

INCH-POUND

MIL-F-64156

15 October 1990

MILITARY SPECIFICATION

FABRIC, CARBON (GRAPHITE) FIBER, NICKEL-COATED

This specification is approved for use by all Departments
and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification establishes the requirements for nickel-coated carbon (graphite) yarn and woven fiber cloth for use as a conductive surface ply to provide lightning strike protection to composites structures. Materials described herein are typically impregnated with a compatible epoxy resin.

1.2 Classification. The nickel-coated carbon (graphite) cloth covered by this specification shall be plain-weave fabric constructed from yarns having a nominal filament count of 3,000 (3k).

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Standards. The following standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

FEDERAL

FED-STD-102 - Preservation, Packaging, and Packing Levels
FED-STD-191 - Textile Test Methods

MILITARY

MIL-STD-1757 - Lighting Qualification Test Techniques For Aerospace Vehicles and Hardware

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, US Army Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MEE, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

AREA CMPS

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2.1.2 Other Government documents. The following Government document, forms a part of this specification to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

OSHA 2206 Occupational Safety and Health, General Industrial Standards

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D123 - Terminology Relating to Textiles
 ASTM D3800 - Standard Test Method for Density of High-Modulus Fibers
 ASTM D3990 - Terminology Relating to Fabric Defects
 ASTM D4018 - Standard Test Methods for Tensile Properties of Continuous Filament Carbon and Graphite Yarns, Strands, Rovings, and Tows

(Applications for copies of ASTM publications should be addressed to American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified in the contract or purchase order, a sample shall be subjected to first article inspection (see 4.3 and 6.2).

3.2 Constituent materials.

3.2.1 Reinforcement. Carbon (graphite) fibers to be nickel-coated and used in the yarn and woven cloth shall have a minimum tensile strength of 350 ksi (2413 MPa) and a modulus of at least 27 Msi (186 GPa). The carbon (graphite) fiber lot number, density, tensile strength, and modulus certification data shall be supplied to the procuring activity.

3.2.2 Nickel-coating. Each carbon (graphite) filament in the 3k yarn shall be coated with nickel. The nominal weight percentage of this nickel-coating shall be 50 percent.

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3.2.3 Tracer yarn. Tracer yarn shall be woven into the cloth. The warp tracer yarns shall be spaced 2 ± 0.25 inches (50 ± 5 mm) apart across the cloth width, and the fill tracer yarns 6 ± 1.0 (150 ± 25 mm) inches apart along the length of the cloth. No nickel-coated carbon (graphite) yarns shall be deleted to incorporate the tracer yarns. Tracer yarns shall not be wound around any nickel-coated carbon (graphite) yarns. Tracer yarns shall be fiberglass; the color shall be red.

3.2.4 Sizing or surface finish. Sizings or surface finishes shall not be employed on the pre-nickel-coated carbon (graphite) fiber. Any surface finish or fiber treatment employed on the exterior of the nickel-coated carbon (graphite) fiber to improve the weaving characteristics of the yarn shall not degrade the properties of the yarn or hinder the bonding characteristics of the impregnating resin to the coated fibers.

3.2.5 Serving. A water-soluble serving material may be employed to improve the weaved characteristics of the yarn. All serving must be removed upon completion of the weaving process to allow for proper spreading of the nickel-coated carbon (graphite) yarn.

3.2.6 Selvage. Selvage width shall be no greater than 1.25 inches (32 mm). Selvage thickness shall be comparable with prepreg thickness. Aramid (Kevlar) or equivalent fibers shall be used for selvage.

3.3 Physical properties.

3.3.1 Coated yarn. The nickel-coated carbon (graphite) yarn shall meet the physical property requirements of table I when tested in accordance with 4.5.1.1.

3.3.2 Woven fabric. The nickel-coated carbon (graphite) woven fabric shall meet the physical property requirements of table II when tested in accordance with 4.5.1.2.

3.4 Mechanical properties. The nickel-coated carbon (graphite) yarn shall meet the mechanical property requirements of table III when tested in accordance with 4.5.2.1.1.

