SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS5382

Issued 2003-07

Aerospace Cable, Fiber Optic

1. SCOPE:

1.1 Purpose:

This standard covers jacketed single-fiber multimode and single-mode fiber optic cables for aerospace usage.

1.2 Classification:

The fiber optic cables covered by this standard shall be as described in the applicable specification sheets and shall be identified by the specification sheet number and title.

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.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS4373	Test Methods for Insulated Electrical Wire
AS16781	Fiber Optics Test Methods and Instrumentation

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-C-12000	Cable, Cord, and Wire, Electric; Packaging of
MIL-HDBK-454	General Guidelines for Electronic Equipment
MIL-PRF-85045	Cables, Fiber Optic, General Specification for
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-790	Standard Practice for Established Reliability and High Reliability Qualified Products List (QPL) Systems for Electrical, Electronic, and Fiber Optic Parts Specifications
MIL-STD-810	Environmental Test Methods and Engineering Guidelines
MIL-STD-2223	Test Methods for Insulated Electrical Wire

2.1.3 ASTM Publications: Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

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

2.1.4 ANSI Publications: Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ANSI/NCSL Z540-1	Laboratories, Calibration and Measuring and Test Equipment

2.1.5 Electronic Industries Alliance/Telecommunications Industry Association: Available from EIA-TIA, 2500 Wilson Boulevard, Arlington, VA 22201-3834.

EIA/TIA-455	Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components
EIA/TIA-455-3	FOTP-3 Procedure to Measure Temperature Cycling Effects on Optical Fibers, Optical Cable, and Other Passive Fiber Optic Components
TIA/EIA-455-11	FOTP-11 Vibration Test Procedure for Fiber Optic Components and Cables
TIA/EIA-455-13	FOTP-13 Visual and Mechanical Inspection of Fiber Optic Components, Devices, and Assemblies
EIA/TIA-455-14	FOTP-14 Fiber Optic Shock Tests (Specified Pulse)
TIA/EIA-455-20	FOTP-20 Measurement of Change in Optical Transmittance
TIA/EIA-455-25	FOTP-25 Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies
TIA/EIA-455-31	FOTP-31 Proof Testing Optical Fibers by Tension
EIA-455-33	FOTP-33 Fiber Optic Cable Tensile Loading and Bending Test
TIA/EIA-455-39	FOTP-39 Optical Fiber Cable Water Wicking Test
TIA/EIA-455-41	FOTP-41 Compressive Loading Resistance of Fiber Optic Cables
TIA/EIA-455-44	FOTP-44 Refractive Index Profile, Refracted Ray Method
EIA/TIA-455-45	FOTP-45 Method for Measuring Microscopic Fiber Geometry of Optical Waveguide Fibers
EIA/TIA-455-46	FOTP-46 Spectral Attenuation Measurement for Long-Length, Graded-Index Optical Fibers
EIA/TIA-455-47	FOTP-47 Output Far-Field Radiation Pattern Measurement
EIA/TIA-455-49	FOTP-49 Procedure for Measuring Gamma Irradiation Effects on Optical Fiber and Optical Cables

2.1.5 (Continued):

TIA/EIA-455-50	FOTP-50 Light Launch Conditions of Long-Length Graded-Index Optical Fiber Spectral Attenuation Measurements
EIA/TIA-455-51	FOTP-51 Pulse Distortion Measurement of Multimode Glass Optical Fiber Information Transmission Capacity
TIA/EIA-455-56	FOTP-56 Test Method for Evaluating Fungus Resistance of Optical Fiber and Cable
EIA/TIA-455-59	FOTP-59 Measurement of Fiber Point Discontinuities Using an OTDR
EIA/TIA-455-71	FOTP-71 Procedure to Measure Temperature-Shock Effects on Fiber Optic Components
TIA/EIA-455-76	FOTP-76 Method for Measuring Dynamic Fatigue of Optical Fibers by Tension
EIA/TIA-455-78	FOTP-78 Spectral Attenuation Cutback Measurement for Single-Mode Optical Fibers
TIA/EIA-455-80	FOTP-80 Measurement of Cutoff Wavelength of Uncabled Single-Mode Fiber by Transmitted Power
TIA/EIA-455-84	FOTP-84 Jacket Self-Adhesion (Blocking) Test for Fiber Optic Cable
EIA-455-162	FOTP-162 Fiber Optic Cable Temperature-Humidity Cycling
EIA/TIA-455-167	FOTP-167 Mode Field Diameter Measurement, Variable Aperture Method in the Far Field
EIA/TIA-455-169	FOTP-169 Chromatic Dispersion Measurement of Single-Mode Optical Fibers by the Phase-Shift Method
TIA/EIA-455-176	FOTP-176 Method for Measuring Optical Fiber Cross-Sectional Geometry by Automated Grey-Scale Analysis
TIA/EIA-455-178	FOTP-178 Measurements of Strip Force for Mechanically Removing Coating from Optical Fibers
EIA-557	Statistical Process Control Systems

2.2 Definitions:

ACCEPTANCE ANGLE: Half the vertex angle of that cone within which optical power may be coupled into an optical fiber.

ATTENUATION: Diminution of optical power (loss of light). Expressed in dB or (for optical fiber) in dB/km.

