min.	4.6.5
Ultimate elongation	percent	recovered	200 Min.	4.6.6
Tear strength	lb/in	recovered	275 Min.	4.6.7
Specific gravity	N/A	either	1.03 - 1.35	4.6.8
<u>Electrical</u>				
Dielectric Strength	volts/mil.	recovered	400 Min.	4.6.9
Volume resistivity	ohm-cm.	recovered	1×10^{12} (Min.)	4.6.10
<u>Fluid Resistance</u>				
Salt water resistance:				
Tensile strength	psi	recovered	1000 Min.	4.6.11
Dielectric strength	volts/mil.	recovered	300 Min.	
Hydraulic oil resistance:				
Tensile strength	psi	recovered	750 Min.	4.6.11
Dielectric strength	volts/mil.	recovered	300 Min.	
Water Absorption	percent change in original wt.	recovered	± 0.5	4.6.12
<u>Environmental</u>				
Ozone resistance	N/A	recovered	No cracking or splitting	4.6.13
Heat aging at 302°F				
Elongation after 168 hrs	percent	recovered	100 Min.	4.6.15
Elongation after 336 hrs	percent	recovered	50 Min.	
Heat shock at 482°F (4 hrs)				
Mandrel bend	N/A	recovered	No drip, flow or cracking	4.6.16

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3.6 Corrosion. The tubing shall not cause pitting of metal test plates when prepared and tested in accordance with 4.6.17. Discoloration or tarnishing of the test plates shall not be cause for rejection.

3.7 Fungus Resistance. The recovered tubing shall not support fungus growth when tested in accordance with 4.6.18.

3.8 Print (Identification) Retention. The tubing exterior surface shall be receptive to permanent hot impression stamping when tested in accordance with 4.6.19.

3.9 Workmanship. Tubing shall be uniform in quality and construction and shall be free of blisters, pin holes, seams, cracks, inclusions of foreign matter, and other defects affecting fabrication, appearance, or performance of parts.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspections and tests requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure that supplies conform to the prescribed requirements.

4.2 Classification of tests. The inspection and testing of tubing shall be classified as follows:

- a. Qualification Tests: Tests performed on samples of material submitted for approval as qualified products.
- b. Acceptance tests: Tests performed on all individual lots of qualified products submitted for acceptance on contract bids.

4.2.1 Lot. A lot shall consist of all tubing of the same size, color and formulation, produced in a single plant run from a single lot of material, and offered for inspection at the same time.

4.3 Qualification tests. Qualification tests shall consist of all of the tests prescribed herein for all of the requirements of this specification.

4.3.1 Qualification sampling instructions. The qualification test sample shall consist of 40 feet of tubing of one size and color. Qualification of any one size of tubing constitutes qualification for only that particular color and range of sizes of which it is a part, see Table III.

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TABLE III TUBING SIZE RANGES

<u>Range of Sizes</u>	<u>Range Number</u>
1/4 and under	I
3/8 thru 1	II
1-1/2 thru 4	III

4.3.2 Qualification Test Report. The manufacturer shall furnish a test report on each size and color submitted for qualification showing test results which substantiate that the material conforms to the requirements of this specification.

4.4 Acceptance Tests. Acceptance tests shall consist of those specified in Table IV:

Table IV. ACCEPTANCE TESTS

<u>REQUIREMENTS</u>	<u>TEST PARAGRAPH</u>
Visual Examination	4.6.1
Dimensions	4.6.2
Longitudinal Change	4.6.2
Color, Expanded Tubing	4.6.3
Secant Modulus	4.6.4
Specific Gravity	4.6.8
Dielectric Strength	4.6.9
Flammability	4.6.14
Heat Shock	4.6.16

4.4.1 Acceptance Sampling Instructions. Samples for tests shall consist of not less than 8 feet in total length of tubing selected at random from each lot.

4.4.2 Test Report. When directed in the contract or purchase order, the manufacturer shall furnish a test report for the specific lot being purchase showing that the product conforms to the acceptance test requirements of this specification. The report shall include specification number and revision, contract or purchase order number, manufacturer's name and compound number.

4.5 Test Conditions. Unless otherwise specified herein, tests shall be performed at room temperature of $75 \pm 5^\circ\text{F}$. In case of dispute, standard referee conditions shall be $73.5 \pm 2^\circ\text{F}$ and 50 ± 5 percent relative humidity.

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4.6 Test Methods. Recovered specimens required by test methods shall be obtained by conditioning the specimens in an oven in accordance with 4.6.2.