3.5 Dimensions.

3.5.1 Width. The woven fabric width shall be as specified in the purchase order or contract. The width variation of a single roll shall be not greater than ± 0.50 inch (± 12.7 mm).

3.5.2 Alignment. The orientation of the fill yarns in woven fabric shall not deviate from a straight line perpendicular to the edge of the material, by more than 1 inch (2.54 mm) in any 12 inches (305 mm), or 2 inches (51 mm) in the total width of the material.

3.6 Workmanship. The coated carbon (graphite) yarn and woven fabric shall be uniform in quality and workmanship, and free of foreign materials and imperfections detrimental to appearance or performance of fabricated parts.

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3.6.1 Yarn defects. Individual yarns shall be free of crimps, creases, tears, and uncoated areas. Yarn splices shall be limited to four per linear yard (meter).

3.6.2 Fabric defects. Defects in the woven fabric shall be limited as follows:

- (a) No more than four spliced yarns, hung filling yarns, or fuzzballs shall be allowed in any linear yard of the woven fabric.
- (b) No more than one kinked or floating yarn, irregular or missing yarn, or unspliced broken yarn shall be allowed in any linear yard of the woven fabric. Broken warp ends shall not be separated by more than 0.25 inch (6.35 mm).
- (c) All fabric tears, cuts, weave separations, or splices shall be handled as nonconforming areas.

3.6.3 Nonconforming areas. The following criteria shall apply to nonconforming areas of the material.

- (a) Areas of the nickel-coated carbon (graphite) tow not meeting the criteria established in 3.6.1 shall not be considered as part of the acceptable material.
- (b) Areas of the woven fabric not meeting the criteria established in 3.6.2 and 3.5 shall be identified by inserts or flags which extend beyond the edge of the material selvage. Such areas shall not be considered as part of the acceptable material.
- (c) Net footage of nonconforming material in each roll shall be reported in the supplier acceptance inspection test report, or itemized in a discrepancy report.

3.6.4 Defect limitations.

3.6.4.1 Individual fiber lots. Individual lots of nickel-coated carbon (graphite) yarn supplied to this specification shall contain no more than 1 percent (of the total linear footage) nonconforming material.

3.6.4.2 Individual fiber rolls. Individual rolls of woven fabric supplied to this specification shall contain no more than 5 percent (of this total linear footage) nonconforming material.

3.6.5 Nonconforming material.

3.6.5.1 Nonconforming nickel-coated carbon (graphite) yarn. Nickel-coated carbon (graphite) yarn not meeting the requirements of 3.6.1, 3.6.4.1 and tables I and III is not acceptable and shall be rejected.

3.6.5.2 Nonconforming woven nickel-coated carbon (graphite) material. Woven nickel-coated carbon (graphite) material not meeting the requirements of 3.5, 3.6.4.2, and table II is not acceptable and shall be rejected.

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3.7 Lightning protection. Woven nickel-coated graphite cloth made in accordance with this specification shall be impregnated with appropriate resin and tested in accordance with MIL-STD-1757A. The configuration of the test specimen shall conform to its end use.

3.8 Nickel adhesion test. Yarn (tow) for use in the fabric shall pass an adhesion test when tested in accordance with 4.5.3.

3.9 Safety. Provisions for storage, handling, use, and disposal of hazardous material listed herein shall be as specified in OSHA 2206 Federal and State regulations. Personnel working to this specification shall follow those provisions.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Certificate of compliance (COC). Unless otherwise specified in the contract or purchase order, the supplier shall furnish with each shipment, a certificate of compliance (in triplicate) signed by a duly authorized representative of the supplier, stating compliance with the requirements specified herein and listing the specific results of all the acceptance tests. The certificate of compliance shall also include this specification number, the purchase order number, and the batch number.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

4.2.1 First article (i.e., preproduction) inspection (see 4.3)

4.2.2 Quality conformance (i.e., lot acceptance) inspection (see 4.4)

4.3 First article inspection.

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4.3.1 First article tests. First article tests include all tests and requirements listed in this specification. All materials which have been properly stored and handled shall be capable of meeting all tests and requirements.

