STATE OF NEW JERSEY
DEPARTMENT OF TRANSPORTATION
TRENTON, NEW JERSEY 08625

METRIC SPECIFICATIONS FOR SINGLE MODE, LOOSE TUBE, SINGLE JACKET FIBER OPTIC CABLE

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New Jersey Department of Transportation Specifications for Fiber Optic Cable - Single Mode, Loose Tube, Single Jacket.

The purpose of these specifications is to describe minimum acceptable design requirements for this equipment.

GENERAL - I

1-1 The Fiber Optic Cable described in this specification shall be all dielectric, single jacketed, gel filled, with loose tubes optimally protected from water infiltration, and contain single mode, dual-window (1 300 nanometers and 1 550 nanometers) fibers and shall conform to these special provisions.

1-2 The construction and testing of the fiber optic cable shall meet or exceed all applicable Electronic Industry Standards (EIA/TIA), International Telegraph and Telephone Consultative Committee (CCITT), ANSI, BELLCORE, ASTM standards and FDDI specifications.

TRUNK CABLE - II

2-1 The fiber optic cable shall be all dielectric and have a single jacket with a maximum cable diameter of 12.0 millimeters. The number of fibers shall be as specified in contract documents (or bid documents).

2-2 The optical fibers shall be contained within loose, gel filled buffer tubes. The loose buffer tubes shall be stranded around an all dielectric central strength member, cable core shall be saturated with a water blocking compound, and surrounded by a tensile strength member. A high or medium density polyethylene outer jacket shall provide for overall protection.

2-3 The fiber optic cable shall include the following components:

A. Color coded, single mode, optical fibers

B. Buffer tubes, gel filled, color coded

C. Central strength member
D. Filler rods as required

E. Stranding

F. Core and cable gel flooding

G. Core separator or binders

H Tensile outer strength member

I. Ripcord

J. HDPE or MDPE outer jacket, co-extruded colored stripe, coded and labeled

2-4 The cable shall be manufacturer rated for 2 669 newtons maximum tensile loading during installation (also called loaded).

2-5 The cable shall be manufacturer rated for 578 newtons maximum tensile loading for the unloaded application (also known as in-service, or long term application).

2-6 The cable shall be designed for a minimum bending radius of 20 times the cable diameter during installation.

2-7 The cable shall be designed for a minimum bending radius of 10 times the cable diameter for unloaded application.

2-8 The cable shall have a crush resistance of 2 200 newtons per millimeter (tested in accordance with FOTP-41).

2-9 The cable shall have an impact resistance of 25 impacts (tested in accordance with FOTP-25) without exhibiting an average increase in attenuation greater than 0.20 decibels at 1 550 nanometers. The cable jacket shall not exhibit evidence of cracking or splitting at the completion of the test.

2-10 The cable shall withstand 25 cycles of mechanical flexing around a mandrel (tested in accordance with FOTP-104) not greater than 20 times the cable diameter at a rate of 30 ±1 cycles/minute without experiencing an average increase in attenuation greater than 0.10 decibels at 1 550 nanometers. No outer cable jacket cracking or splitting shall be observed under 10X magnification.

2-11 The cable twist test shall be tested in accordance with FOTP-85. A length of cable no greater than 4 meters in length shall withstand 10 cycles of mechanical twisting without exhibiting a average increase in attenuation greater than 0.10 decibels. The cable jacket shall not exhibit no cracking or splitting when observed under 10X magnification after completion of test.

2-12 The cable shall have a minimum proof test stress of 689 megapascals (tested in accordance with EIA-455-31A).

2-13 The cable fluid penetration test shall be tested in accordance with FOTP-82. When a one meter static head or equivalent continuous pressure is applied at one end of a one meter length of filled cable for one hour, no water shall leak through the open cable end.

2-14 The cable shall be tested for compound flow testing in accordance with FOTP-81. The filling and flooding compounds shall not flow from the filled fiber optic cable when tested for 24 hours at 65 °C.

2-15 The cable shall meet or exceed the requirements of Paragraphs 2-8 through 2-14 with no average attenuation increase after being subjected to the testing defined.

FIBER CHARACTERISTICS - III

3-1 Each optical fiber shall be glass and consist of a doped silica core surrounded by concentric silica cladding. All fibers in the buffer tube shall be usable fibers which meet attenuation requirements and shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical, and environmental requirements of these specifications.

3-2 The coating shall be a dual layered, UV cured acrylate. The coating shall be mechanically or chemically stripable without damaging the fiber.