BANDWIDTH (FIBER BANDWIDTH): Range of signal frequencies carried on an optical fiber with a defined maximum signal distortion. For multimode fiber, fiber bandwidth is limited by signal distortion and is expressed as a product of signal bandwidth and propagation distance (MHz-km).

BOUND MODE: In an optical fiber, a mode whose field decays monotonically in the transverse direction everywhere external to the core, and which does not lose power to radiation. Bound modes correspond to guided rays in the terminology of geometric optics.

BUFFER: A typically polymeric coating that is used to protect an optical fiber from physical damage, moisture or chemicals, or to provide mechanical isolation. (See also: Fiber Optic Cable, Loose Tube Type and Tight Buffer Type)

a. PRIMARY BUFFER: The buffer coating applied by the fiber manufacturer during the fiber drawing operation. Sometimes referred to simply as “fiber coating” or “primary coating.”

b. SECONDARY BUFFER: Any number of coatings applied over the primary buffer. Secondary buffers may be applied by the fiber manufacturer in an operation secondary to the draw process or by a cable manufacturer. A secondary buffer may also be known as “upjacketing.”

CLADDING: The optical material surrounding the core of an optical fiber. Cladding may be either glass or polymeric, but must always be a material having an index of refraction lower than that of the core material.

CORE: The central region of an optical fiber through which light is transmitted. The core must always be a material having an index of refraction higher than the surrounding cladding material.

CUTOFF WAVELENGTH: For a single-mode fiber under specified conditions, the wavelength at which the fiber’s second order mode is attenuated a specified amount. At wavelengths greater than the cutoff wavelength, a fiber is said to transmit single-mode.

2.2 (Continued):

DISPERSION: A phenomenon due to a wavelength-dependent propagation velocity that results in signal distortion and pulse broadening. In optical fibers, several dispersion effects are present. Material (or chromatic) dispersion is that due to the constituent materials forming the fiber. Waveguide dispersion is due to the dependence of the group and phase velocities on the numerical aperture, core diameter, and wavelength. Modal dispersion or distortion, important only in multimode fibers, results from the variation in path lengths for the different modes of the fiber. For single-mode optical fibers, material and waveguide dispersion are the dominant causes of dispersion.

FAR-FIELD REGION: That region, far from a source or radiating aperture, where the diffraction pattern is essentially the same as that observed at an infinite distance.

FIBER OPTIC CABLE: One or more optical fibers contained in a common jacket, usually with an integral strength member.

a. LOOSE TUBE TYPE: A cable design in which the fiber(s) is placed into a cavity which is much larger than the fiber with its primary buffer. This is intended to give the fiber mechanical independence in applications with high relative motions and/or large temperature swings which could cause differential motion or stress inside conventional tight buffer cable structures.

b. TIGHT BUFFER TYPE: A cable design in which the secondary buffer(s) are applied in a manner resulting in firm contact between the primary buffer and subsequent protective layers.

FIBER OPTIC CABLE ASSEMBLY: One or more fiber optic cables terminated with two or more optical terminations (usually connectors) and so arranged that it can be handled as one unit.

HERMETIC COATING: A thin coating (typically several hundred angstroms of amorphous carbon) applied directly to the fiber surface before the application of the primary buffer, for the purpose of sealing the fiber surface against hydrogen ingress and improving the fiber's fatigue resistance.

INDEX OF REFRACTION (REFRACTIVE INDEX): The index of refraction of a medium, denoted by n, is the ratio of the velocity of light in vacuum to the velocity of light in that medium.

MODE: In any cavity or transmission line, one of those electromagnetic field distributions that satisfies Maxwell's equations and the boundary conditions or that can be designated by a radiation pattern in a plane transverse to the direction of travel. Usually understood to be a single optical path or ray of light.

2.2 (Continued):

MODE FIELD DIAMETER: The measure of the width of the guided optical power's intensity distribution in a single-mode fiber. Usually specified instead of fiber core diameter for single-mode fiber.

NEAR FIELD REGION: That region, near a source or radiating aperture, where the diffraction pattern differs significantly from that observed at an infinite distance.

NUMERICAL APERTURE (NA): A measure of the light gathering ability of a fiber. NA is commonly defined as the sine of the acceptance angle (θ_a) of an optical fiber multiplied by the refractive index of the material in contact with the entrance face of the fiber. For a step index fiber in air, NA = $\sqrt{n_1^2 \quad n_2^2}$ where n_1 and n_2 are the refractive indices of the core and cladding materials, respectively. (See also: Acceptance Angle)

OPTICAL FIBER: A filament, made of dielectric materials, that guides light.

a. GRADED INDEX OPTICAL FIBER: An optical fiber in which the refractive index of the core varies with radial distance from the fiber axis and is lowest near the cladding.

b. STEP INDEX OPTICAL FIBER: An optical fiber characterized by a uniform refractive index in the core and a sharp decrease in refractive index at the core-cladding interface.

c. SINGLE-MODE OPTICAL FIBER: An optical fiber in which only the lowest order bound mode can propagate at the wavelength of interest. (See also: Bound Mode)

d. MULTIMODE OPTICAL FIBER: An optical fiber which will allow more than one bound mode to propagate. (See also: Bound Mode)

OPTICAL TIME DOMAIN REFLECTOMETER (OTDR): A measurement device used to characterize a fiber, wherein an optical pulse is transmitted through the fiber and the resulting light scattered and reflected back to the input is measured as a function of time. Useful in identifying defects and other localized losses.

