



Raychem Wire and Cable

501 Oakside Avenue, Redwood City, CA 94063-3800

SPECIFICATION: WCD 3111

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**WIRE AND CABLE, ELECTRIC, MODIFIED PERFLUOROALKOXY COPOLYMER
RESIN-INSULATED, NICKEL-COATED COPPER**

1. SCOPE

1.1 SCOPE

This specification covers nickel-coated copper wire insulated with modified perfluoroalkoxy copolymer resin (PFA) and single- and multiple-conductor cables which may be shielded and/or jacketed. These products are intended for use in high temperature, high power aerospace applications.

1.2 CLASSIFICATION

Products in accordance with this specification shall be of the following types, as specified in the applicable specification sheet.

Finished Wire: A single conductor, insulated as specified in the applicable specification sheet.

Finished Cable: Any construction other than finished wire, utilizing a wire or wires with or without shielding, or with or without an outer jacket.

1.3 TEMPERATURE INDEX

Products in accordance with this specification have a temperature index rating of at least 10,000 hours at 260°C (*TI 10 kh/260°C*) when tested in accordance with ASTM D 3032, Section 14.

2. APPLICABLE DOCUMENTS

2.1 GOVERNMENT-FURNISHED DOCUMENTS

The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1.1 Department of Defense

SPECIFICATIONS

Federal

UU-T-450 Tissue, Facial

STANDARDS

Federal

FED-STD-228 Cable and Wire, Insulated; Methods of Testing

Military

MIL-STD-104 Limits for Electrical Insulation Color

MIL-STD-681 Identification Coding and Application of Hook Up and Lead Wire

MIL-STD-2223 Test Methods for Insulated Electric Wire

(Copies of Department of Defense documents may be obtained from the Naval Publications and Forms Center, Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094; or at <https://quicksearch.dla.mil/>.)

2.2 OTHER PUBLICATIONS

The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.2.1 American Society for Testing and Materials (ASTM)

D 3032 Standard Test Methods for Hookup Wire Insulation

(Copies of ASTM documents may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959; or at www.astm.org.)

2.2.2 National Electrical Manufacturers Association (NEMA)

WC 27500 Standard for Aerospace and Industrial Electrical Cable

(Copies of NEMA documents may be obtained from the National Electrical Manufacturers Association, 1300 North 17th Street, Rosslyn, Virginia 22209; or at www.nema.org.)

2.2.3 Society of Automotive Engineers (SAE)

AS22759 Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy

AS29606 Wire, Electrical, Stranded, Uninsulated Copper, Copper Alloy, or Aluminum, or Thermocouple Extension, General Specification For

(Copies of SAE documents may be obtained from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001; or at www.sae.org.)

3. REQUIREMENTS

3.1 SPECIFICATION SHEETS

The requirements for the individual wire and cable furnished under this specification shall be as specified herein and in accordance with the applicable specification sheet. In the event of a conflict, the requirements of the specification sheet shall govern.

3.2 QUALIFICATION

The finished wire and cable furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein (see 4.3).

3.3 MATERIALS

Materials not specifically designated herein shall be of the quality and form best suited for the purpose intended. Unless otherwise specified, the materials shall meet the following requirements:

3.3.1 Conductor Material

Conductor material shall be nickel-coated soft or annealed copper in accordance with AS29606.

3.3.2 Shield Material

Shield strands shall conform to the requirements for conductor material (3.3.1). When specified, conforming strands shall be flattened and rectangular in cross-section.

3.3.3 Insulation and Jacket Material

The wire insulation and cable jacket material shall be extruded modified perfluoroalkoxy copolymer resin (PFA).

3.4 CONSTRUCTION

Construction of the finished wire and cable shall be as specified herein and in the applicable specification sheet.

3.4.1 Conductor

3.4.1.1 Conductor Stranding

Conductor stranding shall be in accordance with the applicable specification sheet. For high-strand-count conductor (conductor having strand counts higher than AS29606 of the same wire size), the minimum allowable number of strands may be 98 percent of the number specified in the applicable specification sheet, as long as the dimensional and resistance requirements are met.

3.4.2 Cabling

Cable components shall be twisted in a left-hand lay with a length of lay 8 to 16 times the cabled diameter. Cable components shall meet the requirements of the applicable component specification sheet prior to cabling.