4.3.2 First article sampling. First article inspection shall be based upon the manufacture and successful test of at least one batch of material.

4.3.3 Changes in materials. No change in product formulation, raw materials, production equipment, manufacturing procedures, or methods of inspection and testing, shall be made without notification and approval by the procuring activity. No production material made by the revised procedure shall be shipped prior to the receipt of written approval.

4.3.4 Process control document. Material shall be manufactured to a contractor-approved process control document that shall contain at least the following:

- (a) Procurement specification for raw materials.
- (b) Quality standards for the final product.
- (c) In-process inspection/control procedures.
- (d) Test methods, sampling plans, and acceptance/rejection criteria for (a) through (c).

4.4 Quality conformance inspection.

4.4.1 Acceptance testing. Acceptance tests are those tests to be performed on each batch of material in a shipment. The supplier and procuring activity shall perform acceptance tests as indicated in table IV.

4.4.2 Supplier quality control. The yarn and fabric suppliers shall perform acceptance tests as specified in table IV. Results of these tests shall be included in the supplier acceptance test report as required in 4.4.2.2. Supplier test methods and procedures may be substituted for methods specified herein, with approval from the procuring activity.

4.4.2.1 Supplier sampling.

4.4.2.1.1 Yarn sampling. Each lot of nickel-coated carbon (graphite) yarn shall be tested as required in table IV. Test sampling shall be in accordance with the following schedule:

Pounds of Nickel-Coated Fibers Per Lot	Numbers of Samples
Up to 400	6
401 and over	8

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4.4.2.1.2 Fabric sampling. Each roll of nickel-coated carbon (graphite) fabric shall be tested for conformance to the physical property tests specified in table IV. The woven fabric shall be visually inspected in its entirety for conformance to the applicable portions of 3.4.

4.4.2.2 Acceptance reports.

4.4.2.2.1 Coated carbon (graphite) yarn supplier. The supplier of the coated carbon (graphite) yarn shall furnish with each shipment a copy of a report that shall include:

- (a) Order number and applicable specification number.
- (b) Supplier's material designation.
- (c) Quantity of product in the shipment.
- (d) Lot or batch number.
- (e) A copy of the carbon (graphite) fiber certification data.
- (f) A statement that the product meets all specification requirements
- (g) All acceptance test results performed by the supplier as required in 4.4.1

4.4.2.2.2 Woven fabric supplier. The supplier of the woven fabric shall furnish with each shipment a copy of a report that shall include:

- (a) A copy of the coated carbon (graphite) yarn acceptance report.
- (b) Order number and applicable specification number.
- (c) Supplier's material designation.
- (d) Quantity of product in the shipment.
- (e) Lot or batch number.
- (f) A statement that the product meets all specification requirements.
- (g) All acceptance test results performed by the supplier as required in 4.4.1
- (h) Total footage of nonconforming material per batch, per shipment.
- (i) A defect log describing type, location, and length of defects in each roll.
- (j) Percentage of nonconforming material on each roll.

4.4.2.2.3 Marking. Material suppliers shall verify that each container of coated yarn and woven fabric is marked as required in 5.2.2. Additionally, the fabric supplier shall verify that each roll of woven material is marked as required in 5.1.2.

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4.4.3 Purchaser quality control.

4.4.3.1 Tests. The procuring activity or the purchasing subcontractor shall perform acceptance tests designated in table IV. Additional tests for any required property in this specification may be performed at the option of the purchaser to verify conformance.

4.4.3.2 Test results. The procuring activity or the purchasing subcontractor shall verify that the test results supplied in the supplier's acceptance reports are in compliance with the requirements contained in this specification.

4.4.3.3 Purchase sampling. Each roll of nickel-coated carbon (graphite) fabric shall be tested for conformance to the physical property tests specified in table IV.