PREFORM: A glass structure (usually a rod) from which an optical fiber may be drawn.

QUALIFICATION INSPECTION: Qualification Inspection is a process that demonstrates that a component is capable of fully conforming to all the requirements defined in a standard. Qualification Inspection includes definition of the measurements, tests, analysis, and associated data which provides consistent rationale for acceptance of a particular supplier's design as meeting the standard requirements typically prior to acquisition by the Purchaser.

2.2 (Continued):

QUALIFIED PRODUCTS LIST: A Qualified Products List is a list of suppliers whose products have been evaluated to a defined process and who are authorized to provide those products to a purchaser upon request. When a Qualified Products List is specified, only approved suppliers are authorized to provide products under the part number defined in the component standard. A Qualified Products List is established by a Qualifying Activity.

QUALIFYING ACTIVITY: A Qualifying Activity is a function established by a Purchaser or group of Purchasers that has a defined process used to consistently evaluate all suppliers' products in accordance with the component standard.

QUALITY CONFORMANCE INSPECTION: Quality Conformance Inspection is a process which includes measurements, non-destructive tests, analysis, and associated data that will provide verification that a particular individual component continually conforms to the requirements defined in the standard.

PURCHASER: A purchaser is an activity that can issue a purchase order.

REFRACTION: The bending of a beam of light in transmission through an interface between two media with dissimilar indices of refraction. (See also: Index of Refraction)

SUPPLIER: A Supplier is a manufacturer which has design and production control of the processes used to produce a component.

3. REQUIREMENTS:

3.1 Specification Sheets:

Individual cable requirements shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between the requirements of this standard and the specification sheet, the latter shall govern.

3.2 Physical Characteristics:

3.2.1 Construction Description: The optical fiber and cable layer diameters and material makeup shall be as specified in the applicable specification sheets. Mode field diameter shall be specified in lieu of core diameter for single-mode fibers.

3.2.2 Operational Mode: The principal mode of operation shall be defined as either multimode or single-mode as specified in the applicable specification sheets.

3.2.3 Temperature Rating: The maximum and minimum operating temperatures in degrees Celsius (°C) are noted in the applicable specification sheets.

3.2.4 Storage Temperature Rating: The maximum and minimum storage temperatures in degrees Celsius (°C) are noted in the applicable specification sheets.

3.2.5 Jacket Color: The finished color of the cable jacket shall be determined by the fiber size and mode of operation unless otherwise defined by the specification sheets. The following colors in Table 1 have been defined for fiber optic cables. If cable color does not correspond to this table, the applicable specification sheet shall state “non-standard color”.

TABLE 1 - Color Coding Scheme for Fiber Optic Cable

Fiber Type	Fiber Size (m)	Jacket Color
Multimode	50/125	Orange
Multimode	62.5/125	Slate
Multimode	85/125	Blue
Multimode	100/140	Green
Multimode	200/240	Purple
Single-mode	All	Yellow

3.2.6 Outer Jacket: The cable jacket shall be as specified in the applicable specification sheets. The diameter of the outer jacket shall be as specified in the applicable specification sheets when tested in accordance with 5.2.3.

3.2.7 Cable Weight: When tested in accordance with 5.2.4, the weight shall be as specified in the applicable specification sheets.

3.2.8 Concentricity of Buffered Fiber: The buffer design shall be as specified in the applicable specification sheets. When tested in accordance with 5.3.4, the concentricity shall be as specified on the applicable specification sheets.

3.3 Optical Fiber Requirements:

3.3.1 Attenuation: The attenuation of the fiber prior to cabling or application of other stresses shall be tested in accordance with 5.3.1. The maximum attenuation shall be as specified in the applicable specification sheets. Optical loss shall be given in decibels (dB) per kilometer (km).

3.3.2 Change in Optical Transmittance: The maximum acceptable change in attenuation from the baseline measurement, per unit length, during or after environmental, mechanical or thermal tests shall be as specified in the applicable specification sheets.

3.3.3 Attenuation Uniformity: When tested in accordance with 5.3.3, the fluctuations along the length of the cable shall be as specified in the applicable specification sheet.

3.3.4 Fiber Diameter, Core Offset and Concentricity: When tested in accordance with 5.3.4, the fiber shall meet the dimensional requirements of the applicable specification sheet.

3.3.5 Fiber Tensile Proof Test: When tested in accordance with 5.3.5, the fiber shall meet the requirements of the applicable specification sheet.

3.3.6 Mode Field Diameter: (Single-Mode Only) When tested in accordance with 5.3.6, the fiber mode field diameter shall meet the requirements of the applicable specification sheet.

3.3.7 Cut Off Wavelength: (Single-Mode Only) When tested in accordance with 5.3.7, the fiber cut off wavelength shall meet the requirements of the applicable specification sheet.

3.3.8 Dynamic Fatigue: When specified by the applicable specification sheet, the dynamic fatigue of the optical fiber shall be tested in accordance with 5.3.8. The typical N value shall be as specified.

