Raychem Wire and Cable
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PROCESS-CONTROLLED, OUTER SPACE WIRE AND CABLE, RADIATION-CROSSLINKED, MODIFIED ETFE*-INSULATED

1. SCOPE

1.1 SCOPE

This specification describes the characteristics, processes, and associated quality assurance provisions for process-controlled wire and cable products. These products are manufactured with an extruded insulation and jacket material of radiation-crosslinked, modified ETFE, in conjunction with various conductor and shield materials. The insulation and jacket material covered by this specification has low outgassing properties and is intended for use as a high-temperature, thin-wall insulation system in outer space applications.

1.2 DEFINITIONS

This section defines terms, not defined elsewhere, that are used in this specification and referenced documents.

Cable - Two or more wires twisted together, or one or more wires with an overall shield. Each wire, in this case, is termed a cable component.

Characteristic - Descriptive and/or measurable features or properties that define the part or process relative to design, performance, or process.

Conductor - The central, metallic component of an insulated wire, having a single (solid) strand, or multiple, twisted strands.

Jacket - An extruded layer of insulation applied over a cable. Its function is to provide mechanical and environmental protection rather than electrical properties.

SCD - The Specification Control Drawing describes a single wire or cable construction in one AWG size or a range of AWG sizes. It also contains requirements for certain characteristics.

Shield - A braided, or spiral, covering of round or flat metallic strands covering a wire or cable.

Target Value - The central value for a characteristic that reflects the ideal condition for the part or process.

Tolerance Limits - Values that represent limits of acceptability for a given characteristic.

Wire - A conductor having one or more concentric layers of extruded insulation.

*Ethylene-tetrafluoroethylene

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1.3 STANDARD INSULATION AND JACKET COLORS

Unless otherwise specified, finished wire and cable products shall be supplied with the following colors:

1.3.1 Finished Wire, Cable Jackets, and Single-Conductor Cable

Finished wire, cable jackets, and the component wire of single-conductor cable shall be white in accordance with MIL-STD-104, Class 1 limits.

1.3.2 Multiconductor Cable (Two or More Components)

Insulation colors for component wires of multiconductor cable shall be as specified on customer's purchase order.

2. MANUFACTURING PROCESS FLOW

This section defines and outlines the essential processes, and their relationships, used in the manufacture of the wire and cable described herein. Table 1 identifies the manufacturing process steps used for the basic product constructions offered under this specification. Table 2 identifies the product characteristics that are established and/or subsequently verified at these process steps (subsequent X's in the same row for a particular characteristic(s) indicate steps that have the potential to modify the initially established characteristic, thus the characteristic is rechecked).

Process Step Definitions:

EXTR. - The process of extruding layers of insulation on a conductor, or a jacket on a cable.

BEAM - The process of radiation crosslinking the insulation or jacket.

PID - Product Identification (marking or striping).

CABLE - Twisting two or more wires or components together.

BRAID - Application of a braided or spiral metallic shield.

SPOOL - Packaging of wire or cable on final shipping spools, or in-process spooling for subsequent operations.

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TABLE 1. PRODUCT CONSTRUCTIONS VS. PROCESS STEPS

Construction	Incoming Material	Extr.	Beam	PID	Cable	Braid	Spool
Primary Wire	Conductor; Compound	X	X	opt	---	---	opt
Cable, no shield or jacket	Primary wire	---	---	---	X	---	opt
Jacketed Cable	Unshielded, unjacketed cable; Compound	X	X	opt	---	---	opt
Shielded Cable	Unshielded, unjacketed wire or cable; Shield strands	---	---	---	---	X	opt
Shielded and Jacketed Cable	Shielded wire or cable; Compound	X	X	opt	---	---	opt

X = Essential process step
opt = Optional process step depending on final disposition of product (e.g., finished product or in-process material to be used in another construction)
--- = Not applicable to product