3-3 The cable shall comply with the optical and mechanical requirements over an operating temperature range of -40 °C to +70 °C.

3-4 The required fiber grade shall reflect the maximum individual fiber attenuation, to guarantee the required performance of each and every fiber in the cable. For all fibers, the attenuation specification shall be a maximum attenuation for each fiber over the entire operating temperature range of the cable.

3-5 Single mode fibers within the finished cable shall meet the requirements in the following table:

Fiber Characteristics Table

Parameters	Single Mode Fiber
Type	Step Index
Core diameter	8.3 µm (nominal)
Cladding diameter	124 µm ± 2.0 µm
Core to Cladding Offset	1.0 µm
Cladding Non-circularity	2.0%
Coating Diameter	250 µm ± 15 µm
Proof/Tensile Test	689 MPa, min.
Attenuation:	
@ 1 310 nm	≤ 0.4 dB/km
@ 1 550 nm	≤ 0.4 dB/km
Attenuation at the Water Peak	≤ 2 dB/km @ 1 300 ± 3 nm
Chromatic Dispersion:	
Zero Dispersion Wavelength	1301.5 to 1321.5 nm

Zero Dispersion Slope	0.092 ps/(nm^2•km)
Maximum Dispersion:	3.3 ps/(nm•km for 1285-1 330 nm
	<18 ps/(nm•km) for 1550 nm
Cut-Off Wavelength	<1250 nm
Mode Field Diameter	9.3 ± 0.5 µm at 1300 µm

Macrobending Loss

measured at 1550 nm on loose fiber of 100 turns of 75 mm diameter (tested in accordance with EIA-455-62), shall be less than or equal to:

0.1 dB @ 1 310 nm
0.5 dB @ 1 550 nm

COLOR CODING AND LABELING - IV

4-1 Each optical fiber shall be distinguishable from others in the same buffer tube by means of color coding according to the following:

fiber	1	Blue (Bl)
fiber	2	Orange (O)
fiber	3	Green (G)
fiber	4	Brown (Br)
fiber	5	Slate (S)
fiber	6	White (W)

4-2 In cables containing multiple buffer tubes each buffer tube shall be distinguishable from others in the same cable by means of color coding according to the following:

Buffer Tube - 1 - Blue (Bl)
Buffer Tube - 2 - Orange (O)
Buffer Tube - 3 - Green (G)
Buffer Tube - 4 - Brown (Br)
Buffer Tube - 5 - Slate (S)
Buffer Tube - 6 - White (W)

4-3 Cables shall be distinguishable from each other by co-extruded stripe color coding and labeling, and shall have a co-extruded stripe according to the plans and special specifications. The entire outer jacket of the cable shall have a co-extruded stripe colored by industry standard coloring additive, not by an external applied coloring. The labeling shall be printed on the cable every meter. The label shall be in capital letters and the height of the lettering shall be approximately 2.5 millimeters. The marking shall be in a contrasting color to the cable jacket. The co-extruded stripe colors for the outer jacket shall be one of the following colors as designated in the contract documents:
Blue (Bl)
Orange (O)
Green (G)
White (W)
Red (R)
Black (Bk)

The cable color and label used for each specific cable shall be as designated on the contract documents.

4-4 The colors shall be targeted in accordance with the Munsell color shades and shall meet EIA/TIA-598 "Color Coding of Fiber Optic Cables."

4-5 The color formulation shall be compatible with the fiber coating and the buffer tube filling compound, and be heat stable. The colors shall not fade or smear or be susceptible to migration and it shall not affect the transmission characteristics of the optical fibers and shall not cause fibers to stick together.

BUFFER TUBES - V

5-1 Clearance shall be provided in the loose buffer tubes between the fibers and the inside of the tube to allow for expansion without constraining the fiber. The fibers shall be loose or suspended within the tubes. The fibers shall not adhere to the inside of the buffer tube.

5-2 Single jacketed cables shall have a minimum of 3 and a maximum of 6 buffer tubes with a maximum of 6 fibers in each tube. Diameter of buffer tubes shall be a minimum of 2.0 millimeters and a maximum of 2.4 millimeters.

5-3 The loose buffer tubes shall be extruded from a material having a coefficient of friction sufficiently low to allow free movement of the fibers. Buffer tubes shall be made of a tough abrasion resistant material to provide mechanical and environmental protection of the fibers, yet designed to permit safe intentional "scoring" and breakout, without damaging or degrading the internal fibers.