3.3.9 Chromatic Dispersion: (Single-Mode Only) When tested in accordance with 5.3.9, the chromatic dispersion of the fiber shall meet the requirements of the applicable specification sheet.

3.3.10 Numerical Aperture: When tested in accordance with 5.3.10, the numerical aperture of the fiber shall meet the requirements of the applicable specification sheet.

3.3.11 Radiation Induced Attenuation: When tested in accordance with 5.3.11, the fiber shall meet the minimum optical transmittance requirements of the applicable specification sheet at the specified radiation levels. Radiation testing shall be performed on each individual preform.

3.3.12 Bandwidth: (Multimode Only). The functional bandwidth of multimode optical cable shall be as specified in the applicable specification sheet when tested in accordance with 5.3.12.

3.4 Environmental Requirements:

3.4.1 Fluid Immersion: When tested in accordance with 5.4.1, and with the fluids listed in the applicable specification sheet, finished cable shall have a maximum diameter increase of 10%, shall retain a minimum of 50% of its original jacket elongation and tensile strength, and be free of defects in a visual examination at ten-power magnification. Three cable specimens shall be tested in each fluid and failure of any specimen to meet any of the three requirements shall constitute failure.

3.4.2 Freezing Water Immersion: When tested in accordance with 5.4.2, the cable shall meet the change in optical transmittance requirements of 3.3.2 during and after the test.

3.4.3 Humidity Resistance: When tested in accordance with 5.4.3, finished cable shall have a maximum diameter increase of 10%, shall be free of visual defects and meet the change in optical transmittance requirements of 3.3.2 during and after the test.

3.4.4 Wicking: When tested in accordance with 5.4.4, water penetration shall not exceed the requirements of the applicable specification sheets.

3.4.5 Fungus Resistance: When specified by the applicable specification sheet, cables and materials used in the construction of cables shall be fungus inert as specified in MIL-HDBK-454, Guideline 4. Materials not identified as fungus inert as specified in MIL-HDBK-454, Guideline 4 shall be tested in accordance with 5.4.5.

3.4.6 Outgassing: When tested in accordance with 5.4.6, the cable shall conform to the requirements of the applicable specification sheet.

3.4.7 Vibration: When tested in accordance with 5.4.7, the cable shall meet the minimum optical transmittance requirements of the applicable specification sheet at the specified vibration levels.

3.4.8 Shock: When tested in accordance with 5.4.8, the cable shall meet the minimum optical transmittance requirements of the applicable specification sheet at the specified shock levels.

3.4.9 Jacket Self-Adhesion or Blocking: When tested in accordance with 5.4.9, a post-test visual inspection shall reveal no areas of localized adhesion between contacting cable surfaces, or between the cable and the storage spool.

3.5 Mechanical Requirements:

3.5.1 Cold Bend: When specified in the applicable specification sheet and when tested in accordance with 5.5.1, the cable specimens shall exhibit no cracking of jacket insulation and the change in optical transmittance shall not exceed the value in 3.3.2 after the test.

3.5.2 Cyclic Flex Life: When specified on the applicable specification sheet, and when tested in accordance with 5.5.2, the change in the optical transmittance of the cable specimens shall not exceed the values specified in 3.3.2 during and after the test. There shall be no surface softening and no surface damage, cracking, splitting or crazing after 2000 cycles at the test temperatures specified in the applicable specification sheet.

3.5.3 Impact Resistance: When specified in the applicable specification sheet, and when tested in accordance with 5.5.3, the cable specimens shall exhibit no component breakage and change in optical transmittance shall not exceed the requirements of 3.3.2 during and after the test.

3.5.4 Crush Resistance: When specified in the applicable specification sheet, and when tested in accordance with 5.5.4, the change in optical transmittance of the cable specimens shall not exceed the requirements of 3.3.2 during and after the test, and there shall be no component breakage.

3.5.5 Corner Bend: When tested in accordance with 5.5.5 and the requirements of the applicable specification sheet, the cable specimens shall exhibit no visual jacket damage and the change in optical transmittance shall not exceed the requirements of 3.3.2 during and after the test.

3.5.6 Tensile Load and Bending: When tested in accordance with 5.5.6 and the requirements of the applicable specification sheet, the cable specimens shall exhibit no component breakage, visual jacket damage and the change in optical transmittance shall not exceed the requirements of 3.3.2 during and after the test.

3.5.7 Jacket Material Tensile Strength and Elongation: When tested in accordance with 5.5.7, the jacket material shall meet the requirements of the applicable specification sheet.

3.5.8 Durability of Manufacturer's Identification: When tested in accordance with 5.5.8 and the requirements of the applicable specification sheet, the identification mark shall remain legible.

3.5.9 Cable Strippability: When specified, cable strippability shall be tested in accordance with 5.5.9 After stripping, the optical fiber shall be free of scratches, damage or defects.

3.6 Thermal Requirements:

3.6.1 Flammability: When specified on the applicable specification sheet and when tested in accordance with 5.6.1, the cable shall conform to the requirements of the applicable specification sheet.

3.6.2 Thermal Shock: When tested in accordance with 5.6.2, and the requirements of the applicable specification sheet, the cable shall conform to the requirements of the applicable specification sheet. The change in optical transmittance shall not exceed the requirements of 3.3.2 after the test.