TABLE 2. PRODUCT CHARACTERISTICS VS. PROCESS STEPS

Product Characteristics	Extr.	Beam	PID	Cable	Braid	Spool
Color	X	X	X	---	---	---
Insulation/Jacket Dimensional Properties, Weight	X	---	---	---	---	---
Insulation/Jacket Flaws	X	---	---	X	---	X
Shrinkage	X	---	---	---	---	X
Workmanship	X	X	X	X	X	X
Crosslinked Verification, Insulation/Jacket Elongation, Removability of Insulation	---	X	---	---	---	---
Identification of Product, Identification/Color Striping Durability	---	---	X	---	---	---
Cabling	---	---	---	X	---	---
Shield Coverage and Construction	---	---	---	---	X	---
Conductor and Shield Continuity, Dielectric Withstand	---	---	---	---	---	X

X = Essential process step
--- = Not applicable to product

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3. REQUIREMENTS FOR CHARACTERISTICS

The requirements for wire and cable characteristics are as specified in Table 3 and as detailed herein. The SCD and this specification define the requirements for the specified product. In the event of conflict between the two, the SCD takes precedence.

TABLE 3. WIRE AND CABLE CHARACTERISTICS

Product Characteristics	Wire	Cable	Char.*	Requirement	Procedure
Blocking	X	X	Q	3.3.1	4.6.1
Cabling	---	X	P	3.2.1	4.6.5
Color	X	X	P	SCD and 1.3	4.6.5
Conductor Diameter	X	---	M	SCD	4.6.5
Conductor Elongation and Break Strength	X	---	M	3.1.2	4.6.2
Conductor Material	X	---	M	SCD and 3.1.1	4.6.3 and 4.6.5
Conductor Resistance	X	---	M	SCD	AS22759
Conductor and Shield Continuity	---	X	P100	3.2.2	WC 27500
Conductor Stranding	X	---	M	SCD	4.6.5
Crosslinked Verification	X	X	P	SCD and 3.2.3	4.6.4
Dielectric Withstand	---	X	P100	SCD and 3.2.4	WC 27500
Finished Wire and Cable Diameter	X	X	P	SCD	4.6.5
Flammability, 60°	---	X	Q	3.3.2.2	4.6.6.2
Flammability, Vertical	X	---	Q	3.3.2.1	4.6.6.1
Fluoride Extraction	X	X	Q	SCD	4.6.7
Identification/Color Striping Durability	X	X	P	SCD and 3.2.5	AS22759
Identification of Product	X	X	P	SCD and 3.2.6	4.6.5
Insulation/Jacket Concentricity	X	X	P	3.2.7	ASTM D 3032, Section 16
Insulation/Jacket Construction	X	X	P	SCD	4.6.5
Insulation/Jacket Elongation	X	X	P	3.2.8	4.6.8
Insulation/Jacket Flaws	X	X	P100	SCD and 3.2.9	4.6.9
Insulation/Jacket Material	X	X	M	3.1.3	4.6.3
Insulation/Jacket Tensile Strength	X	X	Q	3.3.3	4.6.8
Insulation/Jacket Thickness	X	X	P	SCD	4.6.5
Insulation Resistance	X	---	Q	3.3.4	4.6.10
Low Temperature - Cold Bend	X	X	Q	3.3.5	4.6.11
Radiation Resistance	X	X	Q	3.3.6	4.6.12
Removability of Insulation	X	---	P	3.2.10	4.6.5
Shield Construction and Coverage	---	X	P	3.2.11	WC 27500
Shield Material	---	X	M	SCD and 3.1.1	4.6.3 and 4.6.5
Shrinkage	X	---	P	SCD	AS22759
Vacuum Stability	X	X	Q	3.3.7	ASTM E 595
Weight	X	X	P	SCD	4.6.14
Weight Loss	---	X	P	3.2.12	4.6.15
Workmanship	X	X	P	3.2.13	4.6.5

*Characteristic Codes: M = Material Specific Characteristic (see 3.1)
P = Process Specific Characteristic (see 3.2)
P100 = Process Specific Characteristic, 100% tested (see 3.2)
Q = Qualification Specific Characteristic (see 3.3)

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3.1 MATERIAL SPECIFIC REQUIREMENTS

These characteristics, noted by the code "M" in Table 3, are initially established and controlled by the incoming raw materials prior to the first process step (see Table 1). 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:

3.1.1 Conductor and Shield Materials

Conductor materials and construction shall be in accordance with AS22759 and the applicable SCD. Shield strand materials shall conform to the requirements specified in WC 27500 and the applicable SCD.

