Document Control

Issue Date	Comments	Revisions	Revision #
2/23/99	Draft		
7/23/99	Draft 2		
12/29/99	Incorporate Bayne Smith's comments Revise external transceivers to specifically prohibit internal card type and to add compliance with NEMA environmental rqmts. Revise cable labeling requirement in FDC to within 6" of termination.	 935.2K1 935.3.05G2	1
1/12/00	Clarify requirement for pressurized high fiber count splice cases	935.2.G.2.d	2
1/12/00	Project: CM-00TS(10) Ct. 1 Fulton County P.I. No. 713155 Project: CM-00TS(10) Ct. 2 DeKalb And Fulton County P.I. No. 713157		
2/1/00	Revise cable labeling requirements to use drop cable ID	935.3.05G2	3
2/3/00	Move Section 935.2.L to 935.2.K		4
3/23/00 3/24/00	Add submittal requirements text & chart. Revise cable storage rqmts. Revise drop cable assembly rqmts. Add to pig tail requirements. Replace FDC section (no pig tails or splices included in cost of FDC). Revise fiber optic connectors rqmts. Edit cable installation guidelines. Deleted rqmt. for electrical schematic wiring diagrams. Delete reference to cabinet, junction box. Added review & approval of fiber optic cable test results by Engr. Specify when test eqpt becomes property of Dept. Add cable end sealing. Revise ECB & PB cable storage methods Revise cable storage requirements	935.1.03 935.3.05.C.1 935.2.E 935.2.D 935.2.J 935.2.F 935.3.05.B.5 935.1.03.F 935.2.H.3 935.1.03.E 935.3.02 935.3.05.B.6 935.3.05.C.3.a 935.3.05.C	5
4/3/00	Delete redundant statement about approval.	935.3.05.A	6
5/31/00	STP-7713(650) Fulton County P.I. 771365		
6/13/00	Change messenger cable rqmt. Clarify measurement of pig tails, fusion splices, and connectors for field spliced drop cable assemblies	935.3.05.B.5 935.4.B, 935.4.D, 935.4.F	7
6/28/00	Project: STP-1330-00(900) Gwinnett County P.I. No. 133090		

Document Control

Issue Date	Comments	Revisions	Revision #
8/17/00	Added metric conversions		8
9/5/00	Corrected cable marker thickness to 0.015" per SPCR 53	935.3.05.G.1	9
12/6/00	Delete metric equivalents	Various locations	10
12/11/00	Project: CM-285-1(360) DEKALB COUNTY P.I. NO. 713410		
1/26/01	SCR #75: Portable f. o. light source and power meter remain property of Contractor	935.3.02	11
2/9/01	Document Control No. NAV01-049		1.0
2/14/01	Entered into CM Document Control		1.0
3/09/01	SCR # 45 Revise transceiver power budgets.	Section 935.2.K.1	1.1
4/4/01	SCR # 45 QAed. New release of document		2.0
12/04/01	SCR # 280	939.3.07	2.1
12/10/01	SCR # 280 QAed. New release of document		3.0
12/19/01	SCR # 310	935.3.01	3.1
1/31/02	New Release of Document		4.0
1/31/02	Issued to Betsy Williams for SCR # 76 update		4.1
3/14/02	Updated per SCR #76	935.3.08	4.1
6/25/02	Update per SCRs 234 & 236	935.1.03 E	4.2
6/25/02	Update per SCRs 319 & 321	935.3.05 G 935.1.03 E	4.3
6/25/02	Published to server		5.0
6/25/02	Issued to Stephanie Kolb for SCR 328		5.1
7/31/02	Inclusion of metric equivalent units. SCR 328	935.2.A; 935.2.B.1.f; 935.2.B.1.g; 935.2.B.4; 935.2.B.5; 935.2.B.7; 935.2.B.8; 935.2.C.1.c; 935.2.C.1.d; 935.2.C.2.b; 935.2.C.3; 935.2.C.4; 935.2.E.1; 935.2.E.2.c; 935.2.F; 935.2.G.2.f; 935.2.G.3.a; 935.2.G.3.b; 935.2.G.3.e; 935.2.I.; 935.2.J; 935.2.K.1; 935.2.02; 935.3.05.B.5; 935.3.05.C.1; 935.3.05.C.2; 935.3.05.G.1; 935.3.05.G.2; 935.3.05.J.2; 935.3.06.A; 935.3.06.B.2.a	5.1
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10/9/02	Updated as per SCR # 320	935.2.C.1.a; 935.2.D.1.	6.1
11/13/02	Published to server		7.0
11/19/02	Modified to meet Office of Contract Administration requirements for format per		7.1

