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| AEROSPACE STANDARD | AS60491™ | |
| | Issued | 2015-12 |
| Sleeve, Protection, For Cable and Harness Protection | | |

RATIONALE

Procurement specification required to standardize protection sleeves presently procured by supplier part numbers.

1. SCOPE (SEE 6.1)

Procurement specification is principally for defining protection sleeves on a cable or group of electrical/fiber optic wires (wiring bundle). Single wire protection depends on the minimum diameter of the wire. Sleeve may be used to protect a wire bundle for a platform installation or for repair of installed damaged jacket or jacket/shielded wire bundles. See AS50881 for aerospace wire bundle protection installations.

1.1 Temperature Operation Range

The sleeve temperature range is -60 to +175 °C/+200 °C/+240 °C/+260 °C depending on material and is defined in the detail specification. Mechanical properties may be reduced with increasing temperature.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and 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.

2.2 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

| | |
|---------|---|
| AMS1424 | Deicing/Anti-Icing Fluid, Aircraft SAE Type 1 |
| AIR1351 | Manufacturers' Identification of Aerospace Electrical and Electronic Wiring Devices and Accessories |
| AS4373 | Test Methods for Insulated Electric Wire |
| AS9100 | Quality Management Systems - Requirements for Aviation, Space and Defense Organizations |
| AS50881 | Wiring Aerospace Vehicle |

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SAE values your input. To provide feedback on this Technical Report, please visit <http://www.sae.org/technical/standards/AS60491>

| | |
|------------|---|
| AS60491/1* | Sleeve, Chafe-protection, Wrap-Around, Self-closing (-55° to +200°C) |
| AS60491/2* | Sleeve, Chafe-protection, Wrap-Around, Self-closing, High Temp (-55° to +260°C) |
| AS60491/3* | Sleeve, Chafe-protection, Expandable (-55° to +200°C) |
| AS60491/4* | Sleeve, Chafe-protection, High Abrasion, Expandable (-55° to +200°C) |
| AS60491/5* | Sleeve, Chafe-protection, Expandable (-55° to +240°C) |
| AS60491/6* | Sleeve, Chafe-protection, Wrap-Around, Self-closing (-55° to +175°C) |
| AS60491/7* | Sleeve, Chafe-protection, Wrap-Around, Self-closing, Shielded, (-55° to +200°C) |
| EIA-557 | Statistical Process Control Systems |
| SAE J2192 | Recommended Testing Methods for Physical Protection of Wiring Harnesses |

*AS60491 detail specification

2.3 U.S. Government Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

| | |
|---------------|---|
| MIL-DTL-5624 | Turbine Fuel, Aviation, Grades JP-4 and JP-5 |
| MIL-DTL-83133 | Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-434), NATO F-35, and JP-8+100 (NATO F-37) |
| MIL-PRF-5606 | Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordinance |
| MIL-PRF-7808 | Lubricating Oil, Aircraft Turbine Engine, Synthetic Base |
| MIL-PRF-23699 | Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Numbers: O-152, O-154, O-156, and O-167 |
| MIL-PRF-87937 | Cleaning Compound, Aerospace Equipment |
| SD-6 | Provisions Governing Qualification |

2.4 NCSL Publications

Available from NCSL International, 2995 Wilderness Place, Suite 107, Boulder, CO 80301, Tel: 303-440-3339, www.ncsli.org.

NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

2.5 ASQ Publications

Available from American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, Tel: 800-248-1946 (United States or Canada), 001-800-514-1564 (Mexico) or +1-414-272-8575 (all other locations), www.asq.org.

ANSI/ASQ Z1.4 Sampling Procedures and Tables for Inspection by Attributes

2.6 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A686 Standard Specification for Tool Steel, Carbon

ASTM B355 Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

ASTM D3032 Standard Test Methods for Hookup Wire Insulation

2.7 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209, Tel: 703-841-3200, www.nema.org.

WC 27500 Standard for Aerospace and Industrial Electric Cable

2.8 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61000-4-21 Testing and measurement techniques – Reverberation chamber test methods

2.9 Other Government Documents

The following other government document forms a part of this specification to the extent specified herein. Unless otherwise specified, the issue shall be the one in effect on the date of the solicitation.

FEDERAL AVIATION ADMINISTRATION

Available from <http://www.ecfr.gov/>

AIRWORTHINESS STANDARDS Part 25 – Transport Category Aircraft

DEFENSE LOGISTICS AGENCY

H4/H8 Catalog of Commercial and Government Entities (CAGE)

(Copies of specifications, standards and other government documents required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

3. REQUIREMENTS

3.1 Detail Specification (see 2.1)

The product requirements shall be as specified herein and in accordance with the applicable detail specification. In the event of any conflict between the requirements of this specification and the detail specification, the latter shall govern. Metric units shall be shown in parentheses.

3.2 Qualification

The components shall be a product that has been tested and has passed the qualification tests specified herein, and has been listed on or approved for listing on the applicable Qualified Products List (see 6.3).

3.3 Materials (see 5.1.1)

Materials shall be specified and listed in the detail specification in accordance with a material specification. Materials shall be certified by the supplier. Additives are permitted by the supplier, but shall be strictly controlled by engineering and manufacturing process control procedures. The procedure control numbers with the latest revision and a generic title shall be available to the Qualifying Activity upon request (see 6.3). Only mold resistance materials shall be used and shall be certified by supplier.