3.4.3 Wraps

Wrap tapes, where specified in the applicable specification sheet, shall be applied with an overlap of 25 percent minimum and shall meet the material and construction requirements of the applicable specification sheet. Overlap is defined as the percentage of tape width covered by successive turns of tape.

3.5 FINISHED WIRE AND CABLE

Finished wire and cable shall conform to the requirements of Table 1 and to those of the applicable specification sheet.

3.5.1 Blocking

When finished wire or jacketed cable is tested in accordance with 4.5.1, adjacent turns and layers of the insulation or jacket shall not block. Blocking shall be defined as a transfer of material between adjacent surfaces when they are separated.

3.5.2 Color

Color shall be in accordance with MIL-STD-104, Class 1. White is preferred. Color code designators and colored stripes, if used, shall be in accordance with MIL-STD-681.

3.5.3 Conductor Elongation

3.5.3.1 AS29606 Conductor Stranding

For conductor composed of AS29606 stranding, the individual strands removed from finished wire, sizes 20 and larger, or the whole conductor removed from finished wire, sizes 22 and smaller, shall have the following minimum elongation when tested in accordance with 4.5.2.1:

Sizes 24 and smaller – 6 percent, minimum

Sizes 22 and larger – 10 percent, minimum

3.5.3.2 High-Strand-Count Conductor Stranding

For high-strand-count conductor stranding (conductor having strand counts higher than AS29606 of the same wire size), the elongation shall be 5 percent, minimum average, for the whole stranded conductor of regular bunch constructions, or for one whole member from rope bunch constructions, as applicable, when removed from finished wire and tested in accordance with 4.5.2.2.

TABLE 1. PROPERTIES OF FINISHED WIRE AND CABLE

Examination or Test	Wire	Cable	Requirement	Test Method	*Inspection Class
Blocking	X	X	3.5.1	4.5.1	Q
Cabling	–	X	3.4.2	4.5.3	P
Color	X	X	Specification Sheet and 3.5.2	4.5.3	P
Conductor Diameter	X	–	Specification Sheet	4.5.3	P
Conductor Elongation	X	–	3.5.3	4.5.2	P
Conductor Material	X	–	Specification Sheet and 3.3.1	4.5.3	V
Conductor Resistance	X	–	Specification Sheet	AS22759	P
Conductor and Shield Continuity	–	X	3.5.4	WC 27500	100%
Conductor Splices	X	–	AS29606	4.5.3	V
Conductor Stranding	X	–	Specification Sheet and 3.4.1.1	4.5.3	V
Dielectric Withstand	–	X	Specification Sheet and WC 27500	WC 27500	100%
Finished Wire and Cable Diameter	X	X	Specification Sheet	4.5.3	P
Flammability	X	X	3.5.5	4.5.4	Q
Humidity Resistance	X	–	3.5.6	4.5.5	Q
Identification and Color Striping Durability	X	X	3.5.7	AS22759	P
Identification of Product	X	X	Specification Sheet and 3.5.8	4.5.3	P
Insulation/Jacket Concentricity	X	X	3.5.9	ASTM D 3032, Sect. 16	P
Insulation/Jacket Construction	X	X	Specification Sheet	4.5.3	P
Insulation/Jacket Elongation and Tensile Strength	X	X	Specification Sheet	4.5.6	P
Insulation/Jacket Flaws	X	X	Specification Sheet and 3.5.10	4.5.7	100%
Insulation/Jacket Material	X	X	Specification Sheet and 3.3.3	4.5.3	V
Insulation Resistance	X	–	3.5.11	4.5.8	Q
Insulation/Jacket Thickness	X	X	Specification Sheet	4.5.3	P
Life Cycle	X	X	Specification Sheet and 3.5.12	4.5.9	Q
Low Temperature-Cold Bend	X	X	Specification Sheet and 3.5.13	4.5.10	P
Minimum Bend Radius	X	–	Specification Sheet and 3.5.14	4.5.11	Q
Shield Coverage	–	X	Specification Sheet	WC 27500	P
Shield Material and Construction	–	X	Specification Sheet, 3.3.2 and WC 27500	WC 27500	P
Shrinkage	X	X	Specification Sheet and 3.5.15	4.5.12	P
Smoke Test	X	–	3.5.16	4.5.13	Q
Surface Resistance	X	–	3.5.17	4.5.14	Q
Thermal Shock	–	X	Specification Sheet and WC 27500	WC 27500	P
Thermal Shock Resistance	X	–	Specification Sheet and 3.5.18	4.5.15	P
UV Laser Marking Contrast	X	X	Specification Sheet and 3.5.19	AS22759	Q
Weight	X	X	Specification Sheet	AS22759	P
Workmanship	X	X	AS22759	AS22759	P
Wraps	–	X	Specification Sheet and 3.4.3	4.5.3	P
Wrap Test	X	–	Specification Sheet and 3.5.20	4.5.17	P