Document Control

Issue Date	Comments	Revisions	Revision #
	TOPPS document 2445-1.		
12/12/02	Published to server		8.0
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1/7/03	Published to server		9.0
1/9/03	Error found in Document Control table. Reference to 935.C removed.	Betsy Williams/Hugh Colton	9.1
1/9/03	Published to server		10.0
6/18/03	Revised as per SCR # 407	935. 2.K.1; 935. 2.K.2; 935.3.05.L; 935.4.J	10.1
6/19/03	Published to server		11.0
8/26/03	Revised as per SCRs 235, 323, and 360	935.1.03.F.4, 935.3.05.G.2 935.3.06.B.1, 935.3.06.B.2.a, 935.3.05.C	11.1
9/4/03	Published to server		12.0
10/9/03	Revised per SCRs 342 and 402	935.1.03; 935.2.C.2.b; 935.2.E; 935.2.J; 935.3.05.M; 935.3.06.E; 935.4.B; 935.4.D	12.1
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10/21/03	Revised per SCR #422	935.2.F	13.1
10/23/03	Published to server		14.0
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11/18/03	Published to server		15.0

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SPECIAL PROVISION

PROJECT: [INSERT PROJECT NUMBER(S)]
[INSERT COUNTY NAME(S)] COUNTIES
P.I. NO. [INSERT P.I. NUMBER(S)]

SECTION 935 – FIBER OPTIC SYSTEM

Delete Section 935 and substitute the following:

Section 935 - Fiber Optic System

The text included herein is written in the imperative mood (sentences often begin with commands). All commands and references in, or in connection with, the text in this document are written to imply **Contractor responsibility for action** unless otherwise specified.

935.1 General Description

This work includes the installation of fiber optic cable and equipment including but not limited to cable, interconnect, patch cords, pig tails, any cable related hardware, connectors, splices, closures, temporary systems, testing, training, or any other fiber optic product as specified on the Plans, or noted in any other Section of these Specifications.

935.1.01 Definitions

Not applicable

935.1.02 Related References

A. Georgia Specifications

Section 150 – Traffic Control

Section 639 – Timber Poles

Section 639 - Guys

Section 647.12 - Lashing

Section 682 – Electrical Wire, Cable and Conduit

B. Referenced Documents

EIA Standard FOP-II, Test Condition 1

EIA/TIA-492AAAA, "Detail Specification for 62.5 μm Core Diameter/125 μm Cladding Diameter Class IA Multimode, Graded Index Optical Waveguide Fibers", Current Edition

EIA/TIA 492-BA000 Class 4A, Current Edition

EIA/TIA-598-A, “Color Coding of Fiber Optic Cable”

National Electrical Code Section 770:

Applicable Flame Tests: UL 1581 and UL 1666 (Non-Plenum Applications)

Applicable Flame Test UL 910 (NFPA 262-1994) (Plenum Applications)

United States Department of Agriculture Rural Utilities Service (RUS) standard 7 CFR 1755.900:

FOTP-25, “Repeated Impact Testing of Fiber Cables”

FOTP-41, “Compressive Loading Resistance of Fiber Optic Cables”

FOTP-123, “Measurement of Optical Fiber Ribbon Dimensions”

FOTP-181, “Lightning Damage Susceptibility Test for Optic Cables with Metallic Components”

935.1.03 Submittals

Prior to any work, obtain approval from the Engineer for the products and procedures to be used on the Project.

The following chart provides the Contractor with an outline of the submittal requirements for the equipment and components for this pay item. This chart is to be used as a guide and does not relieve the Contractor from submitting additional information to form a complete submittal package.

Section 935 Submittal Requirements

Material	Specification Reference	Catalog Cuts	Mfg. Spec.	Factory Test	Materials Cert.	Lab. Test Reports	Install. Proced.	Test Schedule	Test Plan	Test Reports	Submittal Due Date (Cal. Days after NTP)
F.O. Cable (OSP&IP)	935.2.A,B,&C	X	X		X		X	X	X	X	60 Days
Patch Cords & Pig Tails	935.2.D	X	X						X		60 Days
Drop Cable	935.2.E	X	X						X		60 Days
F.O. Connectors	935.2.F	X	X								60 Days
Splice Closure	935.2.G&H	X	X	X		X					60 Days
Mech. Lab Splice	935.2.I	X	X								60 Days
FDC	935.2.J	X	X								60 Days
Transceivers	935.2.K	X	X								60 Days
Splice Procedures	935.1.03C						X				60 Days

Submit submittal data for all equipment, materials, test procedures, and routine maintenance procedures required for these items within 60 calendar days after the Notice To Proceed and prior to any installation, unless noted otherwise in the Contract Documents.

Submit to the Engineer for approval, six (6) copies of the manufacturer’s descriptive literature (catalog cuts), technical data, operational documentation, service and maintenance documentation and all other materials required within these specifications.