3.1.2 Conductor Elongation and Break Strength

Conductor elongation and break strength shall meet the requirements of AS22759 for the AWG, construction, and material specified in the applicable SCD.

3.1.3 Insulation and Jacket Materials

Insulating materials, used for wire insulation or cable jackets, shall be radiation-crosslinked, extruded, modified ETFE.

3.2 PROCESS SPECIFIC REQUIREMENTS

These characteristics, noted by the codes "P" and "P100" in Table 3, are initially established and controlled by one particular process step (see Table 2). Unless otherwise specified, requirements for process specific characteristics shall be as follows:

3.2.1 Cabling

Cable components shall be twisted using 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 SCD prior to cabling.

3.2.2 Conductor and Shield Continuity

One hundred percent of finished cable shall exhibit no loss of continuity in the conductors, or shields, as applicable.

3.2.3 Crosslinked Verification

For finished wire, the insulation shall not crack or fail dielectrically. For finished cable, the jacket shall not crack or, if shielded and jacketed, fail dielectrically.

3.2.4 Dielectric Withstand

One hundred percent of finished cable shall pass the dielectric withstand test with an application time of 15 to 30 seconds, without breakdown, using the voltage specified in the applicable SCD.

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3.2.5 Identification and Color Striping Durability

There shall be no discontinuity of identification mark or color stripe after subjecting the mark or stripe to the number of cycles and the test load specified in the applicable SCD. Additionally, stripes shall not flake or crack when the finished wire, or component wire prior to cabling, is wound back on itself.

3.2.6 Identification of Product

When specified by the procuring activity, finished wire or 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 SCD. 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)*.

3.2.7 Insulation or Jacket Concentricity

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

3.2.8 Insulation or Jacket Elongation

The elongation of the finished wire insulation (for dual-wall insulations, both layers shall be pulled together as a unit), or the cable jacket, shall be not less than 50 percent.

3.2.9 Insulation or Jacket Flaws

One hundred percent of finished wire, unshielded and unjacketed cable (when specified), and shielded and jacketed cable shall pass the impulse dielectric test or the spark test specified in 4.6.9 using the voltage specified in the applicable SCD. Testing shall be performed during the final winding of the wire or cable on shipment spools or reels.

3.2.10 Removability of Insulation

For AWG 10 and smaller finished wires, 0.5 inch *(13 mm)* of insulation shall be readily removable using conventional, hand-operated, wire strippers with properly-sized blades for the construction. The insulation slug shall not bunch, nor shall any conductor strands break during the removal process.

3.2.11 Shield Construction and Coverage

The optical coverage of braided or spiral shields shall be not less than 85 percent. Braided shields shall have an angle of 18 to 35 degrees relative to the axis of the cable.

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3.2.12 Weight Loss

When specimens of cable with woven or spiral, round or flat, shielding are tested in accordance with 4.6.15, the weight loss shall not exceed 0.45 percent.

3.2.13 Workmanship

Workmanship of finished wire and cable shall be uniform and free of external, or internal, physical or cosmetic irregularities.

3.3 QUALIFICATION SPECIFIC REQUIREMENTS

These characteristics, noted by the code "Q" in Table 3, are a function of the combination of materials and processes used to produce a given wire or cable construction. Following qualification, adherence to material specific and process specific requirements assures that the product will continue to meet the initial qualification specific requirements. Qualification specific requirements shall be as follows, when tested on the following constructions:

Wire: 55/0311-22 and 55/LF0311-22, as applicable
Cable: 55/2321-22 and 55/LF2321-22, as applicable

Conductor plating and/or shield plating substitutions may be allowed provided the wire or cable construction is otherwise the same as specified.