3.4 Component Design and Construction

3.4.1 Design (see 6.2)

3.4.1.1 Sleeve Design

Sleeve shall be designed to expand or wrap-around a cable or wire bundle to provide protection against chaffing. Unless otherwise specified in the detail specification, each sleeve shall be built-up of groups of monofilament or multifilament fibers made from the same material or combinations of materials.

3.4.1.1.1 Expandable Sleeve

Expandable sleeve shall be a tubular braid construction capable of expanding to fit different cable or wire bundle shapes and sizes. The range of sizes shall be specified in the detailed specification. The sleeve is a tubular braid which may require the removal of the cable or bundle from which it is installed.

3.4.1.1.2 Wrap-Around sleeve

Sleeve shall be designed to wrap around a cable or wire bundle without complete removal of the cable or bundle from the equipment in which it is installed. The sleeve shall be self-closing or the closing system shall have a locking device (i.e., lacing tape). The self-closing sleeve shall have tracer line which acts as a maximum diameter indicator. The tracer line should not be visible along the leading edge when wrapped on the largest diameter cable or bundle specified by the part number. If the tracer line is visible, the next larger sleeve diameter should be used. For protection sleeve with a shield, the shield shall be attached to inside edge of the sleeve and shall not be exposed to the leading edge of the sleeve.

This sleeve requires a nominal 90 degree overlap of material to ensure protection and prevent creating a foreign object damage in aerospace vehicle applications. Wraparound sleeve sizing is based on the nominal size of the wire bundle, determined by wrapping the material around the bundle and ensuring a nominal 90 degree overlap.

3.4.1.2 The braid of the fibers (when applicable) and metallic strands shall be specified in the detail specification (see 3.4.4).

3.4.1.3 When used, coating materials shall be specified in the detail specification (see 3.3).

3.4.2 Dimensions (see 5.1.2)

Dimensions and overlap angle shall be in accordance with the detail specification.

3.4.3 Weight (see 5.1.3)

The weight of the sleeve per unit length shall be specified in the detail specification.

3.4.4 Sleeve and Shield Coverage (see 5.1.4)

Unless otherwise specified in the detail specification, the sleeve braid of the fiber (when applicable) and the metallic shield strand coverage shall be 85% minimum, or as defined in the detail specification sheet.

Sleeve braid shall be applied with the maximum tension possible so as to prevent loosening or creeping but not to cause broken ends. Braid shall have no gaps. Loose strand ends shall be trimmed to within 0.031 inch (0.79 mm) of the weave and shall lay parallel with the braid. There shall be no splices of the completed braid. The number of braids and the elements of their construction shall be as specified in the detail specification (see 3.1). The percent coverage specified shall be determined in accordance with the formulas shown below.

Weave or shield coverage = $(2F - F^2) \times 100\%$

$$F = \frac{NPd}{\sin a} \quad a = \tan^{-1} \left(\frac{2(W+2\pi d)P}{C} \right)$$

where:

W = Maximum width of braid laid flat

d = Diameter of an individual strand of the braid

N = Number of ends (fiber or wire strands) per carrier

C = Number of carriers (separated group of ends) around the diameter of the braid

P = Minimum number of picks per inch (separation points between carriers) along the length of the braid

a = Smaller angle between longitudinal axis of the cable and the braid strands or wires

F = Fill or space factor

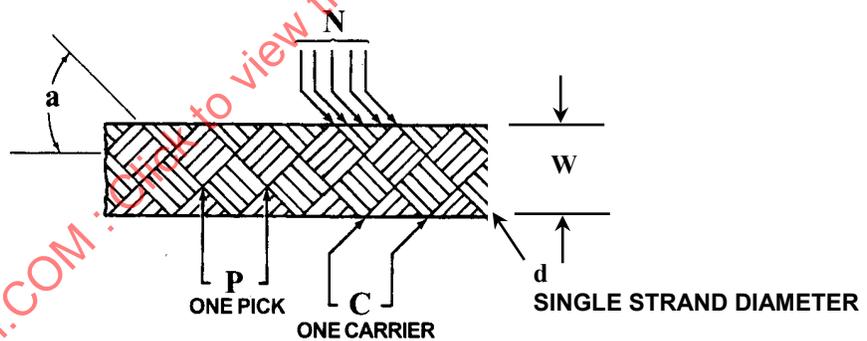


Figure 1 - Sleeve fabric or wire braid

3.4.4.1 Sleeve coverage - braided tubular (see 5.1.4.1)

3.4.4.2 Sleeve overlap - woven wrap-around sleeves (see 5.1.4.2)

3.4.5 Product Identification and Marking (see 5.1.5)

3.4.5.1 Product Identification

The product identification shall be defined by the sleeve color and identification stripe. Unless otherwise specified in the detail specification, the sleeve color number shall be in accordance with Table 1. Part number structure is as follows:



Table 1 - Color code numbers

| Color Number | Color | Color Number | Color |
|--------------|--------|--------------|--------------------|
| 0 | BLACK | 6 | BLUE |
| 1 | BROWN | 7 | PURPLE |
| 2 | RED | 8 | GRAY |
| 3 | ORANGE | 9 | WHITE (or NATURAL) |
| 4 | YELLOW | 57 | GREEN/PURPLE |
| 5 | GREEN | | |

3.4.5.2 Wrap-Around Sleeve Tracer Line

A tracer line shall run continuously along the axis of the sleeve. The tracer line color should be a contrasting color to the main sleeve color; i.e., black sleeve use a white tracer line. For specific cable or bundle type applications (i.e., high temperature, fiber optic, etc.) a stripe with identification colors may be used. The identification stripe color and width shall be defined in the detail specification.

