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SPECIFICATION FOR 400R WIRE AND CABLE PRODUCTS FOR RAIL AND MASS TRANSIT APPLICATIONS, TIN-COATED COPPER

1. SCOPE

1.1 SCOPE

This specification covers wire, insulated with radiation-crosslinked polyolefin in combination with radiation-crosslinked fluoropolymer. This specification also covers single and multiple conductor cables which may be shielded and jacketed. Cable jackets shall be radiation-crosslinked fluoropolymer. The wire and cable covered by this specification is suitable for installation in railway electrical systems and for general purpose use within the limitations of applicable performance requirements.

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, and with or without an outer jacket.

1.3 TEMPERATURE RATING

The maximum conductor temperature of the finished wire and cable for continuous use shall be as specified in the applicable specification sheet.

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

STANDARDS

Military

MIL-STD-104	Limits for Electrical Insulation Color
MIL-STD-681	Identification Coding and Application of Hook Up and Lead 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 http://assist.daps.dla.mil/quicksearch/.)

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)

B 33	Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes
B 193	Standard Test Method for Resistivity of Electrical Conductor Materials
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 Boeing

BSS7238	Test Method for Smoke Generation by Materials on Combustion
BSS7239	Test Method for Toxic Gas Generation by Materials on Combustion

(Copies of Boeing documents may be obtained from The Boeing Company at 100 North Riverside, Chicago, IL 60606; or at www.boeing.com.)

2.2.3 Institute of Electrical and Electronics Engineers (IEEE)

1202	Standard for Flame-Propagation Testing of Wire and Cable

(Copies of IEEE documents may be obtained from the Institute of Electrical and Electronics Engineers, 3 Park Avenue, New York, NY 10016-5997; or at www.ieee.org.)

2.2.4 National Fire Protection Association (NFPA)

130 Standard for Fixed Guideway Transit and Passenger Rail Systems

(Copies of NFPA documents may be obtained from the National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101; or at www.nfpa.org.)

2.2.5 Society of Automotive Engineers (SAE)

AS4373 Test Methods for Insulated Electric Wire

(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.)

2.2.6 Underwriters Laboratories (UL)

UL 1685 Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

(Copies of UL documents may be obtained from Underwriters Laboratories Inc., 1655 Scott Boulevard, Santa Clara, CA 95050-4169; or at www.ul.com.)

3. REQUIREMENTS

3.1 SPECIFICATION SHEETS

The requirements for the individual wires and cables 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 CONSTRUCTION AND 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 tin-coated soft or annealed copper in accordance with ASTM B 33. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces, and skin impurities.

3.3.2 Shield Material

Prior to braiding, strands shall be tin-coated soft or annealed copper meeting the requirements of ASTM B 33. Shield strands shall be free from lumps, kinks, abrasions, scraped or corroded surfaces, and skin impurities.

3.3.3 Insulating Materials

3.3.3.1 Finished Wire

The insulation system of the finished wire shall be in accordance with the applicable specification sheet. The insulation system shall be extruded uniformly over the conductor and be homogeneous, smooth, and free from flaws. The insulation shall not be loose, but be capable of stripping cleanly without damage to the conductor.

3.3.3.2 Cable Jacket

The cable jacket shall be radiation-crosslinked fluoropolymer and shall be removable from the finished cable without adherence to the underlying shield or components.

3.4 FINISHED WIRE AND CABLE

3.4.1 Finished Wire

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

3.4.2 Finished Cable

Finished cable shall conform to the requirements of Table 2 and to those of the applicable specification sheet. Component wires used in the cable shall conform to the requirements of 3.4.1, prior to cabling.

3.4.3 Accelerated Aging

When finished wire is tested in accordance with 4.5.1, there shall be no cracking of the insulation, no dielectric breakdown, and the product identification shall remain legible. When finished cable is tested in accordance with 4.5.1, there shall be no cracking of the jacket and, when applicable, no dielectric breakdown of the jacket.