3.3.1 Blocking

When finished wire or cable is tested in accordance with 4.6.1, 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.

3.3.2 Flammability

3.3.2.1 Finished Wire (Vertical Test)

When finished wire is tested in accordance with 4.6.6.1, the burn length shall not exceed 3 inches *(76 mm)* and the afterburn time shall not exceed 3 seconds.

3.3.2.2 Finished Cable (60° Test)

When finished cable is tested in accordance with 4.6.6.2, 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.

3.3.3 Insulation or Jacket Tensile Strength

The tensile strength of the wire insulation, or the cable jacket, shall be not less than 5000 lbf/inch^2 *(34 N/mm^2)*.

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3.3.4 Insulation Resistance

The insulation resistance of the finished wire shall be not less than 5000 megohms for 1000 feet *(1524 MΩ-1 km)*.

3.3.5 Low Temperature - Cold Bend

When finished wire or cable is tested in accordance with 4.6.11, there shall be no insulation or jacket cracking, and no dielectric breakdown.

3.3.6 Radiation Resistance

When finished wire or cable is tested in accordance with 4.6.12, there shall be no dielectric breakdown.

3.3.7 Vacuum Stability

When specimens of the wire insulation and cable jacket are tested in accordance with ASTM E 595, the Total Mass Loss (TML) shall not exceed 1.00 percent and the Collected Volatile Condensable Material (CVCM) shall not exceed 0.10 percent. These requirements comply with NASA Specification SP-R-0022.

4. QUALITY ASSURANCE PROVISIONS

4.1 QUALITY ASSURANCE SYSTEM

This section defines the Quality Assurance system that is used to assure that all products manufactured in accordance with this specification meet all applicable requirements.

4.2 QUALIFICATION INSPECTION

Qualification inspection shall consist of meeting all characteristics listed in Table 1, as applicable to finished wire or 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 QUALITY CONFORMANCE INSPECTION

Quality conformance inspection shall consist of all material specific and process specific characteristics, represented by the codes "M", "P" and "P100" in Table 3. Quality conformance inspection shall be performed on every lot of wire or cable procured under this specification, unless documentation of a statistical nature provides evidence that reduced inspection is warranted.

4.3.1 Sampling for Quality Conformance Inspection

MIL-STD-1916, inspection level S-3, AQL 1.5 percent, normal inspection, shall apply for all quality conformance testing. ISO 8402 shall apply for definitions of inspection terms used herein. For purposes of this specification, the following shall apply:

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4.3.1.1 Lot

The inspection lot shall include all wire or cable of one part number or description, exclusive of color, subjected to inspection at one time.

4.3.1.2 Unit of Product

The unit of product for determining lot size for sampling shall be one continuous length of wire or cable as offered for inspection.

4.3.1.3 Sample Unit

The sample unit for quality conformance inspection shall be of sufficient length to permit all applicable examinations and tests.

4.4 PROCESS CONTROL

Process control shall be maintained with the use of statistical process control and continuous improvement techniques.

4.4.1 Control Plan

The Control Plan describes the system for controlling the materials, construction, processes, and testing required for each wire and cable product.

4.5 DOCUMENTATION

Test reports shall be prepared and kept in the Quality Control Department files for each manufactured lot of product. The results of the quality conformance inspection (see 4.3) shall be recorded in these test reports.

4.6 TEST PROCEDURES

4.6.1 Blocking

Finished wire shall be tested in accordance with AS22759 at 230 ± 3°C for 4 hours. Finished cable shall be tested in accordance with WC 27500 at 230 ± 3°C for 4 hours.

4.6.2 Conductor Elongation and Break Strength

Elongation and tensile strength tests of the conductor shall be tested in accordance with AS22759, prior to insulation extrusion, except that for high strength alloy conductors, the rate of jaw separation shall be 2 ± 1/2 inches *(51 ± 13 mm)* per minute and the tensile strength shall be reported as the tensile break strength of the conductor rather than in pounds per square inch.