5-4 Buffer tube filling compound shall be a homogenous hydrocarbon-based gel with anti-oxidant additives and used to prevent water intrusion and migration. The filling compound shall be non-toxic and dermatologically safe to exposed skin. The compound shall be chemically and mechanically compatible with all cable components, non-nutritive to fungus, non-hygroscopic and electrically non-conductive. The filling compound shall be free from dirt and foreign matter and shall be readily removable with conventional nontoxic solvents.

5-5 Buffer tubes shall be stranded around a central member by a method that will prevent stress on the fibers when the cable jacket is placed under strain, such as the reverse oscillation stranding process.

5-6 Each buffer tube shall be distinguishable from other buffer tubes in the cable by means of color coding as specified in Section VI.

CENTRAL NON-FIBER MEMBERS - VI

6-1 The central strength member, which functions as an anti-buckling element, shall be a glass reinforced plastic rod with similar expansion and contraction characteristics as the optical fibers and buffer tubes. A linear overcoat of Low Density Polyethylene shall be

applied to the central member if required to achieve the optimum diameter to provide the proper spacing between buffer tubes during stranding.

6-2 Fillers may be included in the cable to lend symmetry to the cable cross-section where needed. Filler rods shall be medium or high density polyethylene. The diameter of filler rods shall be the same as the outer diameter of the buffer tubes.

STRANDING - VII

7-1 Completed buffer tubes shall be stranded around the overcoated central member using stranding methods, lay lengths and positioning such that the cable shall meet mechanical, environmental and performance specifications.

7-2 A polyester binding shall be applied over the stranded buffer tubes to hold them in place. Binders shall be applied with sufficient tension to secure the buffer tubes to the central member without crushing the buffer tubes.

7-3 The binders shall be non-hygroscopic, non-wicking (or rendered so by the flooding compound), and dielectric with low shrinkage.

CORE AND CABLE FLOODING - VIII

8-1 The cable core interstices shall be filled with a polyolefin based compound or equivalent to prevent water ingress and migration.

8-2 The flooding compound shall be homogeneous, non-hygroscopic, electrically non-conductive, and non-nutritive to fungus. The compound shall also be nontoxic, dermatologically safe and compatible with all other cable components.

TENSILE STRENGTH MEMBER - IX

9-1 Tensile strength shall be provided by high tensile strength aramid yarns and fiberglass, which shall be helically stranded evenly around the cable core.

9-2 The cable shall contain one ripcord, spaced apart under the jacket to provide for easy sheath removal.

OUTER JACKET - X

10-1 The jacket shall be free of holes, splits, and blisters and shall be high density cross-linked or medium density polyethylene with minimum nominal jacket thickness of 1.02 ± 0.07 millimeters.

10-2 Jacketing material shall be applied directly over the tensile strength members and flooding compound and shall not adhere to the aramid strength material.

10-3 The outer jacket material shall be co-extruded stripe color coded and labeled according to the color code in Section IV.

10-4 The jacket material shall contain a suitable antioxidant, and shall not promote the growth of fungus.

10-5 The jacket shall be marked with the manufacturer's name, the words "Fiber Optic Cable", date of manufacture, and sequential measurement markings every meter. This is in addition to the labeling in Section IV, Subsection 4-3. The actual length of the cable shall be within ± 1 percent of the length marking. The marking shall be in a contrasting color to the cable jacket. The height of the marking shall be approximately 2.5 millimeters.

10-6 High or medium density polyethylene shall be in accordance with ASTM D 1248, Type II or III, class C, category 4 or 5 and shall contain a suitable antioxidant system. The light absorption coefficient of the jacket shall be at least 400 when measured at a wave length of 375 nanometers as per ASTM D 3349.

SHIPPING - XI

11-1 The fiber optic cable shall be shipped on a strongly constructed reel. The reel shall be designed to prevent damage to the fiber optic cable during shipment and installation.

11-2 All fiber optic cable ends shall be sealed to prevent the escape of the filling compound and the entry of moisture.

11-3 Both fiber optic cable ends shall be equipped with flexible pulling eyes.

11-4 A thermal protective wrap shall be applied over the outer turns of the cable on each reel.

TESTING - XII

12-1 Testing shall include the tests on elements of the passive fiber optic components at the factory.

12-2 The Supplier shall provide all personnel, equipment, instrumentation and materials necessary to perform all testing.