3.4.4 Blocking

When finished wire or cable is tested in accordance with 4.5.2, adjacent turns and layers of the wire or cable shall not block. Blocking shall be defined as a transfer of material between adjacent surfaces when they are separated.

3.4.5 Cabling

Cable components shall be twisted in a left-hand lay with a length of lay 8 to 16 times the cabled diameter.

TABLE 1. PROPERTIES OF FINISHED WIRE

Examination or Test	Requirement	Test Method	*Inspection Class
Accelerated Aging	Specification Sheet and 3.4.3	4.5.1	P
Blocking	3.4.4	4.5.2	Q
Color	Specification Sheet and 3.4.6	4.5.8	P
Concentricity	3.4.7	ASTM D 3032, Section 16	P
Conductor Diameter	Specification Sheet	ASTM D 3032, Section 15	P
Conductor Elongation	3.4.9	4.5.5	P
Conductor Resistance	Specification Sheet	ASTM B 193	P
Conductor Stranding	Specification Sheet	4.5.8	V
Construction	Specification Sheet and 3.3	4.5.8	P
Durability of Product Identification	3.4.10	4.5.7	P
Finished Wire Diameter	Specification Sheet	ASTM D 3032, Section 15	P
Flammability (Large Scale)	Specification Sheet	NFPA 130 (FT4/IEEE 1202 of UL 1685)	Q
Humidity Resistance	Specification Sheet	4.5.9	Q
Identification of Product	Specification Sheet	4.5.8	P
Insulation Elongation and Tensile Strength	Specification Sheet	4.5.10	P
Insulation Flaws	Specification Sheet and 3.4.11	4.5.11	100%
Insulation Resistance	Specification Sheet	4.5.12	Q
Insulation Thickness	Specification Sheet	ASTM D 3032, Section 15	P
Low Temperature-Cold Bend	Specification Sheet and 3.4.12	4.5.13	P
Materials	Specification Sheet and 3.3	4.5.3	V
Notch Propagation	3.4.13	4.5.14	Q
Shrinkage	Specification Sheet	4.5.16	P
Smoke Release	Specification Sheet	NFPA 130 (FT4/IEEE 1202 of UL 1685)	Q
Smoke Test	Specification Sheet	4.5.17	Q
Toxicity	Specification Sheet	BSS7239	Q
Weight	Specification Sheet	4.5.19	P
Workmanship	3.4.14	4.5.8	P

*Inspection Class (see 4.2):

P = In-Process or Lot Test

100% = 100% Finished Product Test

Q = Qualification Test

V = Vendor Test

TABLE 2. PROPERTIES OF FINISHED CABLE

Examination or Test	Requirement	Test Method	*Inspection Class
Accelerated Aging	Specification Sheet and 3.4.3	4.5.1	P
Blocking	3.4.4	4.5.2	Q
Cabling	3.4.5	4.5.8	P
Conductor and Shield Continuity	3.4.8	4.5.4	100%
Construction	Specification Sheet and 3.3	4.5.8	P
Dielectric Withstand	Specification Sheet	4.5.6	100%
Dimensions	Specification Sheet	ASTM D 3032, Section 15	P
Durability of Product Identification	3.4.10	4.5.7	P
Flammability (Large Scale)	Specification Sheet	NFPA 130 (FT4/IEEE 1202 of UL 1685)	Q
Identification of Product	Specification Sheet	4.5.8	P
Insulation Flaws	Specification Sheet and 3.4.11	4.5.11	100%
Jacket Color	Specification Sheet and 3.4.6	4.5.8	P
Jacket Concentricity	3.4.7	ASTM D 3032, Section 16	P
Jacket Elongation and Tensile Strength	Specification Sheet	4.5.10	P
Jacket Flaws	Specification Sheet and 3.4.11	4.5.11	100%
Jacket Thickness	Specification Sheet	ASTM D 3032, Section 15	P
Low Temperature-Cold Bend	Specification Sheet and 3.4.12	4.5.13	Q
Materials	Specification Sheet and 3.3	4.5.3	V
Shield Coverage	Specification Sheet	4.5.15	P
Smoke Release	Specification Sheet	NFPA 130 (FT4/IEEE 1202 of UL 1685)	Q
Smoke Test	Specification Sheet	4.5.17	Q
Toxicity	Specification Sheet	BSS 7239	Q
Weight	Specification Sheet	4.5.19	P
Workmanship	3.4.14	4.5.8	P