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4.6.3 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 SCD. Certificates of compliance shall be kept on file stating that the specified materials have been used and that they met all applicable requirements.

4.6.4 Crosslinked Verification

4.6.4.1 Finished Wire

One inch *(25 mm)* of insulation shall be removed from each end of a 24-inch *(610-mm)* specimen of finished wire. The central portion of the specimen then shall be bent at least halfway around a horizontally positioned smooth stainless steel mandrel of the diameter specified in the applicable SCD. 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 SCD. Each end of the conductor shall be loaded with the weight specified in the applicable SCD so that the portion of the insulation between the conductor and mandrel is under compression while the conductor is under tension. This specimen, so prepared on the mandrel, shall be conditioned in an air-circulating oven at 300 ± 3°C for 1 hour. The velocity of air past the specimen (measured at room temperature) shall be not less than 100 feet *(30 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 (4.6.4.1.1) followed by the voltage withstand test (4.6.13).

4.6.4.1.1 *Bend Test*

At a temperature maintained between 20 and 25°C, one end of the wire specimen shall be secured to the mandrel and the other end to the load weight specified in the applicable SCD. 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 insulation.

4.6.4.2 Finished Cable

Two inches *(51 mm)* of the jacket shall be removed from each end of a 15-inch *(381-mm)* specimen of finished cable, and the shield, if any, shall be pushed back and formed into a pigtail at each end of the specimen. One inch *(25 mm)* of insulation from each conductor shall then be removed from each end of the specimen. The cable specimen shall then be loaded with sufficient weight to hang straight, and shall be conditioned in an air-circulating oven at 300 ± 3°C for 1 hour. The velocity of air past the specimen (measured at room temperature) shall be not less than 100 feet *(30 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 cable specimen shall then be examined for cracking of the jacket. The voltage withstand test (4.6.13) shall then be conducted on shielded and jacketed cable specimens only.

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4.6.5 Examination of Product

Where requirements are not supported by specific test procedures, products shall be examined to determine conformance to this specification and the applicable SCD.

4.6.6 Flammability

4.6.6.1 Finished Wire (Vertical Test)

The test shall be performed in a sheet metal cabinet conforming to FED-STD-191, Method 5903. Two inches *(51 mm)* of insulation shall be removed from one end of an 18-inch *(457-mm)* specimen of wire and the specimen shall be mounted as shown in Figure 1. A 1.5-inch *(38-mm)* high yellow flame from a Bunsen burner conforming to FED-STD-191, Method 5903, shall be applied to the specimen at the junction of the insulation and bare conductor in such a manner that the lower end of the insulation is located 0.75 inch *(19 mm)* into the flame. After 12 seconds of flame application, the burner shall be removed from below the specimen and immediately turned off. The burn length and the time of burning after removal of the flame shall be recorded. The burn length shall be the distance from the original bend made in the conductor to the farthest point of damage. Damage shall consist of bare conductor and charred insulation. Light discoloration of the insulation shall not constitute failure.