Provide submittal data that is neat, legible, and orderly. Neatly organize each package of submittal data and separate by hardware item. Use the “Materials Certification Package Index and Transmittal Form”, contained in Section 105.02 of the Special Provisions, for each pay item to document and list all material and components that are included in the submittal package. Any submittal data submitted without the Index/Transmittal form or that is incomplete will be rejected.

A. Cable Certification

Prior to installing any fiber optic cable on the Project, obtain approval for the cable type, cable manufacturer, fiber content, design and installation procedure from the Engineer. Request approval by submitting catalog cuts and factory specifications for the fiber optic cable.

B. Aerial and Underground Splice Closures:

Provide certification from an independent testing laboratory that certifies that the splice closures conform to the specifications and test procedures.

C. Splicing Procedures

Submit for Department approval the procedure to be used for the splicing of all cables on this project. Within the submittal documents include the proposed process, cleave tool and the specific fusion splicer to be used.

D. Fiber Distribution Center (FDC)

With the submittal data for the pre-terminated FDC (subsection 935.2.J), provide two complete samples of each size and type required in the project. Provide a minimum of 20 feet (6 m) of drop cable with each pre-terminated FDC; any type and manufacture of drop cable is permitted in the sample as long as the cable contains at least as many fibers as the pre-terminated FDC size. For each sample, provide factory test documentation as required in 935.3.06.E.

E. Training

Prior to training, submit resume and references of instructor(s) to Engineer for approval. The instructor shall be qualified in his/her respective field as determined by the Engineer. Submit an outline of the training course and a training plan within 120 days of the Contract Notice to Proceed for approval by the Engineer. Explain in the Training Plan in detail the contents of the course and the time schedule of when the training shall be given. Coordinate actual training with installation schedules as approved by the Engineer.

F. Fiber Optic Test Documentation

Provide the date, time and location of any tests required by this specification (see 935.3.06) to the Engineer at least 72 hours before performing the test. Provide two copies of documentation of the test results to the Engineer within 5 working days of completion of the test for review and approval, or else retest the represented fiber optic cable and provide the documentation within 5 working days of the retest. Bind the test documentation and include the following:

1. OTDR Set-Up: Cable & Fiber Identification

- Cable ID
- Cable Location - begin and end point
- End-to-end cable length in kilometers calculated from cable markings
- Fiber ID, including tube and fiber color
- Operator Name
- Date & Time

2. OTDR Test Parameters: Information to be recorded on each trace

- Wavelength
- Pulse width
- Refractory index
- Range

- Scale

3. Test Results

a. OTDR Test

- Total Fiber Trace distance in kilometers
- Splice Loss attenuation in dB per km
- Events > 0.01 dB
- Trace analysis detailing all events exceeding 0.01 dB

Provide traces on a diskette to the Engineer.

Provide trace data summarized in spread sheet form. At a minimum, the data shall include: cable Id, fiber number, FDC port, fiber distance, test wave length, attenuation in dB per km. The data requirements for each project will be provided through the Engineer.

b. Power Meter End – To – End Attenuation Test

This test is to be performed on each fiber link using test procedures described in document EIA/TIA 526 sections 7 & 14A.

- Length, number and type of splices and connectors
- Link attenuation
- The data shall be provided to the Engineer in Excel or compatible spreadsheet form and on a floppy diskette

G. As-Built Documentation

Submit as built documentation of all work provided in accordance with this specification prior to Contract final acceptance. Include in the as-built documents the following documents as a minimum as they are applicable. Supply manuals and wiring diagrams at the time of installation. Deliver as-builts no later than 30 days after completion of installation or as otherwise specified in the Plans or Specifications.

1. Operator's Manual

Furnish a manual containing detailed operating instructions for each different type of equipment.

2. Maintenance Procedures Manuals

Furnish a manufacturer's manual containing detailed preventative and corrective maintenance procedures for each different type or model of equipment.

3. System Connection Diagrams

Furnish diagrams showing fiber optic and electric system interconnection cables and terminations. Include a diagram showing the location of all equipment in the new equipment racks or frames in hubs.

4. As Built Drawings

Provide the Department with drawings that detail the final installation route of all cable. Show all routes and locations of the final cable installation in-place and complete. For aerial cable installations show poles, pole attachment heights, spans, co-locations, splice closures, maintenance/storage coils, and vertical risers. For underground cable installations show conduit size, quantity and routes, pull boxes and ECBs, closures, and cabinet terminations. Provide as-build drawings showing the final location of new CCTV support poles, new utility poles, and new equipment cabinets. Provide the cable distance marking documentation required in 935.3.05.G.2.

Except for standard bound materials, bind all 8.5”x11” documentation, including 11” x 17” drawings folded to 8.5”x11”, in logical groupings in loose-leaf binders of either the 3-ring or plastic slide-ring type. Permanently and appropriately label each such bound grouping of documentation.

Furnish at least five (5) copies of all bound documentation.