*Inspection Class (see 4.2):

P = In-Process or Lot Test

100% = 100% Finished Product Test

Q = Qualification Test

V = Vendor Test

3.5.4 Conductor and Shield Continuity

When finished cable is tested in accordance with WC 27500, there shall be no loss of continuity in the conductors or shield.

3.5.5 Flammability

When finished wire or jacketed cable is tested in accordance with 4.5.4, the burn length shall not exceed 3 inches (*76 mm*), the afterburn time shall not exceed 3 seconds, and there shall be no flaming of the facial tissue.

3.5.6 Humidity Resistance

When tested in accordance with 4.5.5, the insulation resistance of the finished wire, after humidity exposure, shall be not less than 50,000 megohms for 1000 feet (*15,240 MΩ-1 km*).

3.5.7 Identification and Color Striping Durability

Identification and color striping shall withstand the marking durability test specified in AS22759 for 125 cycles (250 strokes) with a weight of 250 grams. Marking and/or striping on component wire shall be tested prior to cabling.

3.5.8 Identification of Product

When specified by the procuring activity, finished wire or jacketed cable shall be identified by a marking applied to the outer surface. The identification shall consist of the appropriate mark as specified by the contract or the applicable specification sheet. The mark color shall be in accordance with MIL-STD-104, Class 1, and shall be contrasting to that of the marking surface. Identification shall be applied with the vertical axis of the printed characters parallel to the longitudinal axis of the wire or cable when the nominal diameter of the marking surface is 0.050 inch (*1.3 mm*) or smaller. The vertical axis of the printed characters may be either perpendicular or parallel to the longitudinal axis of the wire or cable when the nominal diameter of the marking surface exceeds 0.050 inch (*1.3 mm*).

3.5.9 Insulation or Jacket Concentricity

The concentricity of the wire insulation or cable jacket shall be not less than 70 percent.

3.5.10 Insulation or Jacket Flaws

One hundred percent of finished wire and shielded-and-jacketed cable shall pass the impulse dielectric test or the spark test specified in 4.5.7 using the voltage specified in the applicable specification sheet. Testing shall be performed during the final winding of the wire or cable onto shipment spools or reels.

3.5.11 Insulation Resistance

When finished wire is tested in accordance with 4.5.8, the insulation resistance of the finished wire shall be not less than 50,000 megohms for 1000 feet (*15,240 MΩ-1 km*).

3.5.12 Life Cycle

3.5.12.1 Finished Wire

When finished wire is tested in accordance with 4.5.9.1, there shall be no cracking of the insulation and no dielectric breakdown.

3.5.12.2 Jacketed Cable

When jacketed cable is tested in accordance with 4.5.9.2, there shall be no cracking of the jacket and, when applicable, no dielectric breakdown of the jacket.

3.5.13 Low Temperature-Cold Bend

3.5.13.1 Finished Wire

When finished wire is tested in accordance with 4.5.10.1, there shall be no cracking of the insulation and no dielectric breakdown.

3.5.13.2 Jacketed Cable

When jacketed cable is tested in accordance with 4.5.10.2, there shall be no cracking of the jacket and, when applicable, no dielectric breakdown of the jacket.

3.5.14 Minimum Bend Radius

The minimum bend radius of the finished wire shall be one half the diameter of the mandrel specified in the applicable specification sheet provided there is no cracking of the insulation and no dielectric breakdown when the finished wire is tested in accordance with 4.5.11.

3.5.15 Shrinkage

When finished wire or jacketed cable is tested in accordance with 4.5.12, the insulation or jacket shrinkage, at either end of the specimen, shall not shrink more than that specified in the applicable specification sheet.