The location of the tracer line shall be defined by the angle of overlap in the detailed specification.

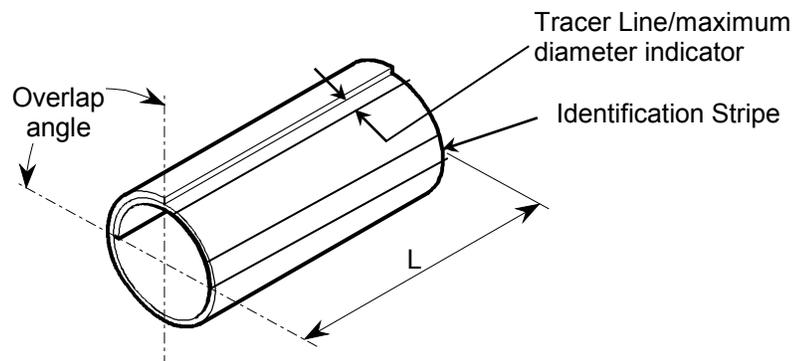


Figure 2 - Tracer line and identification stripe location

3.4.5.3 Marking

Unless otherwise specified in the detail specification sheet, the sleeve shall be identified by a printed marking applied to the outer surface of the sleeve. The identification mark shall not be applied by hot stamp marking or other methods which significantly penetrate the sleeve material. The printed identification shall consist of the following; the sleeve part number as specified in the detail specification sheet, except that inclusion of the color code portion of the part number is not required in the printed marking along with the manufacturer's Commercial and Government Entity (CAGE) designation in accordance with Publication H4/H8. The printed marking shall be at intervals of 6 to 18 inches, as measured from the end of one complete marking to the beginning of the succeeding complete marking. The printing shall be of a color to provide contrast to the sleeve color. Identification printing shall be applied with the vertical axes of the printed characters lengthwise of the sleeve. All printed characters shall be complete and legible.

3.4.6 Product Identification and Marking Durability (see 5.1.6)

The product identification, tracer line and stripe shall not be obliterated after subjection to the durability and legibility of wire identification test unless otherwise specified in the detail specification sheet.

3.4.7 Assembly Instruction (see 5.1.7)

When specified by contract or purchase order, assembly instructions are required with each package spool (see Section 6).

3.4.8 Workmanship (see 5.1.8)

Sleeve shall be uniform throughout the construction, free from splits, foreign material, or defects that affect the serviceability of the sleeve in the installed condition. There shall be no significant fraying of the fiber or shield strands, holes or irregularity in the fiber or metallic strand braid. The sleeve fibers or shield strands on cut end shall not continuously pull out from the sleeve.

3.5 Component Performance

3.5.1 Sleeve Expansion and Removability/Open and Close (see 5.2)

When tested in accordance with the sleeve and expansion and removability/open and close tests of 5.2, the expandable sleeve and wrap-around sleeve shall show no indication of strand breakage, damage or strand separation. Also when tested in accordance with the sleeve and expansion and removability/open and close tests of 5.2, the sleeve shield strands shall not be broken, separated or disconnected (when required) from the sleeve.

3.5.2 Dry Dielectric Voltage (see 5.3)

When tested in accordance with the test methods of 5.3 using dielectric test voltage specified in the detail specification, there shall be no breakdown, flashover or spark-over.

3.5.3 Shielding Effectiveness (see 5.4)

When EMI shielding is required, the shielding effectiveness shall be defined in the detail specification sheet.

3.5.4 Bend Flexibility (see 5.5)

The sleeve shall show minimal wrinkles or lifting of the leading edge (wrap-around sleeve). When applicable, shield resistance shall be in accordance with the detail specification. The sleeve shield strands shall not be broken. The shield attached to the sleeve shall not be disconnected or separating from the sleeve.

3.5.5 Low Temp Flexibility (see 5.6)

The sleeve shall show no indication of cracking or splitting. When applicable, shield resistance shall be in accordance with the detail specification. The sleeve shield strands shall not be broken. The shield attached to the sleeve shall not be disconnected or separating from the sleeve.

3.5.6 Humidity (see 5.7)

When tested in accordance with 5.7, the weight gain of the sleeve should not exceed 5% unless otherwise specified in the detail specification sheet.

3.5.7 Life Cycle/Aging (see 5.8)

The sleeve shall show no indication of cracking or splitting. The sleeve shall pass the bend flexibility test, the dry dielectric test, and sleeve tensile strength test.

3.5.8 Flammability (see 5.9)

Unless otherwise specified in the detail specification, the average burn length may not exceed 8 inches, and the average flame time after removal of the flame source may not exceed 15 seconds. Drippings from the test specimen may not continue to flame for more than an average of 5 seconds after falling (from Appendix F Part I (a)(1)(ii) of 14 CFR Part 25).

3.5.9 Abrasion (see 5.10)

There shall be no penetration of the outer sleeve layer.

3.5.10 Dynamic Cut-Through (see 5.11)

The sleeve cut-through force shall be equal to or greater than the force specified in the detail specification.

3.5.11 Fiber Tensile Strength (see 5.12)

The fiber/strand shall withstand the average minimum tensile strength force and the average percent elongation specified in the detail specification.

3.5.12 Fluid Resistance (see 5.13)

The fiber/strand shall withstand the average minimum tensile strength force and the average percent elongation specified in the detail specification.