935.2 Materials

A. Fiber Optic Cable

Ensure that all fiber optic related products conform to this specification. Install, apply, inspect, and use those products in accordance with the manufacturer’s standard operating and installation procedures and this Specification.

Use only fiber optic cable that meets the following requirements:

Ensure that the optical fiber used in both outside and inside plant cable conforms to the requirements of the United States Department of Agriculture Rural Utilities Service (RUS) standard 7 CFR 1755.900 and this Specification.

All fiber optic cable on this project shall be from a currently ISO9001 certified manufacturer who is regularly engaged in the production of this material using the processes noted within this Specification. All outside plant fiber optic cable used on each individual project shall be from only one manufacturer and manufacturer production batch .

Use only cable that is new and of current design and manufacture.

Ensure that multimode optical fiber used in cables meets EIA/TIA-492AAAA, “Detail Specification for 62.5 μm Core Diameter/125 μm Cladding Diameter Class IA Multimode, Graded Index Optical Waveguide Fibers,” Current Edition and conforms to the requirements for multimode optical fiber in the Optical Fiber Specification Table in this Specification.

Ensure that single mode optical fiber used in cables meets EIA/TIA 492-BA000 Class 4A, Current Edition, and conforms to the requirements for single mode optical fiber in the Optical Fiber Specification Table in this Specification.

For hybrid cables, make the single mode fibers the first fibers in the count as specified in EIA/TIA-598-A, “Color Coding of Fiber Optic Cables.”

Ensure that all optical fibers in the cable are usable fibers.

Ensure that all optical fibers are free of surface imperfections and occlusions to meet the optical, mechanical, and environmental requirements of this specification.

Each optical fiber shall consist of a doped silica core surrounded by a concentric silica cladding. The fiber shall be of a matched clad design.

Use fiber coating that is a dual layered, UV cured acrylate applied by the fiber manufacturer. It shall be removable with commercially available stripping tools in a single pass without damaging the fiber.

The fiber optic cable type, configuration, and installation method will be detailed on the Plans, Drawings, Details, Specifications and in the pay items. The cable and cable installation shall conform to all requirements within the Plans and Specifications.

OPTICAL FIBER SPECIFICATION TABLE	
Multimode Optical Fiber:	
Core Diameter	62.5 ± 3.0 μm.
Cladding Diameter	125.0 ± 2.0 μm.
Core-to-Cladding Offset	≤ 3.0 μm.
Cladding Non-Circularity*	≤ 2.0 %.
Core Non-Circularity**	≤ 5.0 %.
Coating Diameter	250 ± 10 μm.
Index	Graded
Numerical Aperture	0.275 ± 0.015
Maximum Attenuation	≤ 3.5 dB/km @ 850 nm ≤ 1.0 dB/km @ 1300 nm
Attenuation Uniformity	No point discontinuities greater than 0.2dB at 850 nm and 1300 nm.
Bandwidth	≥ 160 MHz•km at 850 nm ≥ 500 MHz•km at 1300 nm.
Tensile Strength	100 kpsi (690 MPa)
Single Mode Optical Fiber	
Typical Core Diameter	8.3 μm.
Cladding Diameter	125.0 ± 1.0 μm.
Core-to-Cladding Offset	≤ 0.6 μm.
Cladding Non-Circularity*	≤ 1.0%.
Coating Diameter	245 ± 10 μm.
Maximum Attenuation	≤ 0.40 dB/km @ 1310 nm ≤ 0.30 dB/km @ 1550 nm
Attenuation Uniformity	No point discontinuity greater than 0.10 dB at either 1310 nm or 1550 nm.
Attenuation at the Water Peak	The attenuation at 1383 ± 3 nm shall not exceed 2.1 dB/km.
Cutoff Wavelength	The cabled fiber cutoff wavelength shall be ≤ 1260 nm.
Mode-Field Diameter	9.3 ± 0.5 μm at 1310 nm 10.50 ± 1.00 μm at 1550 nm
Zero Dispersion Wavelength (λo)	1301.5 nm ≤ λo ≤ 1321.5 nm
Zero Dispersion Slope (So)	≤ 0.092 ps/(nm²•km)
Polarization Mode Dispersion	≤ 0.5 ps/sq.rt. km
Maximum Dispersion	≤ 3.2 ps/(nm•km) for 1285 nm to 1330 nm ≤ 18 ps/(nm•km) at 1550 nm.
Tensile Strength	100 kpsi (690 MPa)

* Defined as: [1-(min. cladding dia. ÷ max. cladding dia.)] X 100
** Defined as: [1-(min. core dia. ÷ max. core dia.)] X 100

B. Outside Plant (OSP) Cable

This section sets forth the general standards for fabrication and design of outside plant fiber optic cable.

1. OSP Cable Construction

a. General Requirements: OSP cable shall be an accepted product of the United States Department of Agriculture Rural Utilities Service (RUS) as meeting the requirements of 7 CFR 1755.900.