4.6.1 Visual Examination of Product. All tubing shall be visually examined to ascertain conformance to this specification with respect to all requirements not covered by specific test methods such as workmanship, marking, etc.

4.6.2 Dimensions. The inside diameter and length of three 10-inch specimens in their expanded form. The diameter shall be determined using pin gages and micrometers. The length shall be measured to an accuracy of ± 0.050 inch. The samples shall then be suspended in a mechanical convection oven maintained at temperature of $392 \pm 5^\circ\text{F}$ at an air velocity of 100 to 200 feet per minute for 45 seconds ($+2$, -0 seconds) for Ranges I and II (Table III) material, and 3 minutes ± 10 seconds for Range III material. Upon removal, they shall be cooled to 68 to 77°F . The inside diameter shall be remeasured and the change in length calculated as a percentage of the original length. The wall thickness of the recovered tubing shall be determined using micrometers.

4.6.3 Color. The color of the expanded tubing and the recovered tubing after subsequent exposure to the environment conditions described below, shall be in accordance with the MIL-STD-104.

4.6.3.1 Color Stability Environment. Recovered specimen of each color of tubing shall be exposed to an environment in accordance with ASTM D1499 using apparatus in compliance with ASTM G23, Type D (or an equivalent apparatus approved in the contract or purchase order) with continuous light and intermittent water spray for a period of not less than 332 hours, followed by stabilization at room conditions for at least two hours.

4.6.4 Secant Modulus. The secant modulus of the recovered tubing shall be tested in accordance with ASTM D882, Method A at two percent strain. The test specimens shall be full sections of tubing for inside diameters of 1/4-inch and smaller and longitudinally cut specimens for inside diameter of 3/8-inch and larger.

4.6.5 Tensile Strength. The tensile strength of the recovered tubing shall be determined in accordance with ASTM D412 using a dumbbell-shaped specimen and one-inch initial jaw separation.

4.6.6 Ultimate Elongation. The ultimate elongation of the recovered tubing shall be determined in accordance with ASTM D412 using the same specimen and separation as described for tensile strength.

4.6.7 Tear Resistance. The tear resistance of the recovered tubing shall be determined in accordance with ASTM D624 using Die B.

4.6.8 Specific Gravity. The specific gravity of the tubing shall be determined in accordance with ASTM D792, Method A-1 except that samples weighing two to three grams shall be used.

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4.6.9 Dielectric Strength. The dielectric strength of the recovered tubing shall be determined on three one-foot samples and tested in accordance with ASTM D876.

4.6.10 Volume Resistivity. The volume resistivity of the recovered tubing shall be determined in accordance with ASTM D257.

4.6.11 Salt Water and Hydraulic Fluid Resistance. Three recovered tubing specimens, each approximately six inches long, shall be immersed in each of the fluids shown in Table V for the time and temperature indicated. Upon removal, the test specimens shall be carefully wiped dry and allowed to remain at room temperature for one hour. At the end of this period, each specimen shall be subjected to the dielectric strength test and the tensile strength test of this specification.

TABLE V. IMMERSION FLUID

FLUID	SPECIFICATION	HOURS	TEMPERATURE (°F)
Hydraulic	WS 6788	20 (+1/2, -0)	68 to 77°F
Salt Water (5% salt)	---	20 (+1/2, -0)	68 to 77°F

4.6.12 Water Absorption. Three weighed, recovered tubing specimens, each approximately four inches long, shall be totally immersed vertically in distilled water, and maintained at a temperature of 68 to 77°F for at least 20 hours. The specimen shall then be washed for 25 to 30 seconds in ethyl alcohol conforming to O-E-760 and dried for 5 to 5-1/2 minutes in a circulating-air oven maintained at a temperature of 175 to 200°F. The specimens shall be removed from the oven, cooled to room temperature and immediately reweighed. The percentage change in weight shall be calculated.

4.6.13 Ozone Resistance. The ozone resistance of the recovered tubing shall be determined in accordance with the ASTM D1149 at 50 ppm ozone concentration and 100 ± 2°F temperature with an exposure time of at least 332 ± 2 hours. The specimen shall be prepared in accordance with Procedure B of ASTM D518.

4.6.14 Flammability. Three recovered test specimens, each 8 inches long, shall be cut for this test. Specimens shall be marked in a manner to indicate 6 inches between marks. Each specimen shall be inserted at one end approximately one-fourth of an inch above the top of the Bunsen burner (or equivalent) which has been lighted. The specimen shall be rotated horizontally in the flame to ignite it as evenly as possible. When flame reaches the first mark, the specimen shall be removed from the flame and held vertical with burning end uppermost in the still air or in a shielded chamber. The specimen shall be self extinguishing before flame has traversed the distance between the marked-off 6-inch length.