4. QUALITY ASSURANCE

4.1 Responsibility for Inspection

Unless otherwise specified herein, the contract or purchase order, the supplier is responsible for the performance of all contract inspection requirements. Except as otherwise specified herein, the contract or purchase order, the supplier may use any facilities suitable for the performance of the inspection requirements. The Qualifying Activity has the right to perform any of the inspections set forth in the standard where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Responsibility for Compliance

All items must meet all technical requirements of this standard. The inspection set forth in this standard shall become a part of the supplier's overall inspection system or quality program. The absence of any inspection requirements in the standard shall not relieve the supplier of the responsibility of assuring that all products comply with all requirements of the contract or purchase order. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the purchaser to acceptance of defective material.

4.3 Test Equipment and Inspection Facilities

Test and measuring equipment and inspection facilities of sufficient accuracy, quality and quantity to permit performance of the required inspection shall be established and maintained by the supplier. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with NCSL Z540.3 or equivalent standards.

4.4 Quality Assurance Compliance

The supplier's reliability assurance program for AS60491 sleeves and assembly procedures shall comply with the AS9100. Other established and industry recognized quality assurance standards that assure all products produced conform to the contract requirements are acceptable. However, if used, it is the responsibility of the supplier to provide evidence of compliance to AS9100. The qualifying activity authority reserves the right to monitor, measure, and validate compliance at their discretion.

4.5 Statistical Process Control

The supplier may implement and use statistical process control techniques in the manufacturing process. The statistical process control (SPC) program shall be developed and maintained in accordance with EIA-557. The SPC program shall be documented and maintained as part of the overall product assurance program.

4.6 Classification of Inspections

The inspections specified herein are classified as follows:

- a. Initial Qualification inspection (see 4.8).
- b. Retention of Qualification inspection (see 4.9).
- c. Quality Conformance Inspection (see 4.10).

4.7 Inspection Conditions

The conditions for the inspections are specified as applicable and all test data shall be compiled in accordance with SD-6.

4.8 Initial Qualification Inspection

Initial qualification inspection shall be in accordance with Tables 2 and 3. Sequential testing is not required except Group 1 and 2 shall be performed on all specimens prior to each Group 3 test. The qualifying activity shall perform or witness the tests specified in Table 2 and the supplier shall perform the tests specified in Table 3. All test laboratories require qualifying activity approval.

4.8.1 Qualification Inspection Procedures

A request for qualification shall be made to the qualifying activity (see 6.3) prior to initiating testing. Testing cannot begin until the supplier has received an authorization letter. The supplier is recommended to provide the qualifying activity a test plan based on the authorization letter to ensure the supplier and qualifying activity maintain communication and document changes as needed. The qualifying activity shall not approve a component that does not meet the requirements specified herein. The qualifying activity has the authority to impose specific specification test requirements to resolve test failures/discrepancies and to waive testing to verify specific product manufacturing changes or qualifications by similarity. Any change in the supplier's process control inspections, quality conformance inspections, or manufacturing control drawings (editorial changes are acceptable) without the express approval of the qualifying activity may result in loss of qualification for that product.

Table 2 - Qualifying activity test requirements

| Examination or Test | Requirement Paragraph | Test Paragraph | Specimens Type (see 4.8.4.1) |
|---|-----------------------|----------------|------------------------------|
| Group 1 | | | |
| Examination of Product | 3.1, 3.3, 3.4 | 5.1 | A |
| Marking Durability | 3.4.6 | 5.1.6 | E |
| Group 2 (Pre-performance tests) | | | |
| Sleeve Expansion and Removability/Open and Close | 3.5.1 | 5.2 | B, C, F |
| Dry Dielectric Voltage | 3.5.2 | 5.3.1 | B, C, F |
| Shielding Effectiveness | 3.5.3 | 5.4 | C |
| Group 3 - After Group 2 (Perform each test individually) | | | |
| Bend Flexibility | 3.5.4 | 5.5 | B, C |
| Cold Bend | 3.5.5 | 5.6 | B, C |
| Humidity | 3.5.6 | 5.7 | B, C |
| Life Cycle/Aging | 3.5.7 | 5.8 | B, C |
| Flammability | 3.5.8 | 5.9 | D |
| Scrape Abrasion | 3.5.9 | 5.10 | F |

Table 3 - Supplier test requirements

| Examination or Test | Requirement Paragraph | Test Paragraph | Specimens Type (see 4.8.4.1) |
|--|-----------------------|----------------|------------------------------|
| Group 1 | | | |
| Examination of Product | 3.1, 3.3, 3.4 | 5.1 | A |
| Marking Durability | 3.4.6 | 5.1.6 | E |
| Group 2 (Pre-performance tests) | | | |
| Removability/Open and Close <u>1/</u> | 3.5.1 | 5.2 | H |
| Dry Dielectric | 3.5.2 | 5.3.1 | H |
| Group 3 - After Group 2 (Sequence not required) | | | |
| Dynamic Cut-Through | 3.5.10 | 5.11 | G |
| Fiber Tensile Strength | 3.5.11 | 5.12 | H |
| Fluid Resistance | 3.5.12 | 5.13 | H |

4.8.2 Initial Qualification Test Report

The qualifying activity shall provide the supplier a data package of all tests performed in accordance with Table 2. The qualifying activity test method procedures shall be made available to the supplier upon request. The supplier shall provide a test report to the qualifying activity for the tests specified in Table 3. The test report shall be signed by the manufacturing authority responsible for ensuring compliance to the specification requirements. The supplier may combine the qualifying activity test data with the supplier's test data into one final test report. The final test report and/or data package shall remain on file with the supplier for a minimum period of six years and be available to the qualifying activity upon request. The supplier test report shall contain as a minimum the following information.