4.4.4 Resampling and retesting. Disposition of material which does not meet the acceptance requirements may be based on three retest specimens. Unless specimen preparation or testing errors are detected, material failing to meet the specified requirements in any retest shall be rejected. Results of all tests shall be reported.

4.5 Material testing.**4.5.1 Physical property test methods.****4.5.1.1 Nickel-coated carbon (graphite) yarn.**

4.5.1.1.1 Nickel-content, coated carbon (graphite) yarn. Flame atomic absorption spectroscopy shall be used to determine the amount of nickel-coating on the carbon (graphite) fiber.

(a) Equipment.

- (1) Atomic absorption spectrometer, Varian 1475, or equivalent
- (2) Single element hollow cathode lamp, nickel, to fit spectrometer
- (3) 400-mL glass beakers (Pyrex)
- (4) 1, 3, 5, and 10-mL Class A volumetric pipettes
- (5) 100-mL Class A volumetric flask
- (6) 1000-mL Class A volumetric flask
- (7) Convection oven (capable of 150°C)
- (8) Hot plates
- (9) Analytical balance (0.01 mg) Mettler AE-163 or equivalent
- (10) Desiccator
- (11) Acid fume hood

(b) Materials. The atomic absorption procedure requires the use of the following chemicals:

- (1) Nitric acid (HNO₃), concentrated
- (2) Nickel (Ni), aqueous standard 1000 mg/L
- (3) Deionized water

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NOTE

Purity for the materials specified in (b) (1), (2), and (3) shall have a minimum purity of no less than American Chemical Society Reagent Grade, or equivalent.

(c) Safety precautions.

- (1) The storage, handling, use and disposal of goods, supplies, materials, articles, items, equipment, machines, tools, parts, components, assemblies, chemicals, and processes referenced herein shall comply with all applicable Federal, state, county, city and other governmental agency laws, ordinances, rules, regulations and codes that pertain to health, safety, and the environment. In addition, personnel shall comply with company manuals, directives, and policies relative to health, safety, and the environment. Personnel who work to this specification shall follow the above provisions.
- (2) Nickel-plated carbon (graphite) fibers are sharp and should be handled wearing gloves.
- (3) Nitric acid is a strong oxidizer. Both the liquid and vapor are toxic and corrosive. Wear rubber gloves and carry out the digestions in an acid fume hood. Dispose of acid wastes according to local guidelines.

(d) Standards. Prepare standards using the following procedures or an equivalent method:

- (1) 100 mg/L Ni stock: Pipette 10 mL of nickel reference standard solution into a 100-mL volumetric flask. Add 2 mL HNO₃ and dilute to volume with water.
- (2) 40 mg/L Ni Standard: Pipette 40 mL of solution specified in (d) (1) into 100-mL volumetric flask. Add 50 mL water, 2 mL HNO₃, and dilute to volume with water.
- (3) 30 mg/L Ni Standard: Pipette 30 mL of solution specified in (d) (1) into a 100-mL volumetric flask. Add 50 mL water, 2 mL HNO₃, and dilute to volume with water.
- (4) 20 mg/L Ni Standard: Pipette 20 mL of solution specified in (d) (1) into a 100-mL volumetric flask. Add 50 mL water, 2 mL HNO₃ and dilute to volume with water.
- (5) Standard Blank: In a 100-mL volumetric flask add 50 mL water, 2 mL HNO₃, and dilute to volume with water.
- (6) 3.15M Nitric acid: Dilute 200 mL of concentrated nitric acid to one liter with purified water.