Only use optical fibers that are placed inside a loose buffer tube.

b. Buffer Tubes: Ensure each buffer tube or ribbon contains up to 12 fibers. The fibers cannot adhere to the inside of the buffer tube.

Use only buffer tubes filled with a non-hygroscopic, non-nutritive to fungus, electrically non-conductive, homogenous gel. The gel shall be free from dirt and foreign matter and readily removable with conventional non-toxic solvents.

Apply binders with sufficient tension to secure the buffer tubes to the central member without crushing the buffer tubes. Use only binders that are non-hygroscopic, non-wicking (or rendered so by the flooding compound), and dielectric with low shrinkage.

c. Cable Core: Protect the cable core with a water blocking material. The water blocking material shall be non-nutritive to fungus, electrically non-conductive and homogenous.

d. Strength Members: Use a central anti-buckling member consisting of a glass reinforced plastic rod to prevent buckling of the cable.

Use high tensile strength aramid, fiberglass, or a combination of aramid and fiberglass yarns to provide tensile strength. Fillers or rods may be included in the cable core to lend symmetry to the cable cross-section where needed.

e. Color : Distinguish each fiber and buffer from others by means of color coding according to the following:

1. Blue	5. Slate	9. Yellow
2. Orange	6. White	10. Violet
3. Green	7. Red	11. Rose
4. Brown	8. Black	12. Aqua

Ensure these colors meet EIA/TIA-598-A, "Color Coding of Fiber Optic Cables."

For cables containing more than 12 buffer tubes, use the color code shown above for tubes 1 through 12, and use stripes or tracers in conjunction with the standard color code for tubes 13 through 24.

The colors shall be stable during temperature cycling and not subject to fading or smearing onto each other or into the gel filling material. Ensure colors do not cause fibers to stick together.

f. Cable Jacket: Include in the cable at least one ripcord under the sheath for easy sheath removal.

Helically strand the high tensile strength yarns evenly around the cable core.

Sheath all dielectric cables with medium density polyethylene. The minimum nominal jacket thickness shall be 0.06 in (1.5 mm). Apply jacketing material directly over the tensile strength members and water-blocking compound. The polyethylene shall contain carbon black to provide ultraviolet light protection and cannot promote the growth of fungus.

Ensure that the jacket or sheath to be free of holes, splits, and blisters.

Ensure that the cable jacket contains no metal elements and is of a consistent thickness.

g. Marking: Mark cable jackets using the following template:

Manufacturer’s Name - Optical Cable - Year - Telephone Handset Symbol - GA DOT - Description

Where the Description conforms to the following depending on cable type:

- Multimode Cable: XXF MM
- Single-Mode Cable: XXF SM

- Hybrid Cable: XXF SM / XXF MM

XX denotes the fiber count

Mark the cable length every meter, every 2 ft if marking the cable in English units. Ensure the actual length of the cable to be within -0/+1% of the length markings.

Use cable marking that is contrasting in color to the cable jacket. The height of the marking shall be approximately 0.10 in (2.5 mm).

2. Additional Requirements for Loose Tube Cable

Use only cable that is all dielectric, loose tube design. Ensure buffer tubes are stranded around a central member using the reverse oscillation, or "SZ", stranding process.

3. Additional Requirements for Ribbon Cable

Ensure that all fibers in a ribbon are parallel and do not cross over each other for the entire length of the cable.

Dimension the ribbon fiber in accordance with FOTP-123, “Measurement of Optical Fiber Ribbon Dimensions.”

Include in the ribbon markings both fiber number and color printed on each fiber.

4. Additional Requirements for Armored Cable

Provide armored cables with an inner sheath of medium density polyethylene. The minimum nominal jacket thickness of the inner sheath shall be 0.04 in (1 mm). Apply the inner jacket directly over the tensile strength members and water blocking material.

Ensure the armor is a corrugated steel tape, plastic-coated on both sides for corrosion resistance, and is applied with an overlapping seam with the corrugations in register.

Apply the outer jacket over the corrugated steel tape armor. Use an outer jacket with a medium density polyethylene and a minimum nominal jacket thickness of 0.06 in (1.5 mm). For the polyethylene, use carbon black to provide ultraviolet light protection and without promoting the growth of fungus.

Use only cable that can withstand a simulated lightning strike with a peak value of the current pulse ≥ 105 kA when tested in accordance with the proposed FOTP-181, "Lightning Damage Susceptibility Test for Optic Cables with Metallic Components." Use a test current that is damped oscillatory with a maximum time-to-peak value of 15 μs (which corresponds to a minimum frequency of 16.7 kHz) and a maximum frequency of 30 kHz. The time to half-value of the waveform envelope (t½) shall be from 40 - 70 μs. Ensure that in addition to the analysis criterion set forth in FOTP-181, the integrity of the buffer tubes (or analogous loose tube, i.e. core tube) and strength members to be intact after removal of the cable specimens from the test box.