- a. The quantitative results for tests specified in Table 3 and the authorization letter.
- b. A tabulated comparison between the dimensions specified herein and each manufacturing control drawing for components not tested.
- c. Corrective Action Reports (as applicable).

4.8.3 Qualification by Similarity

The qualifying activity and the supplier may agree on other similarity test samples for a family of parts not specified herein provided the products and test requirements associated with the agreed upon similarity are specified herein. The qualifying activity may accept data generated under oversight of a User activity, provided the requirements are equal to or greater than the requirements specified herein.

4.8.4 Qualification Sample

For each component tested the supplier shall use the same materials, manufacturing procedures, and methods of inspection as would be used to provide the sleeve to a purchaser. For each detail specification the following specimens shall be tested and will qualify all part numbers listed on a detail specification (family of parts).

4.8.4.1 Specimen Preparation Types A thru J (see Tables 2 and 3 for application)

Each sleeve type specified by a detail specification shall be tested on a wire bundle containing one of the wire types specified for open wiring applications listed in Appendix A of AS50881. The specimen types are as follows:

- a. Unassembled sleeves - Specimens shall include each part number being qualified. The length shall be 5 feet.
- b. Sleeve without a shielded braid over shielded cable - Three specimens of 1/2 inch (13 mm) shall be tested. The sleeve shall be installed on a shielded wire bundle with no outer insulated jacket in accordance with the supplier assembly instruction by the test laboratory performing the tests. Each sleeve specimen shall be 24 inches long with 2 inches of cable extending out each end of the sleeve.
- c. Sleeve with shield braid on an unshielded cable - Three specimens of 1/2 inch (13 mm) shall be tested. The sleeve shall be installed on a cable with no outer insulated jacket or shield in accordance with the supplier assembly instruction by the test laboratory performing the tests. Each sleeve specimen shall be 24 inches long with 2 inches of cable extending out each end of the sleeve.
- d. Sleeve without shield braid on unshielded cable (flammability test) - Three specimens of 3/4 inch (19 mm) shall be tested. The sleeve shall be installed on a cable with no outer insulated jacket or shield in accordance with the supplier assembly instruction by the test laboratory performing the tests. Each sleeve specimen shall be 24 inches long with 2 inches of cable extending out each end of the sleeve.
- e. Sleeve without shield braid on unshielded cable (marking durability) - Three specimens of 3/4 inch (19 mm) shall be tested. The sleeve shall be installed on a stainless steel mandrel in accordance with the supplier assembly instruction by the test laboratory performing the tests. Each sleeve specimen shall be long enough to include all markings or tracer/stripe color.
- f. Sleeve without shield braid on unshielded cable (scrape abrasion) - Three specimens of 1/2 inch (13 mm) shall be tested. The sleeve shall be installed on a cable with no outer insulated jacket or shield in accordance with the supplier assembly instruction by the test laboratory performing the tests. Length of the specimen shall be 6 inches with the cable cut flush with sleeve.
- g. Sleeve without a shielded braid over shielded cable (cut-through test) - Three specimens of 1/2 inch (13 mm) shall be tested. The sleeve shall be installed on a shielded wire bundle with no outer insulated jacket in accordance with the supplier assembly instruction by the test laboratory performing the tests. Each sleeve specimen shall be 24 inches long with 2 inches of cable extending out each end of the sleeve.
- h. Fiber strands of each material type and size being qualified in a sleeve (fluid and QC tests).

4.9 Retention of Qualification Inspection

4.9.1 Retention of qualification inspection shall occur every 36 months after the initial qualification date. The Qualifying Activity may shift the reporting date to accommodate testing schedules, but no later than 18 months from the retention of qualification due date.

- a. Certification: If no production of the qualified products has occurred for the entire reporting period, the Supplier may provide a certification to the Qualifying Activity that no changes in the product materials, manufacturing processes, or site of production has occurred since the initial Qualification Inspection (see 4.8). Certification for more than one reporting period shall not be permitted. The Supplier shall contact the Qualifying Activity to determine the conditions of the Certification. The Supplier may be required to submit the Certification on a specified form provided by the Qualifying Activity.
- b. Component Production: If a qualified component has been produced in the retention period, the component or a component from that family initially qualified shall be submitted (see 4.8.4). Retention of Qualification consists of the tests specified in Table 2 for Initial Qualification and shall be performed or witnessed by the Qualifying Activity.

4.9.2 Retention of Qualification Sample

For each component tested the supplier shall use the same materials, manufacturing procedures, and methods of inspection as would be used to provide the component to a purchaser. A sample shall be the same as for initial qualification except as noted in 4.9.1.

4.9.3 Retention of Qualification Test Report

The qualifying activity shall provide the supplier a data package of all tests performed in accordance with Table 2. The qualifying activity test method procedures shall be made available to the supplier upon request. The supplier shall provide a test report to the qualifying activity for the tests specified in Table 4. The test report shall be signed by the manufacturing authority responsible for ensuring compliance to the specification requirements. The supplier may combine the qualifying activity test data with the supplier's test data into one final test report. The final test report and/or data package shall remain on file with the supplier for a minimum period of six years and be available to the qualifying activity upon request. The supplier test report shall contain as a minimum the following information.

- a. A summary of quantitative results for tests specified in Table 4 and the authorization letter.
- b. A tabulated comparison between the dimensions specified herein and each manufacturing control drawing for components qualified but not tested.
- c. Corrective Action Reports (as applicable).