3.5.16 Smoke Test

When finished wire is tested in accordance with 4.5.13, there shall be no visible smoke.

3.5.17 Surface Resistance

When finished wire is tested in accordance with 4.5.14, the surface resistance of the finished wire shall be not less than 500 megohms-inch (*12,700 megohms-mm*) on both the initial and final readings.

3.5.18 Thermal Shock Resistance

When finished wire is tested in accordance with 4.5.15, the insulation shall not shrink or elongate more than that specified in the applicable specification sheet. There shall be no flaring of the insulation.

3.5.19 UV Laser Marking Contrast

When required by the specification sheet, finished wire and jacketed cable, with a finished maximum diameter of 0.400 inch or less, shall be ultraviolet (UV) laser markable. The mark shall meet a minimum contrast level of 50 percent, or as specified in the applicable specification sheet.

3.5.20 Wrap Test

When finished wire is tested in accordance with 4.5.17, there shall be no cracking of the insulation and no dielectric breakdown.

4. **QUALITY ASSURANCE PROVISIONS**

4.1 **RESPONSIBILITY FOR INSPECTION**

The supplier is responsible for the performance of all the inspection tests specified herein. The supplier may utilize his own or any other inspection facility and services acceptable to the buyer. Inspection records of the examinations and tests shall be kept complete and available to the buyer as required.

4.2 **INSPECTION CLASSIFICATION**

- a. Vendor Control (V): Requirements for raw materials such as conductor and insulation/jacket materials over which the vendor has control and responsibility.
- b. Process Control (P): Inspections performed on samples taken from the lots of wire or cable. Inspections may be performed on finished wire and cable or after the process which establishes the specified characteristic. The Quality Control Plan establishes the frequency of inspection based on process control data.
- c. One Hundred Percent (100%): Tests performed on the total length of each wire or cable. Tests may be performed on the finished product or “in process”, as applicable.
- d. Qualification (Q): Tests performed only at the time of initial qualification or requalification.

4.3 **QUALIFICATION INSPECTION**

Qualification inspection shall consist of all tests listed in Table 1, as applicable to finished wire or to finished cable. Requalification testing shall be performed any time changes in materials or processes occur that are deemed to have the potential for significantly altering the form, fit, function, or appearance of the product.

4.3.1 Sampling for Qualification Inspection

Samples of wire or cable for qualification inspection shall be taken from production lots which have been manufactured under the most current Quality Control Plan. The finished cable sample may consist of any jacketed cable construction. Finished wire samples shall be selected from the following size ranges:

	<u>Wire Size Range</u>	
	<u>AWG</u>	<u>mm²</u>
	16 and smaller	<i>1.23 and smaller</i>
	14 through 10	<i>1.94 through 4.74</i>
	8 and larger	<i>8.61 and larger</i>

4.4 QUALITY CONFORMANCE INSPECTION

Quality conformance inspection consists of a series of tests and inspections that assure that raw materials and manufacturing processes are consistent and result in products that conform to specification requirements. Quality conformance tests and inspections are listed in Table 1 and designated as “P”, “V”, or “100%”, and shall be performed on every lot of wire and cable procured under this specification.

4.5 TEST METHODS

4.5.1 Blocking

A specimen of finished wire or jacketed cable shall be tested in accordance with the insulation blocking test of AS22759 using an oven temperature of $260 \pm 2^\circ\text{C}$. The mandrel shall have a diameter that is 10 to 30 times the finished specimen diameter.

4.5.2 Conductor Elongation

4.5.2.1 AS29606 Conductor Stranding

Elongation tests of the conductor shall be tested in accordance with MIL-STD-2223, Method 5002, using a 10-inch (*254-mm*) initial jaw separation and a jaw separation speed of 10 ± 2 inches (*254 \pm 51 mm*) per minute. Elongation shall be determined by the distance the jaw has traveled. Breaks occurring at the jaws shall be discounted and a new specimen shall be tested.

4.5.2.2 High-Strand-Count Conductor Stranding

For high-strand-count conductor (conductor having strand counts higher than AS29606 of the same wire size), elongation tests of the conductor shall be the same as specified in 4.5.2.1, except that the test shall be performed upon the whole conductor for regular bunch-stranded constructions, or upon one whole member removed from rope bunch-stranded constructions, as applicable, taken from the finished wire. In either case, elongation shall be measured upon breakage of the first strand of the whole conductor or member, as applicable.