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4.6.15 Heat Aging. Four recovered tubing specimens, each 6 inches in length, shall be suspended in a mechanical convection oven maintained at a temperature of $302 \pm 5^\circ\text{F}$ at an air velocity of 100 to 200 feet per minute. Two specimens shall be withdrawn after 168 ± 2 hours, cooled to $68 - 77^\circ\text{F}$, and then tested for ultimate elongation. The remaining two specimens shall be heat aged for a total of 336 hours before removal from the oven, cooled to $68 - 77^\circ\text{F}$ and then tested for ultimate elongation.

4.6.16 Heat Shock. Two recovered tubing specimens, each at least six inches in length, shall be suspended in a mechanical convection oven maintained at a temperature of $482 \pm 9^\circ\text{F}$ for a period of 4 hours (+15 minutes, -0) and at an air velocity of 100 to 200 feet per minute. After removal from the oven, cool to $68 - 77^\circ\text{F}$ and visually inspect for dripping, flowing and cracking. They shall be bent 180° over a mandrel of the diameter shown in Table VI and inspected for cracking. Any side-cracking occurring as a result of the compression of the specimen on the mandrel shall be disregarded.

TABLE VI. MANDREL DIMENSIONS

Nominal Size Expanded Tubing	Mandrel Diameter (inches)
3/64 through 1/4	5/16
3/8 through 1/2	3/8
3/4 through 2	7/16
3 through 4	7/8

4.6.17 Corrosion. Two samples of slit, expanded tubing approximately one square inch in area shall be washed with acetone conforming to O-A-51 and allowed to air dry. The samples shall then be tested for corrosion in accordance with MIL-I-7444, with the following exceptions. The test plates, with tubing in place, shall be conditioned in an air gravity oven maintained at a temperature of $302 \pm 5^\circ\text{F}$, and a pressure of $4 \pm 1/2$ pounds per square inch, for one hour + 10, -0 minutes prior to seven day exposure to the conditions stated in MIL-I-7444. The samples shall be maintained at the above pressure during exposure to high humidity. After the exposure period, the metal plates shall be visually examined for pitting. Discoloration or tarnishing of the metal shall not be cause for rejection.

4.6.18 Fungus Resistance. The fungus resistance of three recovered tubing specimens shall be determined in accordance with ISO 846 Method B.

4.6.19 Print Retention. Hot impression stamp a section of expanded tubing using a Kingsley KW-6 marker at $460 \pm 20^\circ\text{F}$ with B-242 or K289 foil or equivalent marking system. Recover marked specimens per 4.6.2. Wait a minimum of two minutes and rub printed area twenty times with normal thumb pressure. The marking shall not become illegible.

4.7 Rejection and Retest. Failure of any sample of tubing to meet any requirements of this specification shall be cause for rejection of the entire lot represented.

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5.0 PREPARATION FOR DELIVERY

5.1 Packaging. All tubing more than 15 feet in length shall be placed on cores having a minimum outside diameter of 6 inches. Spools shall not be greater than 22 inches in outside diameter and 20 inches in width. Tubing of 15 feet or less shall be packaged in air tight polyethylene film and placed in cardboard boxes or tubes without coiling and not exceeding 220 linear feet per box (standard 48-inch length included).

5.1.1 Length. The total length required shall be as specified on the purchase order. Unless otherwise specified, minimum lengths for spools shall be full spools. One short length may be supplied to fulfill total length requirements. Unless otherwise specified, in the contract or purchase order, minimum piece length for unspooled tubing shall be 4 feet.

5.2 Marking. Each bundle or container of tubing shall be distinctly identified with a tag or label containing the following information:

- a. Tubing, Heat Recoverable, Polyolefin
- b. Specification number and revision letter (if applicable)
- c. Length
- d. Total quantity
- e. Size and color
- f. Expansion ratio
- g. Manufacturer's name
- h. Date of expansion
- i. Manufacturer's product lot number

6.0 NOTES

6.1 Intended Use. The products covered in this specification are intended for use electrical insulation on wires or identification of wiring and cables.

6.2 Ordering Data. Procurement documents should specify:

- a. Title, number, and revision of this specification.
- b. Size and color
- c. Identification marking
- d. Length of pieces (if other than four feet)
- e. Total quantity of each size color
- f. Test samples required (4.3.1 or 4.4.1)
- g. Test report (4.3.2 or 4.4.2)
- h. Test conditions, if other than specified (4.5)

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