*Inspection Class (see 4.2):
P = In-Process or Lot Test
100% = 100% Finished Product Test
Q = Qualification Test
V = Vendor Test

3.4.6 Color

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

3.4.7 Concentricity

The concentricity of the primary wire insulation, finished wire, and the cable jacket, as applicable, shall be 70 percent, minimum.

3.4.8 Conductor and Shield Continuity

Prior to shipment, one hundred percent of all finished cable shall be tested for continuity in accordance with 4.5.4. There shall be no indication of discontinuity in any of the component wires or shields, as applicable.

3.4.9 Conductor Elongation

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 4.5.5.

Sizes 24 and smaller - 6 percent, minimum
Sizes 22 and larger - 10 percent, minimum

3.4.10 Durability of Product Identification

A printed mark on the surface of the wire insulation or cable jacket shall remain legible when tested in accordance with 4.5.7.

3.4.11 Insulation or Jacket Flaws

One hundred percent of finished wire, unshielded and unjacketed cable, and shielded and jacketed cable shall pass the impulse dielectric test or the spark test specified in 4.5.11 using the voltage specified in the applicable specification sheet. Testing shall be performed during the final winding of the wire or cable on shipment spools or reels.

3.4.12 Low Temperature-Cold Bend

When finished wire or cable is tested in accordance with 4.5.13, there shall be no insulation or jacket cracking, and no dielectric breakdown.

3.4.13 Notch Propagation

When finished wire is tested in accordance with 4.5.14, there shall be no dielectric breakdown.

3.4.14 Workmanship

All details of workmanship shall be in accordance with high grade wire and cable manufacturing practices. The insulation shall be free of cracks, splits, irregularities, and imbedded foreign material.

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 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 for wire and in Table 2 for 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.

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 Table 2, designated as "P", "V", or "100%", and shall be performed on every lot of wire or cable procured under this specification.

4.5 TEST METHODS

4.5.1 Accelerated Aging

For finished wire, 1 in. *(25 mm)* of insulation shall be removed from each end of a 24-in. *(600-mm)* specimen. For finished cable, 2 in. *(50 mm)* of the jacket shall be removed from each end of a 24-in. *(600-mm)* specimen. If applicable, the shield shall be pushed back and formed into a pigtail at each end of the specimen. One inch *(25 mm)* of the insulation of each of the primary wires then shall be removed from each end of the specimen. The central portion of the wire or cable specimen then shall be bent at least halfway around a horizontally positioned smooth stainless steel mandrel of the diameter specified in the applicable specification sheet. To prevent sticking of the specimen to the mandrel, the mandrel shall be covered with polytetrafluoroethylene in the form of either a dispersion coating or wrapped tape, provided that the diameter of the mandrel still conforms to the applicable specification sheet. For finished wire, each end of the conductor shall be loaded with the weight specified in the applicable specification sheet so that the portion of the insulation between the conductor and mandrel is under compression while the conductor is under tension. For finished cable, the conductors shall be tied together at each end and loaded with the weight specified in the applicable specification sheet. The specimen, so prepared on the mandrel, shall then be conditioned in an air-circulating oven for the time and at the temperature specified in the applicable specification sheet. The velocity of air past the specimen (measured at room temperature) shall be between 100 and 200 ft *(30 and 60 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 finished wire and cable specimen shall then be subjected to the bend test (4.5.1.1). The voltage withstand test (4.5.18) shall then be conducted on finished wire specimens and shielded and jacketed cable specimens only. In addition for finished wire, a separate specimen which includes an identification marking shall be tested and examined for identification legibility after being exposed for the time and at the temperature specified in the applicable specification sheet.