12-3 Documentation of all test results shall be provided to the Engineer two working days before the material is scheduled to arrive on site.

12-4 Attenuation tests shall be performed in accordance with FOTP-61.OTDR (Optical Time Domain Reflectometer) shall be capable of recording and displaying anomalies of 0.2 decibels as a minimum. Single mode fibers shall be tested at 1 300 nanometers and 1 550 nanometers. The OTDR shall be designed for use on single mode fiber at 1 300 and 1 550 nanometer wavelength, and shall be a unit exhibiting the following characteristics:

dead zone: 15 meters or better
attenuation range: 15 decibels or better
distance range: 10 kilometers or longer
accuracy: ±2.0 meters
printer: must be capable of printer output and internal storage.

12-5 The OTDR shall have a printer capable of producing a verifying test trace with fiber identification, numerical loss values, the date and the operator's name. It shall also have a DOS based 90 millimeter disk recording capability that has associated software to do comparisons and reproductions on A4 paper (210 by 297 millimeters) paper, via a personal computer.

12-6 The factory test shall include verification of the fiber specifications as listed in the Fiber Characteristics Table which shall be supplied by the manufacturer with the appropriate documentation. After the cable has been placed on the shipping reel and before shipping, 100 percent of all fibers shall be tested for attenuation. Any cable that has been in storage shall be tested or retested before shipping. Copies of the results shall be maintained on file with a file identification number for a minimum of 10 years, attached to the cable reel in a waterproof pouch, and submitted to the Engineer prior to the delivery of the cable to the job site.

12-7 The cable shall not be installed until all of the tests have been completed and with written approval by the Engineer. Copies of traces and test results shall be submitted to the Engineer. If the OTDR test results are unsatisfactory, the reel of fiber optic cable shall be considered unacceptable and all records corresponding to that reel of cable shall be marked accordingly.

12-8 The unsatisfactory reels of cable shall be replaced with new reels of cable at the Supplier's expense. The new reels of cable shall then be tested to demonstrate acceptability. Copies of the test results shall be submitted to the Engineer.

TRAINING - XIII

13-1 Prior to the acceptance of the first OTDR unit or any cable, training shall be provided for the Department's engineering, maintenance and operations staff, at a facility provided by the Department. The training shall include all material and manuals required for each participant. The training shall be as follows:

13-2 Maintenance training of OTDR operation shall be provided for a minimum of 16 hours for at least 5 personnel with an electronics background. The training shall include operation instructions, theory of operation, circuit description, field adjustments, preventive maintenance procedures, troubleshooting, interpretation of results, and repair of all components.

13-3 Fiber optic cable installation training shall be provided for a minimum of 24 hours for at least 10 personnel with a background in cable installation. The training shall include operation of all cable laying equipment, theory of operation, field adjustments, preventive maintenance procedures, troubleshooting, and repair of all components.

13-4 Engineering training shall be provided for a minimum of 16 hours for at least 20 engineering and operations personnel. The training shall include a complete demonstration of the operation, capabilities of the equipment, and interpretation of results of the OTDR and a complete demonstration of fiber optic cable laying.

INSTRUCTIONS AND GUARANTEES - XIV

14-1 Ten sets of maintenance and repair manuals shall be included with the furnished cable.

14-2 No changes or substitutions in these requirements will be acceptable unless authorized in writing. Inquiries regarding this specification shall be addressed to the Manager, Office of ITS Engineering, New Jersey Department of Transportation, P.O. Box 613, 1035 Parkway Avenue, Trenton, New Jersey 08625.

14-3 The Supplier agrees upon the request of the Manager, Office of ITS Engineering to deliver to the Office, a sample of the cable, approximately 600 millimeters in length, to be supplied in compliance with these specifications for inspection and test before acceptance. The sample shall not be returned.

14-4 The supplied cable shall carry a two-year warranty, from the date of project acceptance by the State, to be free of defects. The installer shall fully test the cable prior to installation and within the warranty period. The installer shall be fully responsible for the installation of defect free cable and for the replacement of any cable found to be defective due to improper construction or improper installation for two years after the State's acceptance of the project.

14-5 The cable supplied shall be in successful operation in an underground conduit environment for a minimum of one year. A total of at least 32 kilometers of the proposed cable must be in operation, at least 16 kilometers of which is within one facility. The owner of this facility shall be a public utility (i.e., Telephone, Cable TV, or Transportation) in North America. The supplier shall include the name and address of the Chief Engineer of the facility at which the cable is in operation as part of the submittal.