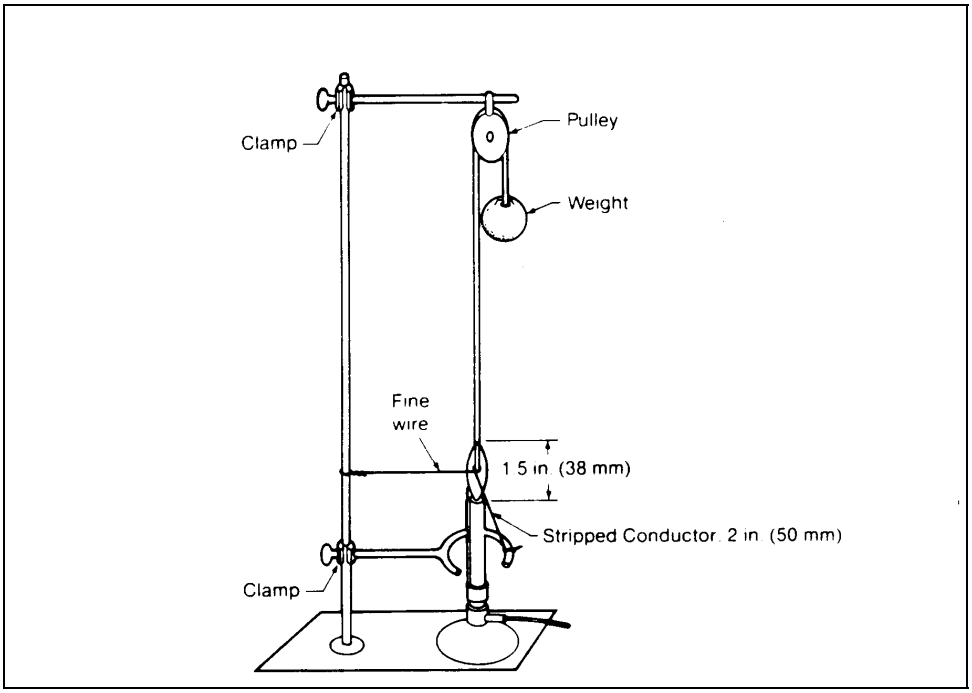

FIGURE 1. FLAMMABILITY TEST APPARATUS - VERTICAL FLAME TEST (shown without metal cabinet)

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4.6.6.2 Finished Cable (60° Test)

4.6.6.2.1 *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.

4.6.6.2.2 *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 the appropriate weight shall be attached. Weight shall be sufficient to hold the specimen taut throughout the test. With the burner held perpendicular to the specimen and at an angle of 30 degrees from the vertical plane of the specimen (see Figure 2), 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.

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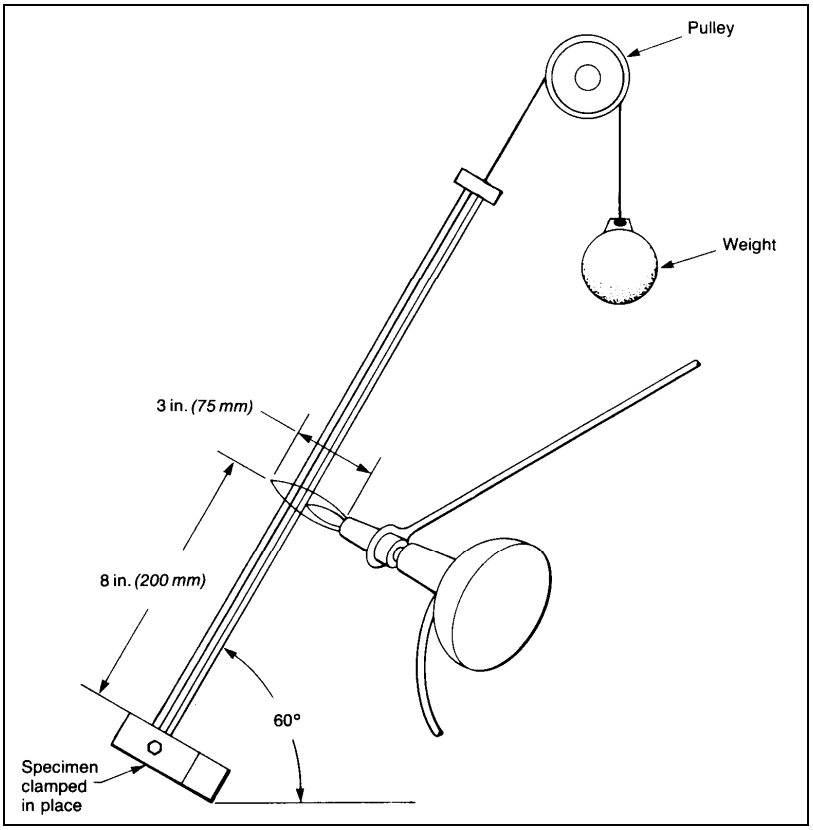

FIGURE 2. FLAMMABILITY TEST APPARATUS - 60° TEST (shown without chamber)