(e) Specimen Preparation. Preparation for testing shall be accomplished as follows:

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- (1) Cut 100 continuous inches (at least 1 gram) of fiber from the sample in triplicate.
 - (2) Dry the fiber sample at 75°C for 30 minutes in a convection oven then cool in a desiccator.
 - (3) Weigh the fiber sample and record the weight in grams (W_1).
- (f) Dissolution of Nickel.
- (1) Place the fibers in a beaker cleaned with 3.15 M HNO_3 . Perform the transfer quantitatively.
 - (2) Add 90 mL of deionized water to wet the fibers and carry a reagent blank through the procedure.
 - (3) In a fume hood, add 85 mL of concentrated nitric acid.
 - (4) Heat the solution to 90°C for 30 minutes. Carefully swirl solution 3-4 times with glass rod to promote dissolution of nickel from fibers during digestion.
 - (5) Allow solutions to cool, then transfer quantitatively to 1.0-L volumetric flask. Rinse the fiber with water (X4), use a stirring rod to agitate carbon fiber in rinse. Dilute to volume with deionized water. Do all the above in acid fume hood.
 - (6) Pipette 6 mL of each solution (5) into a separate 100-mL volumetric flask. Do in duplicate. Add 50 mL water. Add 2 mL HNO_3 and dilute to volume with water.
- (g) Analysis.
- (1) Consult standard operating procedure for set-up of atomic absorption instrument.
 - (2) Use a fuel lean flame with a 10-cm single slit burner head. Optimize for maximum signal at 232.0 nm using the highest concentration standard.
 - (3) Typical Instrument Conditions
Element: Ni
Wavelength (nm): 352.4
Slit (nm): 0.5
Flame: Air-acetylene, oxidizing (lean, blue)
Lamp Current (ma): 4.0
Linear to (mg/L): 60.0
 - (4) Prepare calibration curve using the blank and the three working standards (20,30,40, mg/L Ni).
 - (5) Run solutions prepared in (f) (6) against calibration curve. Record the nickel concentrations in milligrams per liter (mg/L). Nickel

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concentrations are interpolated from a least-square fit of the calibration standards.

(h) Data reporting.

- (1) Calculate nickel weight in the samples by:

Ni in Sample (g) $W_2 =$

$$\frac{(\text{Nickel Concentration}) (\text{Dilution Factor}) (\text{Initial Solution Volume})}{1000 \text{ mg/g}}$$

Where: Nickel Concentration is expressed as mg/L recorded in (g)(5)

$$\text{Dilution Factor} = \frac{\text{Dilution Volume (100-mL)}}{\text{Aliquot Volume (1 mL)}} = 100$$

Initial Solution Volume = 1.0 Liter from (f)(5)

- (2) Calculate the weight percent nickel on the fiber by:

$$\text{Weight percent Nickel on fiber} = \frac{(W_2)}{(W_1)} \times (100)$$

Where: W_2 is weight of nickel plating

W_1 is total weight of fiber sample

- (3) Record the weight percent nickel on the fiber for each sample.
- (4) Report raw data, calculated data, set number, sample identity and lot number for each sample.

4.5.1.1.2 Density. ASTM D3800 shall be used to determine the density of the nickel-coated yarn. Sample size shall be a minimum of 0.5 gram of continuous material. Calculate the fiber density in grams per cubic centimeter (gm/cm^3) using the following formula. Report the individual values and the arithmetic mean of three determinations.

$$\text{Fiber Density} = \frac{(W_3 - W_1) \times 0.9975}{(W_3 - W_1) - (W_4 - W_2)}$$

Where: W_1 = Weight of wire in air

W_2 = Weight of wire in liquid

W_3 = Weight of wire sample in air

W_4 = Weight of wire and sample in liquid

4.5.1.1.3 Yarn yield. The nickel-coated carbon (graphite) yarn shall be tested for yield as follows:

- (a) Cut approximately 2 yards and measure to the nearest 0.05 yard (L).
- (b) Weight the yarn sample to the nearest milligram (W).

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- (c) Calculate the yield in yards per pound (yds/lb) of the nickel-coated yarn using the following formula:

$$\text{Yield} = \frac{L}{W} (4.54 \times 10^5)$$

- (d) Report the individual values and the arithmetic mean of three determinations.

4.5.1.2 Woven fabric.

4.5.1.2.1 Nickel content, woven fabric. Nickel content of the woven fabric shall be determined by atomic absorption. Test procedures are as specified in 4.5.1.1.1.