5. Additional Requirements for All Dielectric Self Supporting (ADSS) Cable

When shown as such in the Plans, use only cable that is all dielectric and designed for fully self-supporting installation (no messenger cable).

Use high tensile strength, aramid yarns to provide tensile strength.

Ensure that the cable is designed for spans up to 600 ft (200 m) with a typical sag value of 2%.

6. Cable Performance

All OSP cable shall meet or exceed the requirements of the Fiber Optic Test Procedure (FOTP) criteria referenced in 7 CFR 1755.900. Upon the request of the Department, provide certification from an independent testing laboratory that certifies that the cable conforms to the specifications and test procedures.

a. Pulling Tension: Ensure that the cable can withstand a maximum pulling tension of 600 lbf (2.7 kN) during installation (short term) and 200 lbf (890 N) long term installed.

b. Temperature Range: Provide only OSP cable with shipping, storage, and operating temperature range of -40 °F to +160 ° F (-40 °C to +71 °C). The installation temperature range of the cable shall be -20 °F to +160 °F (-30 °C to +71 °C).

C. Inside Plant (IP) Cable

This section sets forth the general standards for fabrication and design of inside plant fiber optic cable.

1. IP Cable Construction

a. Strength Members: For the strength member, use a high modulus U.S. manufactured aramid yarn. The aramid yarns shall be helically stranded around the buffered fibers. Ensure that non-toxic, non-irritant talc is applied to the yarn to allow the yarns to be easily separated from the fibers and the jacket. For all IP cables used in plenum structures, use only IP cable that meets NEC UL-910 requirements for plenum rated cables.

b. Cable Jacket: Ensure the jacket to be continuous, free from pinholes, splits, blisters, or other imperfections. The jacket shall be smooth, as is consistent with the best commercial practice. The jacket should provide the cable with a tough, flexible, protective coating, able to withstand the stresses expected in installation and service.

Use orange cable jackets for multi-mode and yellow cable jackets for single mode.

Design the cable jacket for easy removal without damage to the optical fibers by incorporating a ripcord under each cable jacket. Ensure that a non-toxic, non-irritant talc is applied to the aramid/fiberglass yarns to allow the yarns to be easily separated from the fibers and the jacket.

Ensure that the nominal thickness of the cable outer jacket is sufficient to provide adequate cable protection while meeting the mechanical, flammability, and environmental test requirements of this document over the life of the cable.

c. Color: Use color coded individual fibers for identification. The color coding shall be in accordance with EIA/TIA-598-A “Color Coding of Fiber Optic Cables” as stated in 935.2.B.1.e. Use coloring material that is stable over the temperature range of the cable, is not susceptible to migration, and does not affect the transmission characteristics of the optical fibers. Use color coded buffered fibers that will not adhere to one another. When grouping fibers into individual units, number each unit on the sub-unit jacket for identification. Repeat the number approximately every 6.0 in (150 mm).

d. Marking: Mark the outer cable jacket at least every 3 ft (1 m) with the manufacturer's name or UL file number, date of manufacture, fiber type, flame rating, UL symbol, and sequential length marking (e.g. "62.5/125 MICRON Type OFNR - UL"). Use print color that contrasts to the color of the jacket and is permanent and legible for the life of the cable.

2. Construction by Cable Type

a. Interconnect Cables: Use interconnect cable to connect the distribution panels of a fiber optic cable plant with the actual electronic devices. The cross connect system requires either one or two fiber cable or cordage dependent upon the electronic connector requirement. Construct interconnect cable by surrounding the 900 μm tight buffered fibers with layered U.S. manufactured aramid yarns and a jacket of PVC or Copolymer depending on NEC requirements. Use the aramid yarns as tensile strength members. The cordage shall be allowed in one fiber simplex, two fiber duplex (round) or two fiber ZIP cordage.

b. FDC Interconnect Cable: Use this cable to splice a factory preconnectorized "pig tail" cable on to an OP cable end, routing that cable within an FDC and its splice cabinet, and connecting to the termination panels of the FDC. Construct FDC interconnect cable of 900 μm tight buffered fiber (single mode or multi-mode optical fiber) surrounded with U.S. manufactured aramid fibers, and jacketed with flame retardant jacket material. Ensure that the optical fiber is proof tested to 100 kpsi (690 MPa) and that it meets all the optical fiber requirements of this Specification. Ensure that the factory-installed connectorization meets all requirements of this Specification. Match the fiber count and buffer tube configuration of the FDC interconnect cable to be exactly equivalent to the OP cable being terminated in the FDC, unless additional fibers (using other buffer tube colors) are required for an FDC that is larger than the OP cable. Use an orange exterior jacket for the FDC interconnect cable for multi-mode and a yellow exterior jacket for single-mode. Label FDC interconnect cables exactly as for the OP cable when the FDC interconnect cable must be routed to the exterior of the FDC and its splice cabinet.