3.6.3 Property Retention after Thermal Aging: When tested in accordance with 5.6.3 at the temperatures and duration listed on the applicable specification sheet, the cable shall conform to the requirements of the applicable specification sheet.

3.6.4 Storage Life: When tested in accordance with 5.6.4 and the requirements of the applicable specification sheet, the cable shall conform to the requirements of the applicable specification sheet. The change in optical transmittance shall not exceed the requirements of 3.3.2 after the test.

3.6.5 Temperature Cycling: When tested in accordance with 5.6.5 and the requirements of the applicable specification sheet, the cable shall conform to the requirements of the applicable specification sheet. This test shall be performed on specimens loosely coiled and specimens wrapped tightly around a mandrel as specified by the applicable specification sheet. The change in optical transmittance shall not exceed the requirements of 3.3.2 at the low and high temperatures during and after the tests.

3.6.6 Temperature Cycling in Vacuum: When required by the applicable specification sheet and when tested in accordance with 5.6.6, the cable shall meet the minimum optical transmittance requirements of the applicable specification sheet during and after temperature cycling in a vacuum. This test shall be performed on specimens of loosely coiled cable.

3.6.7 Cable Jacket Shrinkage: When specified, jacket shrinkage shall be tested in accordance with 5.6.7. The recorded shrinkage of the cable jacket shall not exceed the requirement of the applicable specification sheet.

3.7 Identification Marking:

Except as otherwise specified in the procurement contract, the finished cable shall be identified by a marking applied to the outer surface of the cable or visible through the outer surface. The identification marking shall consist of the following information, at intervals of 50 to 100 cm (approximately 20 to 40 inches), as measured from the beginning of one complete marking to the beginning of the succeeding complete marking.

a. Complete Standard Number (e.g., AS5382/1)
b. Manufacturer's CAGE code
c. The words " AEROSPACE CABLE, FIBER OPTIC"
d. Lot Identification

The identification marking shall be complete and legible and shall meet the durability requirements specified in 3.5.8. The vertical axis of the printed characters may be either crosswise or lengthwise of the cable.

3.8 Workmanship:

All details of workmanship shall be in accordance with high quality aerospace manufacturing practices. The jacket shall be free of foreign materials and irregularities such as cracks, splits, and bubbles. Color shall be uniform (free of mottling and streaking).

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The supplier 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 supplier may use any facilities suitable for the performance of the inspection requirements specified herein. The purchaser and the qualifying activity reserve the right to perform any of the inspections set forth in the standard where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for Compliance: All items must meet all the technical requirements of the product standard. The inspections 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. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the purchaser to accept defective material.

4.1.2 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 ANSI/NCSL Z540-1 or equivalent standards.

4.1.3 Product Assurance Program: A product assurance program shall be established and maintained in accordance with MIL-STD-790 or equivalent. Evidence of such compliance shall be verified by the qualifying activity of this standard as a prerequisite for qualification and continued qualification.

4.1.4 Statistical Process Control: The supplier shall implement and use statistical process control techniques in the manufacturing process when specified by the applicable specification sheet. 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 as specified by MIL-STD-790.

4.2 Classification of Inspection:

The inspections specified herein are classified as follows:

a. Materials Inspection (see 4.3)
b. Qualification inspection (see 4.4)
c. Periodic Qualification Inspection (see 4.5)
d. Quality Conformance Inspections (see 4.6)

4.2.1 Inspection Conditions: All inspections shall be performed in accordance with the test conditions specified in applicable paragraphs. When the cable construction utilizes spliced fibers, test samples shall be selected to include the fiber splices.

4.3 Materials Inspection:

Materials inspection shall consist of certification, supported by verifying data, that materials used in fabricating the delivered cable are in accordance with the requirements of 3.1.

4.4 Qualification Inspection:

The supplier shall develop initial qualification inspection data, which consists of all the applicable examination and tests, performed in the group sequences, as specified in Table 2.

4.4.1 Qualification Samples: For each product part number to be tested, the number and length of samples subjected to each test shall be as specified in Table 2. The supplier shall, for each sample, use the same ingredients, manufacturing procedures, and methods of inspection as would be used to provide the product to a purchaser's contract.

4.4.1.1 Qualification inspection shall be performed on sample units produced with equipment and procedures normally used in production. Qualification samples shall be from a single production run for each standard type submitted.

4.4.1.2 Inspection Routine: The sample shall be subjected to the qualification inspection specified in Table 2 in the order shown. All sample units shall be subjected to the inspection of Group I and II. Specimens shall be cut from each sample unit in lengths at least as long as specified in Table 2. Test specimens from each sample unit shall be subjected to the tests of Group III through Group V, inclusive, of Table 2; however, each test specimen shall be subjected to only one group of tests in addition to Groups I and II. Test specimens for Group VI shall be cut from undamaged test specimens from Groups III, IV or V. Optical tests shall be performed on the sample when required in Section 3 as specified by the individual test in Section 5.

4.5 Periodic Qualification Inspection:

Periodic Qualification Inspection shall consist of the inspections specified in Table 3, and the submittal conditions established by the Qualifying Activity (see 7.5). These tests shall be conducted in the order shown. Periodic Qualification Inspection shall be made on sample units selected from production units which have passed groups A and B Quality Conformance Inspections (see 4.6).