4.5.3 Examination of Product

All samples shall be examined carefully to determine conformance to this specification and to the applicable specification sheet with regard to requirements not covered by specific test methods.

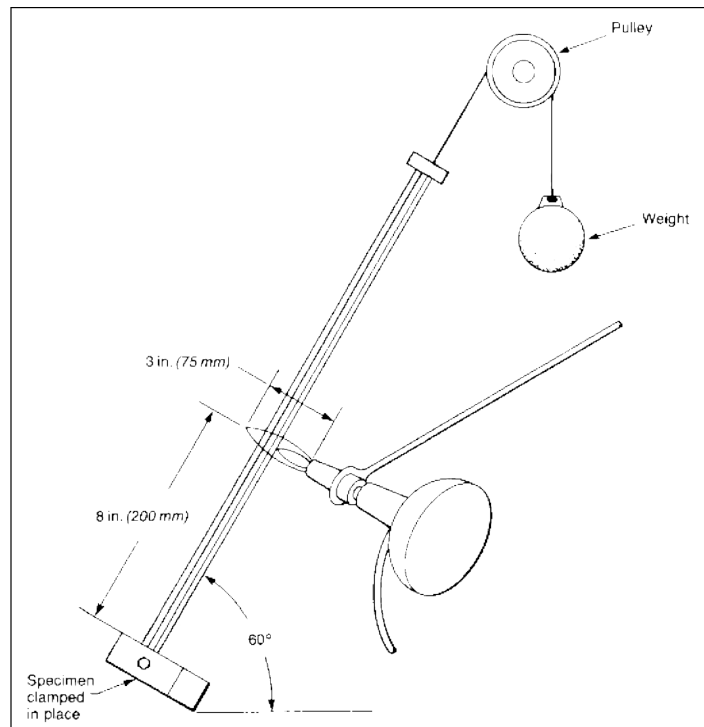
4.5.4 Flammability

4.5.4.1 Test Apparatus

The test shall be performed within a test chamber approximately 1 foot (*0.30 m*) square by 2 feet (*0.61 m*) in height, open at the top and front to provide adequate ventilation for combustion but to prevent drafts. The specimen holder shall be so designed that the lower end of a 24-inch (*610-mm*) specimen is held by a clamp, while the upper end of the specimen passes over a pulley and can be suitably weighted to hold the specimen taut at an angle of 60 degrees with the horizontal, in a plane parallel to and approximately 6 inches (*152 mm*) from the back of the chamber. The test flame shall originate from a Bunsen type gas burner with a 0.250-inch (*6.4-mm*) inlet, a needle valve in the base for gas adjustment, a nominal bore of 0.375 inch (*9.5 mm*), and a barrel length of approximately 4 inches (*102 mm*) above the air inlets. The burner shall be adjusted to furnish a 3-inch (*76-mm*) high conical flame with an inner cone approximately 1 inch (*25 mm*) in length and a flame temperature not less than 954°C at its hottest point, as measured with an accurate thermocouple pyrometer. A sheet of facial tissue conforming to UU-T-450 shall be suspended taut and horizontal 9.5 inches (*241 mm*) below the point of application of the flame to the specimen and at least 0.50 inch (*13 mm*) from the chamber floor, so that any material dripping from the specimen shall fall upon the tissue.

4.5.4.2 Test Procedure

A 24-inch (*610-mm*) specimen shall be marked at a distance of 8 inches (*203 mm*) from its lower end to indicate the point for flame application and shall be placed in the specified 60-degree position in the test chamber. The lower end of the specimen shall be clamped in position in the specimen holder and the upper end shall be passed over the pulley of the holder and a weight equal to one half the test load specified for the life cycle test of the same wire or cable in the applicable specification sheet shall be attached. With the burner held perpendicular to the specimen and at an angle of 30 degrees from the vertical plane of the specimen (see Figure 1), the hottest portion of the flame shall be applied to the lower side of the specimen at the test mark. The period of test flame application shall be 30 seconds and the test flame shall be withdrawn immediately at the end of that period. The distance of flame travel upward along the specimen from the test mark and the time of burning after removal of the test flame shall be recorded, also the presence or absence of flame in the facial tissue due to incendiary dripping from the specimen. Charred holes or charred spots in the tissue shall be ignored in the absence of actual flame. Breaking of the specimen shall not be considered as failure, provided the requirements for flame travel limits, duration of flame, and absence of incendiary dripping are met.