4.6.7 Fluoride Extraction

For finished wire or filler, prior to cabling, or for finished cable, approximately 0.5 gram of insulation, filler, or jacket material, as applicable, shall be removed, cut into 3-inch *(76-mm)* lengths and weighed to the nearest milligram. A polystyrene test tube (without its cap) shall also be weighed to the nearest 0.1 gram. After filling with approximately 14 ml of distilled water, the polystyrene test tube shall be reweighed. The insulation, filler, or jacket specimen shall then be placed into the test tube, making sure that the specimen is fully submerged, and the test tube cap is tightly attached. The test tube shall then be partially immersed in a 70 ± 2°C water bath so that the water levels of the bath and the test tube are equal. The test tube shall be so conditioned for 168 hours with the set-up being periodically checked to make sure that the specimen is still submerged. After conditioning, the test tube shall be removed from the bath and allowed to cool. The cap shall then be removed from the test tube, and the tube, water and specimen shall be weighed to determine the water weight loss. If the water loss is more than 0.5 gram, the test shall be rerun. Otherwise, 5 ml of the test tube water shall be analyzed for fluoride ion content using an Ion Chromatograph. The fluoride ion content shall be reported in ppm of water and shall not exceed the amount specified in the applicable SCD. A blank test in accordance with 4.6.7.1 should also be conducted in case the result is needed for calculation purposes.

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4.6.7.1 Blank Test

A blank test follows the same procedure as 4.6.7 except that a specimen is not included. What is tested is the distilled water and the specimen tube. Ideally, there are no fluoride ions in either the test tube or the distilled water such that the result for the blank test would be zero. However, there may be a low non-zero result (i.e. 0.005 ppm). If this occurs, the ppm of fluoride for the blank test must be subtracted from the ppm of fluoride obtained from the specimen. A blank test also performs the same function as a calibration as it can indicate a problem with the test procedure. For example, should the blank test produce a result of 15 ppm of fluoride, this would be an indication that the ion chromatograph is not functioning correctly, tap water was used in place of distilled water, etc.

4.6.7.2 Calculation

If necessary, the blank test result shall be subtracted from the specimen result to obtain the net fluoride ion content (ppm). The fluoride ion content of the insulation, filler, or jacket weight shall then be calculated as follows:

$$\text{F ion} = \frac{\text{Net F ion (ppm) x Original water weight}}{\text{Specimen weight}}$$

4.6.8 Insulation or Jacket Elongation and Tensile Strength

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

4.6.9 Insulation or Jacket Flaws

4.6.9.1 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 SCD 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 cable.

4.6.9.2 Spark Test

Finished wire and cable shall be passed through a chain electrode spark test device using the voltage specified in the applicable SCD 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.

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4.6.10 Insulation Resistance

The uninsulated ends of the 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 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:

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

4.6.11 Low Temperature - Cold Bend

Finished wire shall be tested in accordance with AS22759 at -85 ± 2°C for 4 hours, using the applicable mandrel and test load specified below, except that only 1 specimen shall be tested and the voltage withstand test shall be as specified herein (4.6.13). Finished cable shall be tested in accordance WC 27500 at -85 ± 2°C for 4 hours, using the applicable mandrel and test load specified below, except the voltage withstand test shall be as specified herein (4.6.13). Dissecting the cable specimen and testing the individual wires shall not be required.

Wire: 0.50-inch *(13-mm)* mandrel, 1-lb. *(0.45 kg)* test load
Cable: 3.00-inch *(76-mm)* mandrel, weight shall be sufficient to keep cable vertical and tangent to mandrel during bending operation.

4.6.12 Radiation Resistance

A 10-foot *(3.0-m)* specimen of the finished wire or cable shall be subjected to an electron radiation dosage of 500 megarads *(5 MGy)* at an average rate of between 5 and 10 megarads *(50 and 100 kGy)* per minute. Following exposure, the center portion of the specimen shall be wound around a mandrel with a diameter that is 25 to 30 times the finished specimen diameter. The ends of the specimen shall extend at least 6 inches *(152 mm)* beyond the wound portion. The specimen shall then be removed from the mandrel without unwinding and shall be subjected to the voltage withstand test (4.6.13).