4.10 Quality Conformance Inspection

Inspection of product for delivery shall consist of Group A inspections specified in Table 4. Additional Quality Conformance (QC) inspections may be required in the detail specification. A supplier's normal quality control and production tests may be used to fulfill Group A inspections, provided the tests are at least equal to the quality required by the Group A tests. Statistical process control in accordance with EIA-557 or equivalent may be used to demonstrate conformance in place of these inspections.

4.10.1 Lot Formation

A production batch compound shall consist of all compounds prepared in one mixing operation at one time, and using the same formulation for each complete lot. A lot shall have a control number and consist of sleeve type of one detail specification that has been made at the same plant under essentially the same conditions, and processed in a continuous operation from acceptable production compound batches that are available for inspection at one time.

4.10.2 Lot Inspection Sample

One sample from each 25 feet (7.62 m) of the lot shall be subjected to the Group A requirements or one sample from each continuous length over 25 feet when specified by contract or the detail specification. Material certifications for the sample shall be verified.

Table 4 - Group A, quality conformance inspections

| Examination or Test | Requirement Paragraph | Test Paragraph |
|---|-----------------------|----------------|
| Examination of Product | 3.1, 3.3, 3.4 | 5.1 |
| | | |
| Removability/Open and Close (one cycle) | 3.5.1 | 5.2 |
| | | |
| Sleeve and Shield Coverage | 3.4.4 | 5.1.4 |
| - Tubular Braid use PPI | 3.4.4.1 | 5.1.4.1 |
| - Woven Open-wrappable use over Overlap | 3.4.4.2 | 5.1.4.2 |

4.10.3 Failure Criteria

Unless otherwise specified in the detail specification, a lot is considered rejected if the test sample fails a Group A requirement or material certifications are not available. A rejected lot shall be scrapped, and the scrapped material cannot be reprocessed.

5. TEST METHODS

Unless otherwise specified test specimens shall be assembled in accordance with the supplier assembly instruction. Testing shall be conducted with a mandrel or wire bundle as defined by the types specimens defined in 4.8.4.1.

5.1 Examination of Product (see 3.1, 3.3, and 3.4)

- 5.1.1 Examine material certifications for compliance with material requirements in 3.3 and the detail specification (see 3.4.1).
- 5.1.2 Dimensions and angles shall be verified using calibrated tools with a minimum unit scale one digit greater than the maximum tolerance specified by the dimension being measured. Dimensions shall be performed in the center and each end of the specimen (see 3.4.2).
- 5.1.3 Weight shall be verified by cutting a 10 feet (3 m) length of the sleeve and accurately measuring the weight. The resultant measurements shall be converted to pounds per 1,000 feet (kg per km). Record weight and the calculated value per unit length as specified in the detail specification (see 3.4.3).
- 5.1.4 Sleeve and/or shield shall be laid flat and examined under 3X magnification. Using the braid coverage formula (see 3.4.4) the braid coverage shall be verified.

5.1.4.1 Picks Per Inch (PPI)

The number of intersections (crossing lines) of braided filaments in 1 inch of braided material. Select the mandrel size corresponding to the max expansion for the braid (see detail specification sheet) and slide the braided material to be measured onto the mandrel. Place the pick counter on the braided product to be measured (see Figure 3). Look into the lens of the pick counter and count the number of picks in the 1 inch window in the direction of the length of the braided product (perpendicular to the base of the mandrel) (see Figure 4).



Figure 3 - Pick counter

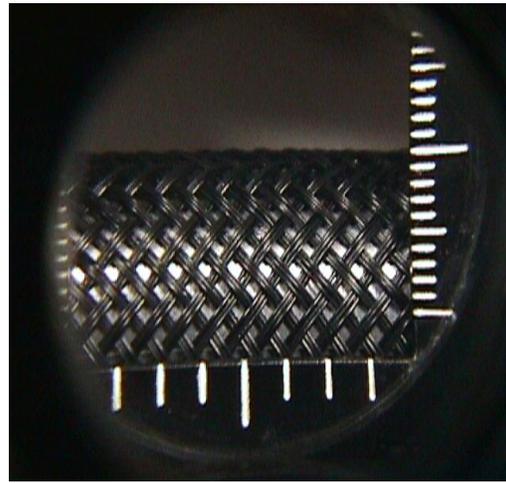


Figure 4 - Pick count

5.1.4.2 Degree Overlap Measurement for Self-Wrapping sleeves

An approximately 2 feet long sample is installed on a mandrel of the products nominal diameter. The overlap of the product upon itself is measured at both ends with a tape measure. The total product width is also in the same location. The percent overwrap is calculated for each end as well as the average percent overlap of both ends together.

$$\text{Degree overwrap} = [\text{overlap} / (\text{total width} - \text{overlap})] \times 360$$

5.1.5 Product Identification and marking shall be visually confirmed. Verified that the supplier's symbol is register or submitted for registration in accordance with AIR1351 (see 3.4.5).

5.1.6 Product Identification and marking durability shall be tested for in accordance with AS4373 Test Method 711 on the ½ inch (13 mm) diameter sleeve unless otherwise specified in the detail specification sheet (see 3.4.6).

5.1.7 Assembly Instructions shall be examined for clarity and simplicity (see 3.4.7).

5.1.7.1 Bundle configuration shall be ½ inch (13 mm) comprised of 20 gauge wires M22759/11 or 16.

5.1.7.2 Wrap-around sleeving should be installed per manufacturer's recommended installation instructions.

5.1.8 Workmanship shall be visually examined with a 3X magnification. Visually examine sleeve for strand fraying, holes or irregular areas in the weave (coating, strands, etc.) or braid separation from the sleeve.