**FIGURE 1. FLAMMABILITY TEST APPARATUS
(shown without chamber)**

4.5.5 Humidity Resistance

A specimen of finished wire at least 26 feet (7.9 m) in length shall be tested in accordance with AS22759.

4.5.6 Insulation or Jacket Elongation and Tensile Strength

For wire, specimens of the entire insulation shall be carefully removed from the conductor and tested for elongation and tensile strength in accordance with FED-STD-228, Methods 3031 and 3021, respectively, using 1-inch (25-mm) bench marks, a 1.2-inch (30-mm) initial jaw separation, and a jaw separation speed of 2 inches (51 mm) per minute. For cable, the method shall be the same, but only the cable jacket shall be tested.

4.5.7 Insulation or Jacket Flaws

4.5.7.1 Impulse Dielectric Test

Finished wire and shielded-and-jacketed cable shall be tested in accordance with ASTM D 3032, Section 13, at the voltage specified in the applicable specification sheet with the conductor or shield, as applicable, grounded at one end or both ends. When specified in the contract or order, dielectric failure, untested portions, or portions which have been exposed to fewer or more than the specified pulses may be marked by stripping the insulation or jacket, or by any other suitable method of marking as specified in the contract, in lieu of being cut out of the wire or cable.

4.5.7.2 Spark Test

Finished wire and shielded-and-jacketed cable shall be passed through a chain electrode spark test device using the voltage specified in the applicable specification sheet at a frequency of 60 or 3000 Hz. The conductor or shield, as applicable, shall be grounded at one or both ends. The electrode shall be of a suitable bead chain or fine mesh construction that will give intimate metallic contact with practically all of the wire or cable surface. Electrode length and speed of specimen movement shall be such that the wire or cable is subjected to the test voltage for a minimum of 0.2 second. Any portion showing breakdown shall be cut out, including at least 2 inches (51 mm) of insulation or jacket on each side of the failure.

4.5.8 Insulation Resistance

The uninsulated ends of a wire specimen at least 26 feet (7.9 m) in length shall be connected electrically to a DC terminal. The specimen shall be immersed to within 6 inches (152 mm) of its ends in a water bath at $25 \pm 5^\circ\text{C}$ containing 0.5 to 1.0 percent of an anionic wetting agent. After 4 hours minimum of immersion, the specimen shall be subjected to a potential of 250 to 500 volts applied between the conductor and the water bath, which serves as the second electrode. The insulation resistance of the specimen shall be determined after one minute of electrification at this potential and shall be calculated as follows:

$$\text{Megohms for 1000 feet} = \frac{\text{Specimen resistance (megohms)} \times \text{Immersed length (feet) (or meters)}}{1000}$$

(or $M\Omega$ -1 km)

4.5.9 Life Cycle

4.5.9.1 Finished Wire

Four inches (102 mm) of insulation shall be removed from each end of a 40-inch (1016-mm) specimen of finished wire. Both ends of the specimen shall be connected together and the test load specified in the applicable specification sheet shall be attached to the connected specimen ends. The specimen loop shall then be suspended over a stainless-steel mandrel with a sintered polytetrafluoroethylene coating. The mandrel shall have the diameter specified in the applicable specification sheet and shall be of sufficient rigidity so as not to flex under load. This specimen, so prepared on the mandrel, shall be conditioned in an air-circulating oven at $290 \pm 2^\circ\text{C}$ for 500 hours. The velocity of air past the specimen (measured at room temperature) shall be between 100 and 200 feet (30 and 61 m) per minute. After conditioning, the oven shall be shut off, the door opened, and the specimen allowed to cool in the oven for at least 1 hour. When cool, the specimen shall be freed from tension, removed from the mandrel, and straightened. The specimen shall then be subjected to the bend test (4.5.9.3) followed by the voltage withstand test (4.5.16).