4.5.1.1 Bend Test

At a temperature maintained between 20 and 25°C, one end of a finished wire or cable specimen shall be secured to the mandrel and the other end to the load weight specified in the applicable specification sheet. 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 then shall 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 then shall be examined visually for cracking of the insulation or jacket, as applicable.

4.5.2 Blocking

One end of a finished wire or cable specimen of sufficient length to perform the test shall be affixed to a metal mandrel. For finished wire, the diameter of the mandrel shall be as specified in Table 3 and the free end shall be weighted with a test load equal to the test load specified for the cold bend test of the same size wire in the applicable specification sheet. For finished cable, the diameter of the mandrel shall be the same as specified in the applicable specification sheet for the cold bend test of the same size wire and the free end shall be loaded with weights sufficient to keep the cable vertical and tangent to the mandrel during the bending operation. The wire or cable specimen shall then be spirally wound around the mandrel so at least three turns are in close contact with one another. The winding shall be continued until there are three layers of turns with each layer in close contact with one another. The mandrel and specimen shall then be placed in an air oven for the time and at the temperature specified in the applicable specification sheet. After conditioning, the mandrel and specimen shall be removed from the oven and allowed to cool to room temperature. After cooling, the specimen shall be unwound manually and examined for evidence of blocking.

TABLE 3.
MANDRELS FOR FINISHED WIRE BLOCKING

Wire Size Range (AWG)	Minimum Diameter of Mandrel (as Times Nominal Diameter of Finished Wire)
30-16	50x
14-10	40x
8-4	30x
2-0000	20x

4.5.3 Certification of Materials

Prior to incorporation in a wire or cable construction, incoming (raw) materials must meet internal procurement requirements that are not covered in this specification or the applicable specification sheet. Certificates of compliance shall be kept on file stating that the specified materials have been used and that they met all applicable requirements.

4.5.4 Conductor and Shield Continuity

To establish continuity, 25 volts DC, maximum, shall be applied to both ends of each conductor and shield of the cable through an appropriate indicator, such as an ohmmeter, light, or buzzer. The test voltage may be applied to the conductors and shields individually, or in a series.

4.5.5 Conductor Elongation

Elongation tests of the conductor shall be tested in accordance with AS4373, Method 402, using a 10-inch *(254-mm)* initial jaw separation and a jaw separation speed of 10 ± 2 inches *(254 ± 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.

4.5.6 Dielectric Withstand

The voltage specified in the applicable specification sheet shall be applied between each component wire and shield, if any, for the period of time specified. There shall be no dielectric breakdown.

4.5.7 Durability of Product Identification

The durability of a mark that has been printed on the surface of the wire insulation or cable jacket shall be checked by trying to remove the mark by rubbing it lightly ten times with a piece of cotton, wool, or cloth which has been soaked in water.

4.5.8 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.

4.5.9 Humidity Resistance

4.5.9.1 Test Apparatus

The apparatus shall consist of a test chamber capable of maintaining an internal temperature of 71 ± 5°C and an internal relative humidity of 95 ± 5 percent. The test chamber shall be capable of being so sealed as to retain the total moisture content in the test space. The heat loss from the chamber shall be sufficient to reduce the internal temperature from 71 ± 5°C to 23 ± 2°C within a period of 16 hours from the time of removal of the source of heat. Distilled or demineralized water shall be used to obtain the required humidity.