4.5.1.2.2 Areal weight. FED-STD-191, Method 5041, shall be used to determine the areal weight of the nickel-coated carbon (graphite) fabric. Report the individual results and the arithmetic mean of three determinations.

4.5.1.2.3 Yarn count. FED-STD-191, Method 5050, shall be used to determine the number of warp and fill yarns per inch. Report the individual results and the arithmetic mean of three determinations.

4.5.2 Mechanical property test methods.

4.5.2.1 Nickel-coated carbon (graphite) yarn.

4.5.2.1.1 Tensile properties. Tensile properties of the nickel-coated carbon (graphite) yarn shall be determined in accordance with ASTM D4018, Method I, with the following exceptions:

- (a) A 10-inch (25.4-cm) length of tow with a 5-inch (12.7-cm) gage length shall be substituted for the standard 13-inch (33.0-cm) length with 6-inch (15.2-cm) gage length (see ASTM D4018).
- (b) The rate of separation of the grips shall be 0.5 inch per minute (12.7 mm/minute) to produce a strain rate of one percent per minute (see ASTM D4018).

Report results in accordance with ASTM D4018. Report raw data, calculated results, sample identity, lot number, and batch number for each sample.

4.5.3 Nickel adhesion test.

4.5.3.1 Principle: Nickel coated carbon fiber is thermally cycled between -196°C (liquid nitrogen) and 138°C (280°F). If the nickel coating is not firmly adherant to the carbon fiber, the combination of temperature change and the mechanical boiling action as the fiber is introduced into the liquid nitrogen would remove enough of the nickel coating to increase the linear electrical resistance of the nickel coated fiber.

4.5.3.2 Experimental. The experimental set-up is shown in figure 1. It shall consist of a 4-point resistance meter and a fixture comprising four brass posts for electrical contact. A length of nickel coated carbon fiber

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shall be cut, placed in the fixture as shown and attached to 100-g weights on either end to provide a known, constant tension on the fiber. The linear electrical resistance shall be read directly from the meter.

Alternatively, a small current (<100 mA D.C.) shall be passed between the two outside posts using a small D.C. power supply. The voltage drop between the two inside posts shall be measured with a voltmeter. The resistance of the fiber shall be calculated using Ohm's Law:.

$$R = E/I$$

where: E = measured voltage in volts
 I = applied current in amps
 R = resistance of the fiber tow in ohms

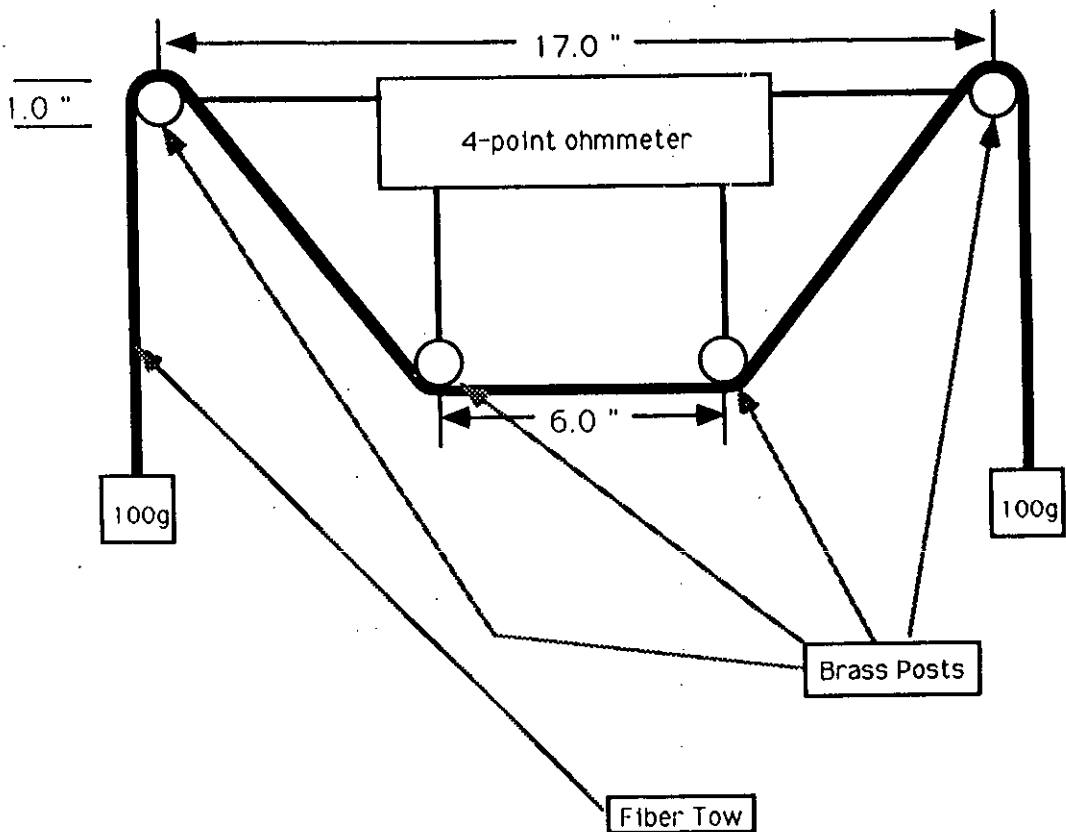
4.5.3.3 Procedure.