4.5.9.2 Jacketed Cable

Two inches (51 mm) of the jacket shall be removed from each end of a 15-inch (581-mm) specimen of finished cable. The shield (if any) shall be pushed back and formed into a pigtail at each end, and one inch (25 mm) of insulation shall be removed from the component wires at each end of the specimen. The cable specimen shall then be conditioned hanging straight in the oven as specified in 4.5.9.1 above, for 500 hours at $290 \pm 2^\circ\text{C}$. After conditioning, the oven shall be shut off, the door opened, and the specimen allowed to cool in the oven for at least 1 hour. When cool, the cable specimen shall then be subjected to the bend test (4.5.9.3), followed by the voltage withstand test (4.5.16) for shielded-and-jacketed cables only.

4.5.9.3 Bend Test

The bend test shall be conducted at a temperature maintained between 20 and 25°C. For finished wire, one end of the wire specimen shall be secured to the mandrel and the other end to a weight equal to one half the test load specified in the applicable specification sheet. For jacketed cable, the mandrel shall be as specified in Table 2 and sufficient weight shall be used to maintain contact with the mandrel. The mandrel shall be rotated until the full length of the specimen is wrapped around the mandrel and is under the specified tension with adjoining turns in contact. The mandrel shall then be rotated in the reverse direction until the full length of the specimen which was outside during the first wrapping is now next to the mandrel. This procedure shall be repeated until two bends in each direction have been formed in the same section of the specimen. The specimen shall then be examined for cracking of the wire insulation or cable jacket, as applicable.

**TABLE 2.
MANDREL DIAMETERS FOR CABLES FOR
BEND TEST AFTER LIFE CYCLE**

Finished Cable Diameter		Mandrel Diameter	
in.	mm	in.	mm
≤ 0.083	≤ 2.11	0.75	19
> 0.083 and ≤ 0.111	> 2.11 and ≤ 2.82	1.00	25
> 0.111 and ≤ 0.139	> 2.82 and ≤ 3.53	1.25	32
> 0.139 and ≤ 0.194	> 3.53 and ≤ 4.93	1.75	44
> 0.194 and ≤ 0.250	> 4.93 and ≤ 6.35	2.25	57
> 0.250 and ≤ 0.334	> 6.35 and ≤ 8.48	3.00	76
> 0.334 and ≤ 0.444	> 8.48 and ≤ 11.3	4.00	102
> 0.444 and ≤ 0.556	> 11.3 and ≤ 14.1	5.00	127
> 0.556 and ≤ 0.667	> 14.1 and ≤ 16.9	6.00	152
> 0.667 and ≤ 0.889	> 16.9 and ≤ 22.6	8.00	203
> 0.889 and ≤ 1.111	> 22.6 and ≤ 28.2	10.0	254
> 1.111 and ≤ 1.556	> 28.2 and ≤ 39.5	14.0	356
> 1.556 and ≤ 2.000	> 39.5 and ≤ 50.8	18.0	457

4.5.10 Low Temperature-Cold Bend

4.5.10.1 Finished Wire

A specimen of finished wire shall be tested in accordance with the insulation low temperature resistance test specified in AS22759 at $-65 \pm 2^\circ\text{C}$ for 4 hours, except the diameter of the mandrel and the test load shall be as specified in the applicable specification sheet.

4.5.10.2 Jacketed Cable

Jacketed cable specimens shall be tested in accordance with the cold bend test specified in WC 27500, except the test temperature shall be $-65 \pm 2^\circ\text{C}$.

4.5.11 Minimum Bend Radius

The center portion of a sufficient length of finished wire shall be wound 2 times around a mandrel having a diameter as specified in the applicable specification sheet. The ends of the specimen shall extend at least 6 inches (*152 mm*) beyond the wound portion and shall be secured to each other. The specimen shall then be removed from the mandrel without unwinding and shall be conditioned in an air-circulating oven at $290 \pm 2^\circ\text{C}$ for 500 hours. After conditioning, the oven shall be shut off, the door opened, and the specimen allowed to cool in the oven for at least 1 hour. When cool, the specimen shall be removed from the oven and visually examined, without magnification, for cracks. The insulation shall then be removed for a distance of 1 inch (*25 mm*) from each end of the specimen and the specimen shall then be subjected to the voltage withstand test (4.5.16).

4.5.12 Shrinkage

A specimen of finished wire or jacketed cable shall be tested in accordance with the insulation shrinkage test specified in AS22759 using an oven temperature of $290 \pm 2^\circ\text{C}$.