c. For cables with less than 8 fibers: Use fibers that are stranded around a U.S. manufactured aramid yarn central member and surrounded by layered U.S. manufactured aramid yarns. Use aramid yarns to serve as the tensile strength member of the

cable. Apply a ripcord between the aramid yarns and the outer jacket to facilitate jacket removal. The outer jacket shall be extruded over the aramid yarns for physical and environmental protection.

d. For cables with 8 to 24 fibers: Use cables that have individual fibers stranded around a glass reinforced plastic (GRP) central member and surrounded by layered U.S. manufactured aramid yarns. The GRP central member provides anti-buckling to ensure consistent attenuation performance across the operating temperature range of the cable. Apply a ripcord between the aramid yarns and the outer jacket to facilitate jacket removal. The outer jacket shall be extruded over the aramid yarns for physical and environmental protection

e. For cables with 24 to 72 fibers: Group together the buffered fibers in six-fiber sub-units. In each sub-unit, strand the individual fibers around a U.S. manufactured aramid yarn central member and surround the sub-unit by layered aramid yarns. Incorporate a ripcord in the sub-unit design to facilitate access to the individual fibers. The sub-unit jacket shall be extruded over the aramid yarns for additional physical and environmental protection. Strand the sub-units around a GRP central member. The GRP central member provides anti-buckling to assure consistent attenuation performance across the operating temperature range of the cable. Insert a ripcord beneath the outer jacket to facilitate jacket removal. The outer jacket shall be extruded around the units for physical and environmental protection.

f. For cables with more than 72 fibers: Group together the buffered fibers in twelve fiber sub-units. In each sub-unit, strand the individual fibers around a dielectric central member and surround the sub-unit by layered aramid yarns. Incorporate a ripcord in the sub-unit design to facilitate access to the individual fibers. The sub-unit jacket shall be extruded over the aramid yarns for additional physical and environmental protection. The sub-units may be stranded around a dielectric central member. Insert a ripcord beneath the outer jacket to facilitate jacket removal. The outer jacket shall be extruded around the units for physical and environmental protection.

3. Temperature Range

Ensure that the storage temperature range for the cable on the original shipping reel to be -40° F to +160° F (-40 °C to +71 ° C). The operating temperature range for riser cables shall be 0 °F to +160 °F (-18 °C to +71 °C). The operating temperature range for plenum cables shall be 32° F to +160° F (0 °C to 71 °C).

4. Crush Resistance Requirements

Ensure that the cable can withstand a minimum compressive load of 0.061 plf (0.89 N/m) applied uniformly over the length of the compressive plate. Use only cable that has been tested in accordance with FOTP-41, “Compressive Loading Resistance of Fiber Optic Cables.” While under the compressive load, the fibers shall not experience an attenuation change of greater than 0.4 dB at 1550 nm for single-mode or greater than 0.6 dB at 1300 nm for multimode. After the compressive load is removed, the fibers shall not experience an attenuation change greater than 0.2 dB at 1550 nm for single-mode or greater than 0.4 dB at 1300 nm for multimode.

5. Impact Resistance Requirements

Use only cable that can withstand a minimum of 20 impact cycles. Use only cable that has been tested in accordance with FOTP-25, “Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies.” The fibers shall not experience an attenuation change greater than 0.2 dB at 1550 nm for single-mode or greater than 0.4 dB at 1300 nm for multimode.

6. Flammability

Use only cables that are UL-listed in accordance with NEC, Article 770. Riser cables (OFNR) shall pass UL-1666. Plenum cables (OFNP) shall pass UL-910.

D. Patch Cords and Pig Tails

1. Patch Cords

Use patch cords consisting of a length of fiber optic cable terminated on both ends. For all IP cables used in plenum structures, use only IP cable that meets NEC UL-910 requirements for plenum rated cables.

a. Construction: Ensure that all factory preconnectorized assemblies adhere to the applicable cable, cordage, and fiber specifications stated in these Specifications.

All inside plant (IP) patch cords shall meet NEC jacketing requirements.

Use orange outer jackets for multimode and yellow jackets for single mode.

Use connector boots of two (2) colors for all duplex patch cords, zip cord or round. Use white or off white for one leg of the duplex cord (non-printed zip leg) and red for the opposite leg (printed zip leg) of the duplex cord.

For all assemblies for outside plant (OSP) where loose tube is used, include a fan-out kit installed at each connectorized end.

Ensure that all connectors conform to Subsection 935.3.04.A.

No splices of any type are allowed within a patch cord assembly.

b. Testing: Fully test each assembly and place those test results on a test tag for each mated pair of connectors. Attach the tag to one end of each pair within the assembly.