1. Set up linear electrical resistance measurement apparatus as discussed above.
2. Preheat an oven to 138°C (280°F).
3. Measure 5 lengths of nickel coated carbon fiber, each 1 meter in length.
4. Measure the linear electrical resistance of each length of fiber, recording the resistance values.
5. Immerse the nickel coated fiber in liquid nitrogen for one (1) minute.
6. Remove the nickel coated fiber from the liquid nitrogen and place the fiber in an oven, preheated to 138°C (280°F), for one minute.
7. Repeat steps 5 & 6 fourteen (14) times to give a total of fifteen (15) cycles between liquid nitrogen and the preheated oven.
8. After the fifteenth cycle, measure the linear electrical resistance of each nickel coated carbon fiber sample and record the resistance values.

4.5.3.4 Results. The linear electrical resistance values of the nickel coated fiber shall be approximately the same, within experimental error, before and after the thermal cycling. If the resistance increases more than 25% after thermal cycling, the nickel coating shall be deemed not adherant. Typical values for 3k NCG (50% Ni by weight), using the test procedure described are given below:

	<u>Initial Resistance</u>	<u>Resistance after Cycling</u>
	1.0701	1.043
Std. Dev.	0.01	0.08
N	5	5

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FIGURE 1. Experimental set-up.

5. PACKAGING

5.1 Preservation.

5.1.1 Interior packaging. Each roll of material shall be packaged in a moisture-proof bag which will prevent moisture penetration into the nickel-coated carbon (graphite) yarn.

5.1.2 Material identification.

5.1.2.1 Yarn identification. Each spool of material shall be identified by a label in the spool which utilizes legible characters which will not be effaced by normal handling. Each label shall provide the following information:

- (a) Manufacturer's material designation
- (b) Lot number
- (c) Spool number
- (d) Date of manufacture
- (d) Quantity (pounds and linear yards)

The purchase order number shall be marked in or out of the spool.

5.2 Packing.

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5.2.1 Exterior packaging. The protected spools and rolls of material shall be packed in an exterior shipping container, identified with a package number, which is capable of protecting the materials adequately during transit and storage, and meeting carrier rules and regulations applicable to the mode of transportation and FED-STD-102.

5.2.2 Exterior marking. The exterior of each shipping container shall be marked with the following information in such a manner that the markings shall not smear or be obliterated during normal handling:

- (a) Manufacturer's materials designation
- (b) Purchase order number
- (c) Lot number
- (d) Roll number
- (e) Date of manufacture

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The nickel-coated carbon (graphite) fabric covered by this specification is intended primarily for use as a conductive surface ply to provide lightning strike protection of structural composites. This material is also used for electromagnetic interference (EMI) shielding and electrostatic dissipation (ESD) applications.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents shall specify the following:

- (a) Title, number and date of this specification.
- (b) Whether first article inspection is required (see 3.1).
- (c) Roll width and total length of fabric.