4.5.13 Smoke Test

A specimen of finished wire shall be tested in accordance with the smoke resistance test specified in AS22759 with the conductor temperature stabilized at $290 \pm 2^\circ\text{C}$.

4.5.14 Surface Resistance

A specimen of finished wire shall be tested in accordance with MIL-STD-2223, Method 3004, except that the required humidity shall be maintained by ASTM E 104, Method A, and without instrumentation of the chamber. All specimens, after having been provided with the required electrodes, but prior to testing, shall be cleaned by the procedure described in the test method. The specimens shall be positioned in the test chamber so that their ends are at least 1 inch (*25 mm*) from any wall of the chamber.

4.5.15 Thermal Shock Resistance

A specimen of finished wire shall be tested in accordance with the insulation thermal shock test specified in AS22759 using an oven temperature of $260 \pm 2^\circ\text{C}$.

4.5.16 Voltage Withstand (Post Environmental)

The uninsulated ends of the specimen shall be attached to an electric lead. The specimen shall be immersed in a 5-percent, by weight, solution of sodium chloride in water at 20 to 25°C , except that the uninsulated ends and 1.5 inches (*38 mm*) of insulated wire or cable at each end of the specimen shall protrude above the surface of the solution. After immersion for 5 hours, the voltage specified in the applicable specification sheet at 60 Hz shall be applied between the conductor or shield, as applicable, and the water bath which shall be grounded. The voltage shall be gradually increased at a uniform rate from zero to the specified voltage in 0.5 minute, maintained at that voltage for a period of 5 minutes for wire specimens or 1 minute for cable specimens, and then gradually reduced to zero in 0.5 minute.

4.5.17 Wrap Test

A specimen of finished wire shall be tested in accordance with the wrap test specified in AS22759 for extruded insulation using an oven temperature of $290 \pm 2^\circ\text{C}$, except the diameter of the mandrel shall be as specified in the applicable specification sheet.

5. STANDARD PACKAGING

Unless otherwise specified (see 6.1), the following shall define the standard spooling and labeling requirements for finished wire and cable furnished under this specification. Standard shipping tolerance on ordered quantity shall be ± 10 percent.

5.1 SPOOLING REQUIREMENTS

All layers of wire and cable shall be wound on spools or reels (see 5.1.3) with sufficient tension to prevent shifting of layers and creation of crossovers within layers.

5.1.1 Finished Wire

Finished wire lengths shall be wound on spools or reels with the ends spliced together to provide one mechanically and electrically continuous length. Unless otherwise specified, the minimum continuous length between splices shall be in accordance with Table 3.

TABLE 3. FINISHED WIRE LENGTHS

Wire Size Range (AWG)	Minimum Length
10 and smaller	100 feet (30 m)
8 and larger	50 feet (15 m)

(NOTE: Metric lengths specified above apply only to those orders placed in metric.)

5.1.2 Finished Cable

Finished cable lengths shall be wound on spools or reels in such a manner that all ends are accessible. Unless otherwise specified, the minimum continuous length for all cable shall be 50 feet (15 m).

5.1.3 Spools and Reels

Spools and reels shall be of a nonreturnable type. Each spool and reel shall have an appropriate diameter for the respective wire or cable size. In no case shall the barrel of the spool or reel have a diameter less than 3.5 inches (89 mm). Spools and reels shall be suitably finished to prevent corrosion under typical storage and handling conditions. Loaded plastic spools shall not exceed 50 pounds (23 kg). Loaded wooden reels shall have no weight restriction.

5.1.4 Containers

Unless otherwise specified (see 6.1), finished wire and cable shall be delivered in standard commercial containers so constructed as to ensure acceptance by common or other carrier for safe transportation at the lowest rate to the point of delivery.

5.2 LABELING REQUIREMENTS

All spools and reels shall be identified with the following information:

Manufacturer's Part Number
Lot Number
Quantity in Feet (*or Meters*)
Name of Manufacturer

6. NOTES

6.1 ORDERING DATA

Procurement documents should specify the following:

- a. Title, number, and revision of this specification
- b. Applicable specification sheet part number
- c. Quantity
- d. Special preparation for delivery requirements, if applicable (see Section 5)

6.2 METRIC UNITS

Metric units (where shown in parentheses) are for information only.

6.3 TRADEMARKS

Raychem, TE Connectivity, TE connectivity (logo), and TE (logo) are trademarks.