5.2 Sleeve Expansion and Removability/Open and Close Test (see 3.5.1)

5.2.1 Expandable Sleeve

5.2.1.1 Expandable Sleeve Initial-Performance Test

Install the sleeve on to a Teflon coated mandrel with diameter equal to the designated cable in accordance with supplier assembly instruction (see 4.8.4). Expand the sleeve to its maximum diameter and collapse the sleeve against the mandrel in accordance with supplier assembly instruction. Repeat the cycle a total of 50 times. Examine the sleeve for strand breakage, damage or strand separation and shield separation (when required) from the sleeve. Install the expandable sleeve back on the mandrel in accordance with supplier assembly instruction.

5.2.1.2 Expandable Sleeve Post-Performance Test

Perform one cycle of the initial-performance test. Examine the sleeve for strand breakage, damage or strand separation and shield separation (when required) from the sleeve.

5.2.2 Wrap-Around Sleeve

5.2.2.1 Wrap-Around Sleeve Initial-Performance Test

Wrap the sleeve on to a Teflon coated mandrel with diameter equal to the designated cable in accordance with supplier assembly instruction (see 4.8.4). Completely open and remove the sleeve from the mandrel. Wrap the sleeve back on the mandrel in accordance with supplier assembly instruction. Repeat the cycle a total of 50 times. Verify that the self-wrapping sleeve still maintains the self-wrapping tension. Examine the leading edge of the sleeve for lifting of the sleeve along the leading edge. Examine the sleeve shield for strand breakage, damage or strand separation and shield separation (when required) from the sleeve. Wrap the sleeve back on the mandrel in accordance with supplier assembly instruction.

5.2.3 Wrap-Around Sleeve Post-Performance Test

Perform one cycle of the initial-performance test. Examine the sleeve shield for strand breakage, damage or strand separation and shield separation (when required) from the sleeve.

5.3 Dry Dielectric Voltage Test (3.5.2)

5.3.1 Dry Dielectric Test

The specimen (sleeve wrapped around a Teflon coated mandrel with diameter equal to the designated cable size (see 4.8.4.1)) shall be clamped firmly in a horizontal position to three contact plate jigs equal to that shown in Figure 5. Two jigs shall clamp the specimen 1 inch from each end and the third shall clamp the specimen in the center. The bottom contact plate shall be placed underneath the specimen and the upper contact plate shall be placed on top of the specimen directly over the bottom plate. Unless otherwise specified in the detail specification, a 1/4-pound weight shall be placed on the upper plate, directly over the specimen, to ensure contact with the surface area. If necessary, the specimen should be supported such that the specimen sits in a straight position. The dielectric voltage specified in the detail specification shall then be applied between the shield under the specimen insulation sleeve and the two contact plates on each jig. The voltage shall be gradually increased at a uniform rate from zero to the specified voltage in 1/2 minute, maintained at that voltage for 1 minute, and gradually reduced to zero in 1/2 minute.

5.3.2 Post Life Cycle Dry Dielectric Test

The specimen from the life cycle test shall be clamped firmly in a horizontal position, leaving the center of the bend portion of the cable accessible to a contact plate jig equal to that shown in Figure 5. The bottom contact plate shall be placed underneath the bundle and shall make contact with the center portion of the bend area. The upper contact plate shall be placed on top of the specimen, directly over the bottom plate. Unless otherwise specified in the detail specification a 1/4-pound weight shall be placed on the upper plate, directly over the specimen to insure contact with the sleeve. Both ends of the specimen shall be supported such that the specimen sits in a straight position. The voltage specified in the applicable detail specification shall then be applied between the shield under the specimen insulation sleeve and the contact plates of the jig. The voltage shall be gradually increased at a uniform rate from zero to the specified voltage in 1/2 minute, maintained at that voltage for 1 minute, and gradually reduced to zero in 1/2 minute.