6.3 Definitions. See ASTM D123 and D3990.

6.4 Subject term (key word) listing.

Composite structures	RMI/RFI shielding
Lightning strike protection	

Custodian:
Army - MR
Navy - AS

Preparing activity:
Army - MR

Project CMPS-0024

Review activities:
Navy - SH

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TABLE I. Physical property requirements for nickel-coated carbon (graphite) yarn.

Property	Requirements, Range	Test Procedure
Nickel Content, percent weight	45 - 55	4.5.1.1.1
Density of Coated Fiber, gm/cm ³	2.95 - 3.20	4.5.1.1.2
Yarn Yield, yds/lb (m/Kg)	990 - 1343 (2000-2710)	4.5.1.1.3

TABLE II. Physical property requirements for woven nickel-coated carbon (graphite) fabric.

Property	Requirements, Range	Test Procedure
Nickel Content, percent weight	45 - 55	4.5.1.2.1
Areal Weight, gm/m ²	400 ± 50	4.5.1.2.2
Yarn Count/Inch (2.5 cm), warp and fill	12.0 x 12.0 ± 0.5	4.5.1.2.3

TABLE III. Mechanical property requirements for nickel-coated carbon (graphite) yarn.

Property	Requirements	Test Procedure
Ultimate Tensile Strength, ksi, (MPa) (min)	350 (2400)	4.5.2.1.1
Tensile Modulus, Msi (GPa), (min)	27 (190)	4.5.2.1.1
Strain to Failure %, (min)	1.0	4.5.2.1.1

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TABLE IV. First article and acceptance tests.

Test	Testing Required				No. of Specimens per Sample	Test Method	Require- ments
	First Article	(Yarn Supplier)	Product (Fabric Supplier)	Acceptance (Fabric Purchaser)			
Visual	X	X	X	X	--	3.6	3.6
Dimensions	X	--	X	X	--	3.5	3.5
Nickel Content	X	X	--	X	3	4.5.1.1.2	Tables I & II
Density	X	X	--	X	3	4.5.1.1.2	Table I
Yarn Yield	X	X	--	X	3	4.5.1.1.3	Table I
Areal Weight	X	--	X	X	3	4.5.1.2.2	Table II
Yarn Count inch	X	--	X	--	3	4.5.1.2.3	Table II
Tensile Strength	X	X	--	--	5	4.5.2.1.1	Table III
Tensile Modulus	X	X	--	--	5	4.5.2.1.1	Table III
Tensile Strain to Failure	X	X	--	--	5	4.5.2.1.1	Table III
Lightning simulation test	X			X	1	MIL-STD-1757	3.7
Nickel adhesion test	X	X			5	4.5.3	3.8

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL <i>(See Instructions -- Reverse Side)</i>	
1. DOCUMENT NUMBER MIL-F-64156	2. DOCUMENT TITLE FABRIC, CARBON (GRAPHITE) FIBER, NICKEL-COATED
3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION (Mark one) <input type="checkbox"/> VENDOR <input type="checkbox"/> USER <input type="checkbox"/> MANUFACTURER <input type="checkbox"/> OTHER (Specify): _____
b. ADDRESS (Street, City, State, ZIP Code)	
5. PROBLEM AREAS	
a. Paragraph Number and Wording:	
b. Recommended Wording:	
c. Reason/Rationale for Recommendation:	
6. REMARKS	
7a. NAME OF SUBMITTER (Last, First, MI) - Optional	b. WORK TELEPHONE NUMBER (Include Area Code) - Optional
c. MAILING ADDRESS (Street, City, State, ZIP Code) - Optional	8. DATE OF SUBMISSION (YYMMDD)