4.5.1 Periodic Qualification Samples: Sample units shall be selected from those types covered by a single specification sheet in accordance with Table 4, 12 months after the date of notification of qualification and every twelve months thereafter, except when the total production in a 12 month period is less than two units of product (2 km) inspection need not be made until either production is at least 2 units of product or a total of 36 months has elapsed since the inspection was performed in which case only one sample unit shall be tested.

TABLE 2 - Qualification Inspection

Inspection	Requirement Paragraph	Test Paragraph	Specimen Quantity and length (1)(2)
Group I			
Visual and mechanical	3.2, 3.4, 3.5, 3.6, 3.7, 3.8	5.1, 5.2	3 units, 400 m each (3)
Group II			
Attenuation	3.3.1	5.3.1	3 units, 400 m each (4)
Bandwidth	3.3.12	5.3.12	3 units, 400 m each (4)
Numerical aperture	3.3.10	5.3.10	3 units, 400 m each (4)
Group III			
Temperature cycling	3.6.5	5.6.5	10 units, 10 m each (5)(6)
Humidity Resistance	3.4.3	5.4.3	10 units, 10 m each (5)(6)
Storage life	3.6.4	5.6.4	2 units, 400 m each (on reels)
Cold bend	3.5.1	5.5.1	3 units, 10 m each (7)
Cyclic flexing	3.5.2	5.5.2	6 units, 5 m each (2 each from 3 reels)
Crush	3.5.4	5.5.4	3 units, 5 m each (5)(6)
Impact	3.5.3	5.5.3	3 units, 5 m each (5)(6)
Property retention after thermal aging	3.6.3	5.6.3	10 units, 10 m each (5)(6)
Temperature cycling with mandrel wraps	3.6.5	5.6.5	10 units, 10 m each (5)(6)
Freezing water immersion (ice crush)	3.4.2	5.4.2	4 units, 10 m each(5)(6) (1 each from 2 cables)
Fungus	3.4.5	5.4.5	2 units, 2 m each (1 each from 2 reels)
Cable strippability	3.5.9	5.5.9	6 units, 1 m each (2 each from 3 reels)
Flammability/flame extinguishing	3.6.1	5.6.1	3 units, 6 m each (7) (1 each from 3 reels)
Tensile load & bending	3.5.6	5.5.6	10 units, 10 m each (5)(6)
Group IV			
Thermal shock	3.6.2	5.6.2	10 units, 10 m each (5)(6)
Fluid immersion	3.4.1	5.4.1	2 units (for each fluid required), 2m each (7)
Group V			
Jacket self-adhesion or blocking	3.4.9	5.4.9	2 units, 30 m each (8) (1 each from 2 cables)
Corner bend	3.5.5	5.5.5	2 units, 5 m each (5)(6)
Group VI			
Cable jacket material tensile strength & elongation	3.5.7	5.5.7	5 units
Cable shrinkage			
Durability of identification	3.6.7	5.6.7	3 units, 2 m each (7)
Wicking	3.5.8	5.5.8	3 units, 2 m each (7)
	3.4.4	5.4.4	2 units, 2 m each (7)

TABLE 2 - Qualification Inspection (Continued)

NOTES:

(1) Tolerance on 400 m lengths is plus or minus 2 percent provided results are normalized to 400 m.

(2) Tolerance on shorter lengths is plus or minus 5 percent.

(3) The visual and mechanical inspection shall only be conducted on a 1 m section of each sample.

(4) The same samples used in the visual and mechanical inspection shall be used.

(5) Specimens shall be cut at random from the entire length of the reel.

(6) Half of the specimens shall be cut from the two samples used in the storage temperature test.

(7) A specimen cut from two of the samples used in the storage temperature test.

(8) The same samples as used in the storage temperature test shall be used.

TABLE 3 - Periodic Qualification Inspection

Inspection	Requirement Paragraph	Test Paragraph
GROUP I		
Temperature cycling	3.6.5	5.6.5
GROUP II		
Humidity resistance	3.4.3	5.4.3
Storage temperature	3.6.4	5.6.4
Cold bend	3.5.1	5.5.1
Cyclic flexing	3.5.2	5.5.2
Impact resistance	3.5.3	5.5.3
GROUP III		
Thermal aging	3.6.3	5.6.3
Temperature cycling with mandrel wraps	3.6.5	5.6.5
Freezing water immersion (ice crush)	3.4.2	5.4.2
Fungus resistance	3.4.5	5.4.5
Cable strippability	3.5.9	5.5.9
Flammability/flame extinguishing	3.6.1	5.6.1
GROUP IV		
Fluid immersion	3.4.1	5.4.1
Jacket self-adhesion or blocking	3.4.9	5.4.9
Corner bend	3.5.5	5.5.5
GROUP V		
Cable jacket materials tensile strength and elongation	3.5.7	5.5.7
Cable shrinkage	3.6.7	5.6.7
Durability of identification marking	3.5.8	5.5.8
Wicking	3.4.4	5.4.4

TABLE 4 - Sampling Plan for Periodic Qualification Inspection

Units of Product from 36 Months' Production	Sample Unit Size
2	1
3 to 8, inclusive	2
9 to 30, inclusive	3
31 to 80, inclusive	4
81 to 130, inclusive	5
131 to 180, inclusive	6
181 to 240, inclusive	7
241 to 300, inclusive	8
over 300	4 percent

4.5.2 Failures: If one or more specimens fail to pass periodic qualification inspections, the production unit shall be considered to have failed.