4.5.9.2 Test Procedure

A specimen of wire at least 12 feet *(3.7-m)* in length shall be placed in the test chamber and the temperature and relative humidity raised over a 2-hour period to the values specified in 4.5.9.1 and maintained at such for a period of 6 hours. At the end of the 6-hour period, the heat shall be shut off. During the following 16-hour period, the temperature must drop to 23 ± 2°C. At the end of the 16-hour period, heat shall be supplied again for a 2-hour period to stabilize at 71 ± 5°C. This cycle (2 hours heating, 6 hours at high temperature, 16 hours cooling) shall be repeated 15 times so that the total time of the test is 360 hours. At the end of the fifteenth cycle, the 10-foot *(3.0-m)* center section of the specimen shall be immersed in a 5-percent, by weight, solution of sodium chloride in water at room temperature. The insulation resistance of the specimen shall be measured with the outer surface of the specimen grounded, through an electrode in the electrolyte and with a potential of 250 to 500 volts DC applied to the conductor of the specimen after 1 minute of electrification at this potential. The insulation resistance shall be converted to megohms for 1000 feet *(MΩ-1 km)* as described in 4.5.12.

4.5.10 Insulation or Jacket Elongation and Tensile Strength

For wires, specimens of the finished wire shall have the jacket carefully removed from the primary insulation. The primary insulation shall then be carefully removed from the conductor and tested for elongation and tensile strength in accordance with AS4373, Method 705, using 1-inch *(25-mm)* bench marks, a 1-inch *(25-mm)* initial jaw separation, and a jaw separation speed of 20 inches *(508 mm)* per minute. For cables, the method shall be the same, except only the cable jacket shall be tested with a jaw separation speed of 2 inches *(51 mm)* per minute.

4.5.11 Insulation or Jacket Flaws

4.5.11.1 Impulse Dielectric Test

Finished wire and 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 or jacket 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.

4.5.11.2 Spark Test

Finished wire and 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.

4.5.12 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 ± 5°C containing 5-percent, by weight, solution of sodium chloride. 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:

$$\text{Megohms for 1000 feet (or } M\Omega\text{-l km)} = \frac{\text{Specimen resistance (megohms) x Immersed length (feet) (or meters)}}{1000}$$

4.5.13 Low Temperature-Cold Bend

4.5.13.1 Finished Wire

One end of a wire specimen at least 3-feet *(0.91-m)* in length shall be secured to a rotatable mandrel in a cold chamber and the other end to a load weight. The diameter of the mandrel and the test load shall be as specified in the applicable specification sheet. Provision shall be made for rotating the mandrel by means of a handle or motorized drive located outside the chamber. The specimen and the mandrel shall be conditioned for the time and at the temperature specified in the applicable specification sheet. At the end of this period, and while both mandrel and specimen are still at this low temperature, the specimen shall be wrapped helically around the mandrel for its entire length, or for 20 turns whichever is the lesser number of turns, without opening the chamber. The bending shall be accomplished at a uniform rate of 2 rpm. The specimen shall then be removed from the cold chamber and from the mandrel without straightening 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 (4.5.18).

4.5.13.2 Finished Cable

One end of a cable specimen of sufficient length shall be secured to a rotatable mandrel in a cold chamber and the other end to a load weight. The diameter of the mandrel and the test load shall be as specified in the applicable specification sheet. Provision shall be made for rotating the mandrel by means of a handle or motorized drive located outside the chamber. The specimen and the mandrel shall be conditioned for the time and at the temperature specified in the applicable specification sheet. At the end of this period, and while both mandrel and specimen are still at this low temperature, the cable shall be wrapped around the mandrel 180° without opening the chamber. The time required for bending around 180° of the mandrel shall be one-half minute at a uniform rate of speed. The specimen shall then be removed from the cold chamber and from the mandrel and visually examined, without magnification, for cracks. Shielded and jacketed cable specimens shall then be subjected to the voltage withstand test (4.5.18). After being subjected to the cold bend test or voltage withstand test of the jacket, the specimen shall be dissected. The individual wires shall then be immersed within 3 inches *(76 mm)* of their ends for 1 hour in a 5% salt solution. At the end of this period, a potential of 1000 volts rms at commercial frequency shall be applied for 1 minute from each conductor to the salt solution.