4.6.13 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. Immediately following specimen immersion, the voltage specified in the applicable SCD 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.

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4.6.14 Weight

The weight of each lot of finished wire or cable shall be determined by Procedure I (4.6.14.1). Lots failing to meet the weight requirement of the applicable SCD when tested in accordance with Procedure I shall be subjected to Procedure II (4.6.14.2). All spools or reels failing to meet the requirements of the applicable SCD when tested to Procedure II shall be rejected.

4.6.14.1 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 SCD.

4.6.14.2 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 SCD. 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.

4.6.15 Weight Loss

A 5-foot *(1.5-m)* length of shielded cable shall be flush cut and weighed to the nearest 0.001 grams. Prior to weighing, the jacket surface of cables with jackets may be wiped clean with a suitable low boiling solvent such as isopropyl alcohol to remove any accumulation of debris. If a wipe is performed, the test specimen should be allowed to re-equilibrate to ambient conditions for 30 minutes. After cleaning, the sample should be handled using cotton gloves to avoid any contamination with finger oils. The cable jacket, if any, shall be removed by longitudinally slitting with a razor blade or a similar tool. After removal, the jacket and shielded inner bundle shall be wrapped into a loose coil and suspended in a forced air flow oven at 250 ± 2ºC for 20 minutes. After this conditioning, the collective test specimen shall be allowed to cool to ambient conditions for 30 minutes and then reweighed to the nearest 0.001 grams. The percent weight loss shall be calculated per the following formula:

$$\% \text{ Weight Loss} = \frac{(\text{Original Weight} - \text{Final Weight})}{\text{Original Weight}} \times 100$$

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5. STANDARD PACKAGING

Unless otherwise specified (see 5.1.5 and 7.1), 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 in accordance with Table 4.

TABLE 4. FINISHED WIRE LENGTHS

Wire Size Range (AWG)	Minimum Length
30 through 10	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 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 7.1), 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.

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5.1.5 Optional Spooling Requirements

As an option to standard spooling requirements, finished wire and cable lengths may be wound on spools or reels with all ends exposed and sealed with heat-shrinkable end caps, and the plastic spools sealed in reclosable plastic bags. If required, this option must be specified on customer's purchase order.

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. APPLICABLE DOCUMENTS

6.1 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.

6.1.1 Department of Defense

SPECIFICATIONS

Federal

UU-T-450	Tissue, Facial

STANDARDS

Federal

FED-STD-191	Textile Test Methods

Military

MIL-STD-104	Limits for Electrical Insulation Color
MIL-STD-1916	DOD Preferred Methods for Acceptance of Product

(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/.)

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6.1.2 National Aeronautics and Space Administration (NASA)

SP-R-0022 General Specification for Vacuum Stability Requirements of Polymeric Material for Spacecraft Application

(Copies of NASA documents may be obtained from the National Aeronautics and Space Administration; Lyndon B. Johnson Space Center, Mail Code: JM 62, Houston, Texas 77058; or at http://www.global.ihs.com/.)

6.2 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.

6.2.1 American Society for Testing and Materials (ASTM)

D 3032 Standard Test Methods for Hookup Wire Insulation
E 595 Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials From Outgassing in a Vacuum Environment

(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.)

6.2.2 International Organization for Standardization (ISO)

8402 Quality Management and Quality Assurance - Vocabulary

(Copies of ISO documents may be obtained from the International Organization for Standardization; or at www.iso.org.)

6.2.3 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.)

6.2.4 Society of Automotive Engineers (SAE)

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

(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.)

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7. NOTES

7.1 ORDERING DATA

Procurement documents should specify the following:

a. Title, number, and revision of this specification
b. Applicable SCD part number and color code (see 1.3)
c. Quantity
d. Special preparation for delivery requirements, if applicable (see Section 5)

7.2 METRIC UNITS

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

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