4.5.3 Disposition of Specimens: Specimens that have been tested to periodic qualification inspection shall not be delivered on the contract or purchase order.

4.5.4 Noncompliance: If a sample fails to pass periodic qualification inspection, the Supplier shall notify the Qualifying Activity of such failure and take corrective action on the materials or processes, or both, as warranted. Acceptance and shipment of the product shall be discontinued until corrective action, acceptable to the Qualifying Activity, has been taken. After the corrective action has been taken, periodic qualification inspection shall be repeated on additional sample units (all tests and examinations, or the test which the original failed, at the option of the Qualifying Activity). Groups A and B inspections may be re-instituted; however, final acceptance and shipment shall be withheld until the periodic qualification inspection has shown that the corrective action was successful. In the event of failure after re-inspection, information concerning the failure shall be furnished to the Qualifying Activity.

4.6 Quality Conformance Inspection:

Quality conformance inspection shall consist of the inspections and tests specified for Group A inspection (Table 5) and Group B inspection (Table 6).

4.6.1 Inspection of Product for Delivery: Inspection of product for delivery shall consist of Group A inspection.

4.6.1.1 Unit of Product: A unit of product shall be 1 km of cable of the same part number. If a production run is less 1 km, then the quantity produced shall be one unit of product.

4.6.1.2 Production Run: A production run shall consist of the number of units of product produced on the same production line or lines, and offered for inspection at the same time. All of the units of product in the production run submitted shall have been produced during the same production period with the same materials and processes and with optical fiber from the same preform.

4.6.1.3 Sample Unit: A sample unit shall be selected at random from the production run.

4.6.1.4 Specimens: A specimen shall be an individual length of cable cut from the sample unit.

4.6.2 Group A Inspection: Group A inspection shall consist of the inspections and tests specified in Table 5.

4.6.2.1 Sampling Plan: Group A inspection shall be performed on 100% of delivered product. There shall be no failures.

4.6.2.2 Disposition of Sample Units: Sample units from which a specimen has failed any of the Group A inspection tests shall not be delivered on any order.

TABLE 5 - Group A Inspection

Inspection	Requirement Paragraph	Test Paragraph
Visual and mechanical	3.4, 3.5, 3.6, 3.7	5.1 and 5.2
Attenuation	3.3.1	5.3.1 and 5.3.2
Bandwidth	3.3.12	5.3.12
Numerical aperture	3.3.10	5.3.10

4.6.3 Group B Inspection: Group B inspection shall consist of the inspections specified in Table 6. In cases where certain requirements and tests are applicable, these tests shall be conducted in the order shown. Group B inspections shall be made on sample units that have passed the Group A inspection.

TABLE 6 - Group B Inspection

Inspection	Requirement Paragraph	Test Paragraph
Thermal shock	3.6.2	5.6.2

4.6.3.1 Sampling Plan: Sample units shall be selected from those types covered by a single specification sheet in accordance with Table 7, three months after the date of notification of qualification and every three months thereafter, except when the total production in a three month period is less than 2 units of product (2 km) inspection need not be made until either production is at least 2 units of products or a total of 12 months have elapsed since the inspection was performed in which case only one sample unit shall be tested.

TABLE 7 - Sampling Plan For Group B Inspection

Units of Product from 12 Months' Production	Sample Unit Size
2	1
3 to 8, inclusive	2
9 to 30, inclusive	3
31 to 80, inclusive	4
81 to 130, inclusive	5
131 to 180, inclusive	6
181 to 240, inclusive	7
241 to 300, inclusive	8
over 300	4 percent

4.6.3.2 Failures: Production units in which one or more sample units have failed a Group B inspection test shall be rejected.

4.6.3.3 Rejected Production Units: If a production unit is rejected, the supplier may screen out the defective units of product (if possible), and resubmit for re-inspection. Such production units shall be separate from new production units, and shall be clearly identified as re-inspected production units.

4.6.3.4 Disposition of Sample Units: Sample units from which a specimen has failed any of the Group B inspection tests shall not be delivered on any order, even though the production unit submitted is accepted.

5. TEST METHODS:

5.1 Visual and Mechanical Examinations:

Visual and mechanical examinations shall be performed in accordance with Electronic Industries Alliance TIA/EIA-455-13 to verify that the design, construction, physical characteristics, dimensions, marking and workmanship are in accordance with the applicable specification sheet. Visual examination shall be accomplished utilizing ten-power magnification. Visual inspection for the color of the cable may be accomplished without magnification

5.2 Fiber and Cable Construction Inspections:

5.2.1 Fiber: The fiber used in the cable construction shall meet the requirements as specified on the applicable specification sheet.

5.2.2 Cable: Cable construction shall meet the requirements as specified on the applicable specification sheet.

5.2.3 Finished Cable Diameter: The diameter of finished cable shall be computed from the circumference measurement determined in accordance with AS4373 Method 901.