4.5.14 Notch Propagation

One inch *(25 mm)* of insulation shall be removed from a 24-inch *(610-mm)* specimen of finished wire. At approximately the center of each specimen, the insulation shall be notched (cut) to a depth of 0.002-inch *(0.05-mm)* at four points equally spaced from one another around the circumference and 1 inch *(25 mm)* apart along the length and in a plane perpendicular to the conductor. The notch shall be made with a commercial grade stainless steel safety razor blade mounted in a suitable guide to control the depth of the notch. The specimen shall be conditioned at room temperature for 3 hours, after which the specimen shall then be bent around a mandrel having a diameter 3 ± 0.3 times the minimum specified diameter of the wire with the notch on the outside of the bend. The specimen shall then be subjected to the voltage withstand test (4.5.18), except a voltage of 750 volts shall be applied.

4.5.15 Shield Coverage

The percent coverage of a round braid shield shall be determined by the following formula:

$$K = 100 (2F - F^2)$$

Where:

K = percent coverage
F = NPd/sin α
N = number of strands per carrier
P = picks per inch of cable length
d = diameter of one of the round shield strands
α = angle of braid with axis of cable

4.5.16 Shrinkage

A 12 inch *(305 mm)* specimen of finished wire, with flush cut ends, shall be placed in an air-circulating oven at the temperature specified in the applicable specification sheet for 6 hours. The specimen shall then be removed from the oven and allowed to cool to room temperature. The difference between the ends of each layer of insulation, including the jacket, and the conductor shall be measured at each end of the specimen. The maximum amount of shrinkage of any layer at either end shall not exceed the value specified in the applicable specification sheet.

4.5.17 Smoke Test

When required by the specification sheet, the smoke test shall be tested in accordance with BSS7238 with the following definitions:

D4 = the average optical smoke density at 4 minutes.
Dm = the average maximum optical smoke density obtained during the 4 minute test.

4.5.18 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 sheet at 60 Hz shall be applied between all the conductors and shields tied together, 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 finished wire specimens and 1 minute for finished cable specimens, and gradually reduced to zero in 0.5 minute.

4.5.19 Weight

The weight of each lot of finished wire or cable shall be determined by Procedure I (4.5.19.1). Lots failing to meet the weight requirement of the applicable specification sheet when tested in accordance with Procedure I shall be subjected to Procedure II (4.5.19.2). All spools or reels failing to meet the requirements of the applicable specification sheet when tested to Procedure II shall be rejected.

4.5.19.1 Procedure I

A length of wire or cable, sufficient to produce a measured weight to at least 3 significant figures, shall be weighed and converted to the weight per unit length shown on the applicable specification sheet.

4.5.19.2 Procedure II

The net weight of the finished wire or cable on each spool or reel shall be obtained by subtracting the tare weight of the spool or reel from the gross weight of the spool or reel containing the finished wire or cable. The net weight of wire or cable on each spool or reel shall be divided by the accurately determined length of finished wire or cable on that spool or reel and the resultant figure converted to the weight per unit length shown on the applicable specification sheet. When wood or other moisture absorbent materials are used for spool or reel construction, weight determinations shall be made under substantially uniform conditions of relative humidity.

5. STANDARD PACKAGING

Unless otherwise specified (see 6.1), the following shall define the standard spooling and labeling requirements for wire and cable furnished under this specification. Standard shipping tolerance on ordered quantity, for both wire and cable, 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 100 feet *(30 m)*.

5.1.2 Finished Cable

Finished cable lengths shall be wound on spools or reels with all ends exposed. There shall be no more than 5 lengths per spool or reel and no length shall be less than 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.