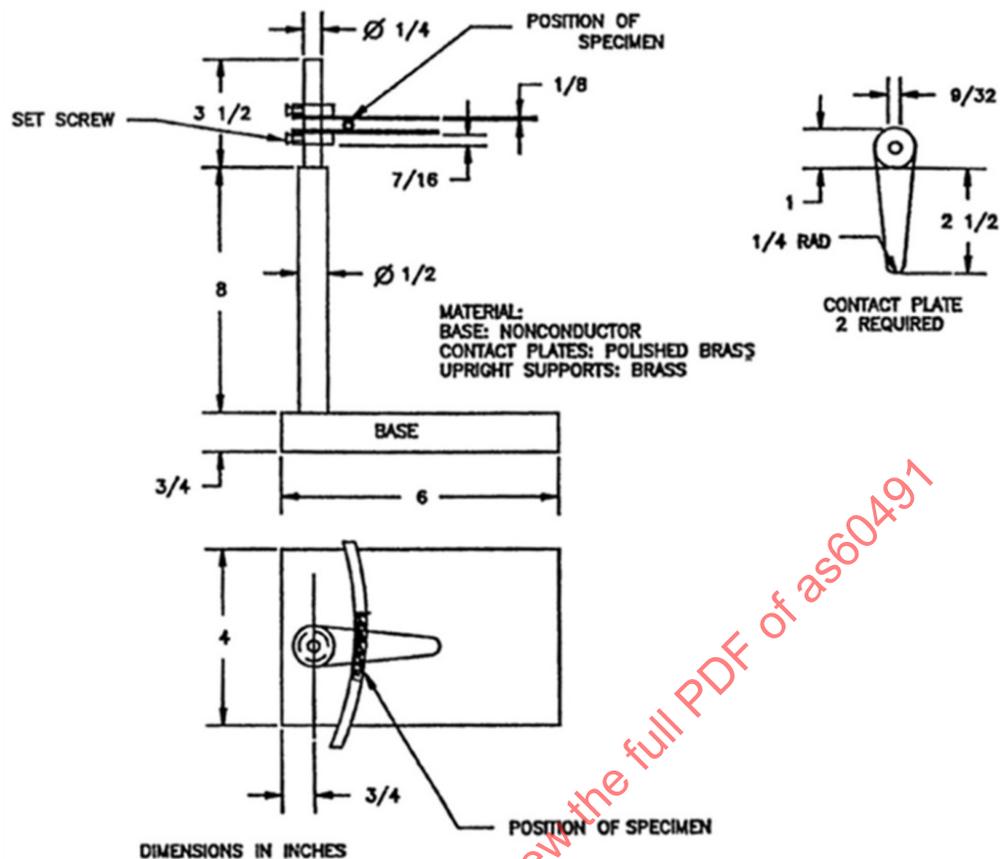


Figure 5 - Dry dielectric test fixture

5.4 Shielding Effectiveness (see 3.5.3)

Testing of the shielding effectiveness shall be defined in the detail specification.

5.5 Bend Flexibility Test (see 3.5.4)

The sleeve cable combination shall be rotated in accordance with AS4373 Test Method 712 around a mandrel six times the diameter of the cable on which the sleeve is wrapped. Secure only the cable to the mandrel and weight. A weight shall be used that will ensure the outer sleeve is in full contact with mandrel surface. The choice of weight shall not significantly compress the sleeve on the mandrel. For larger cable sizes, a manual wrap without the weight may be used, if the weight is too large to secure to the cable. Caution shall be taken not to compress the sleeve on the mandrel. While the wrapped position visually examine the sleeve for wrinkles or lifting of the leading edge (wrap-around sleeve). Examine the sleeve shield for strand breakage and shield separation from the sleeve.

5.6 Low Temp Flexibility (see 3.5.5)

The specimen sleeve and a steel mandrel of the size specified in Table 5 shall be conditioned in a cold chamber for 4 hours at the temperature specified in the applicable specification sheet. After completion of the conditioning period and while still in the cold chamber at the specified temperature, the specimen shall be bent around the mandrel through not less than 360 degrees. Unless otherwise specified in the specification sheet, the time to complete the bend shall be 10 seconds \pm 2 seconds. Visually examine the sleeving for cracks.

Table 5 - Mandrel Sizes for Bend Tests

| Nominal Sleeve ID (Maximum, After Unrestricted Shrinkage) inches (mm) | Mandrel Diameter ^{1/} inches (mm) |
|---|---|
| 0.023 to 0.125 (0.60 - 3.18) | 0.313 ± 0.002 (7.94 ± 0.05) |
| 0.126 to 0.250 (>3.18 - 6.35) | 0.375 ± 0.003 (9.53 ± 0.08) |
| 0.251 to 1.000 (>6.35 - 25.40) | 0.438 ± 0.004 (11.11 ± 0.10) |
| 1.001 to 2.000 (>25.40 - 50.80) | 0.875 ± 0.005 (22.23 ± 0.13) |
| 2.001 to 3.000 (>50.80 - 76.20) | 1.000 ± 0.005 (25.40 ± 0.13) |
| 3.001 to 4.000 (>76.20 - 101.60) | 1.125 ± 0.005 (28.58 ± 0.13) |

^{1/} Unless otherwise specified in the specification sheet.

5.7 Humidity Test (see 3.5.6)

The sleeve shall be tested in accordance with SAE J2192 Section 7.4.

5.8 Life Cycle/Aging (see 3.5.7)

The sleeve cable combination shall be tested in accordance with AS4373 Test Method 807 on a mandrel size six times the cable size at the maximum rated temperature. Attached a sufficient weight to each end of the cable (not the sleeve) to insure the sleeve is in contact with 180 degrees of mandrel surface. Remove from chamber and visually examine the sleeve cable combination for cracking and splitting. For sleeve types without a shield or an attached shield, perform the bend flexibility test follow by the post life cycle dry dielectric test follow by the sleeve tensile strength test. For sleeve types with an unattached or attached shield, perform the bend flexibility test follow by the post life cycle dry dielectric test, the shield resistance test (if applicable) follow by sleeve the tensile strength test.

5.9 Flammability (see 3.5.8)

The specimen shall be tested in accordance with Appendix F Part I (b)(1), (2), (3) and (4) of 14 CFR Part 25 (12 second vertical burn). Record time duration and flame travel after removal of the flame, and the time to extinguish any flaming drippings.

5.10 Abrasion (see 3.5.9)

5.10.1 Temperature - Ambient Temperature

5.10.2 Test Sample

The ½ inch (13 mm) diameter sleeve cable or sleeve over a mandrel combination of at least 15 inches (381 mm) and shall be restrained by suitable clamps over the assembly.

5.10.3 Abrasive Force

A total weight of 2.5 pounds (1.1 kg) shall be applied to the sleeve cable combination or sleeve over a mandrel combination under test.

5.10.4 Rate of Application

The abrasive force shall be applied at a rate of 200 cycles per minute ± 10 cycles per minute (cpm) through a total stroke of 3 inches (76 mm), 1.5 inches (38 mm) per side.