5.2.4 Finished Cable Weight: The finished cable weight shall be determined in accordance with AS4373, Method 902.

5.3 Optical Fiber Testing:

5.3.1 Attenuation: Optical fiber attenuation shall be measured in accordance with TIA/EIA-455-78 for single-mode fiber and EIA/TIA-455-46 for multimode fiber. Multimode launch conditions shall be in accordance with TIA/EIA-455-50 or as specified on the applicable specification sheet.

5.3.2 Change in Optical Transmittance: This test shall evaluate the change in optical transmittance of the fibers due to exposure of the cable to one or more inspection (environment and physical) tests.

5.3.2.1 Method: The change in optical transmittance of each fiber shall be measured in accordance with TIA/EIA-455-20, utilizing a monitor fiber to evaluate the change in transmittance due to exposure of the cable to environmental and physical tests. Any optical power detection method may be utilized if the method has the sensitivity to measure the differential optical power levels as specified in the individual test requirements of Section 3, and if the method provides repeatable readings (less than 3 percent variation). A pretest optical power measurement shall be made and the specimen shall then undergo inspection testing. All optical power measurements, subsequent to the pretest measurement, shall be referenced to the pretest value and the change in dB calculated.

5.3.2.2 Guidelines: These types of measurements require highly stable optical devices (source and detector) and repeatability of loss at the device-to-fiber interface. Use of the same reference fiber for calibrating the light source power output just prior to making all the measurements on the cable specimen, will enhance the measurement accuracy.

5.3.3 Attenuation Uniformity: The attenuation uniformity of each individual fiber shall be measured in accordance with TIA/EIA-455-59. The uniformity shall be measured from one end of the fiber, and shall meet the requirements specified in 3.3.3.

5.3.4 Fiber Diameter, Core Offset, and Concentricity: Fiber geometry shall be measured in accordance with TIA/EIA-455-176 or TIA/EIA-455-45, Method B.

5.3.5 Fiber Tensile Proof Test: Fiber tensile proof test shall be performed in accordance with TIA/EIA-455-31.

5.3.6 Mode Field Diameter: Mode field diameter of single-mode fiber shall be determined in accordance with EIA/TIA-455-167.

5.3.7 Cut Off Wavelength: The cut off wavelength of uncabled single-mode fiber by transmitted power shall be determined in accordance with TIA/EIA-455-80.

5.3.8 Dynamic Fatigue: Dynamic fatigue of the optical fiber shall be measured in accordance with TIA/EIA-455-76. This measurement shall be used to calculate the N-value of the buffered fiber.

5.3.9 Chromatic Dispersion: Chromatic dispersion for single-mode optical fiber shall be measured in accordance with TIA/EIA-455-169.

5.3.10 Numerical Aperture: Measurement of the refractive index of the core and cladding of the optical fiber shall be in accordance with TIA/EIA-455-47. This measurement shall be used to calculate the numerical aperture (NA) of the fiber.

5.3.11 Radiation Induced Attenuation: Radiation induced attenuation shall be measured in accordance with EIA/TIA-455-49.

5.3.12 Bandwidth: The fiber optic cable bandwidth shall be measured in accordance with TIA/EIA-455-51. Light launch conditions shall be as specified on the applicable specification sheet.

5.4 Environmental Testing:

5.4.1 Fluid Immersion: One specimen of finished cable shall be immersed in each of the fluids listed in the applicable specification sheet for the time and at the temperature specified. Each specimen shall be approximately 2 meters in length and shall be immersed such that the two ends are exposed to the atmosphere and not contacting the fluid. After each immersion, the specimen shall be removed, blotted to remove excess fluid, and suspended in air at room temperature for not less than 3 hours 30 minutes and not more than 4 hours 30 minutes. After drying, the specimens shall be tested for diameter change, tensile strength, and elongation retention.

5.4.2 Freezing Water Immersion: Freezing water immersion test shall be performed in accordance with SAE AS16781 Method 4050, except the specimens shall be off the reel and loosely coiled and shall be completely immersed in water. The vessel containing the water need not be sealed.

5.4.3 Humidity Resistance: Humidity testing shall be performed in accordance with TIA/EIA-455-162. The special test conditions specified in (a) through (c) shall apply to these tests:

a. Pretest and post-test measurements of the cable outer diameter shall be made and reported.

b. Visual inspection of the specimen shall be made using ten-power magnification in accordance with 5.1.

c. The change in optical transmittance shall be measured during and after the test in accordance with 5.3.2.

5.4.4 Wicking: Cable wicking shall be tested in accordance with TIA/EIA-455-39. Visual examination shall be made in accordance with 5.1.

5.4.5 Fungus Resistance: Fungus resistance shall be tested in accordance with TIA/EIA-455-56.

5.4.6 Outgassing: Cables and materials shall be tested for outgassing in accordance with ASTM E 595.

5.4.7 Vibration: Cables shall be tested for vibration resistance in accordance with TIA/EIA-455-11, Condition VI.

5.4.8 Shock: Cables shall be tested for shock resistance in accordance with EIA/TIA-455-14.

5.4.9 Jacket Self-Adhesion or Blocking: Blocking characteristics shall be tested in accordance with TIA/EIA-455-84 to qualify the cable jacket self-adhesion property. The cable specimen shall be conditioned at the high storage temperature plus or minus 2 °C for a period of 48 hours prior to testing for blocking. After the test exposure, the specimen shall be visually examined in accordance with 5.1.