Individually package each assembly within a plastic bag and clearly mark on the outside of that bag the submitted manufacturer's part number.

2. Pig Tails

Use pig tails that consist of a length of fiber optic cable terminated on one end. Use only pig tails with factory installed connectors in accordance with Subsection 935.2.F. Provide pig tails with 900 micron tubing or 3 mm fan out tubing as required for the application. Ensure that the other end of the cable is suitable for splicing to another cable. The pig tail shall conform to the same construction and testing requirements as patch cords.

E. Drop Cable Assembly – Outside Plant

Drop cable assembly is defined as a connectorized fiber optic cable (drop cable) and appropriate fan out (if required) used for connectivity between a primary fiber trunk or feeder cable and field devices such as signal controllers, closed circuit television cameras, video detection system cameras, changeable message signs, etc.

1. General Requirements

Provide a loose tube design drop cable in the drop cable assembly meeting the requirements for outside plant cable as specified in Subsection 935.2.B. Provide the drop cable assembly type (multimode, single-mode or hybrid) and fiber count specified in the Plans.

2. Assembly Construction

Provide a drop cable assembly as specified in the Plans and meeting the following requirements. Where drop cables are to be terminated in field cabinets with FDCs, use only drop cables that are factory pre-terminated, that use splice-on factory-connectorized pigtails, or are included in pre-terminated FDCs. Where drop cables are to be terminated in field cabinets without FDCs, use only drop cables that are factory pre-terminated or that use field-installed fan-outs and field-installed connectors. For drop cable terminations without FDCs and for factory pre-terminated drop cable assemblies, label each individual fiber with its drop cable fiber number (“1,” “2,” etc.) on a self-laminating clear overwrapping label on the fan-out tubing within 2 in. (50 mm) of the terminating fiber connector.

a. Pre-terminated Drop Cable Assembly: Install pre-terminated drop cable assemblies with loose tube design fiber optic cable, factory-installed fiber optic connectors in accordance with Subsection 935.2.F on each drop cable fiber, and factory-assembled fan outs with 3 mm fan out tubing. Use metallic crimps between the drop cable strength members and the fan out tubing strength members, and use heat-shrink tubing seals.

b. Field-spliced Drop Cable Assembly: Install field-spliced drop cable assemblies with loose tube design fiber optic cable, fusion spliced factory-connectorized pig tails in accordance with Subsection 935.2.D and Subsection 935.2.F on each drop cable fiber.

c. Fan Out - Loose Tube Cable Design: Install field-installed fan outs (if required) in accordance with Subsection 935.3.05.J. Additionally, secure the fan out tubing to the main cable sheath in a hard epoxy plug transition that extends a minimum of 2.0 in (50 mm) onto the cable and 2.0 in (50 mm) onto the 3 mm tubing.

F. Fiber Optic Connectors

Furnish and install ST compatible connectors unless otherwise specified. Use ceramic ferrule connectors for single-mode and multi-mode applications. Install connectors as per manufacturer application and recommendations, including proper termination to the outer-tubing (900 micron tubing, 3 mm fan out tubing, etc.) required for the application.

Use connectors rated for an operating temperature of -40 °F to +167 °F (-40 °C to +75 °C).

Use only factory-installed connectors for all applications unless otherwise shown in the Plans. Use factory-installed connectors installed with a thermal-set heat-cured epoxy and machine polished mating face.

Where barrel couplers are used in passive termination applications such as FDCs, use only ST compatible ceramic-insert couplers. Use only manufacturer recommended single-mode couplers for single-mode connector applications. Provide dust caps for both sides of couplers at all times until permanent connector installation.

Provide connectors listed below that do not exceed the maximum loss listed for each connector.

Connector Type	Installation	Max. Loss	Typical Loss	Optical Return Loss
Multimode	Field	0.70 dB	N/A	N/A
Single-mode	Field	0.70 dB	0.35 dB	>35 dB
Multimode	Factory	0.50 dB	N/A	N/A
Single-mode	Factory	0.50 dB	0.25 dB	>45 dB

G. Splice Closure - Underground

1. Use

Install closures designed for use under the most severe conditions such as moisture, vibration, impact, cable stress and flex temperature extremes. Splice closures shall pass the factory test procedures and minimum specifications listed below:

2. Physical Requirements

Use a cylindrical closure or rectangular dome type closure with cable entry at one end only and a sealed one-piece high-density polyethylene dome body.

Ensure that the closure prevents the intrusion of water without the use of encapsulate.

Ensure that the closure’s cable entry end has a flexible thermoplastic rubber end seal with pre-template cable ports.

The closure size shown in the Plans specifies the number of splices to be accommodated by the closure. With the closure, provide all materials to accommodate the number of splices specified by the closure size, including splice tray, storage, and organizing materials.

Provide a closure that is capable of accommodating splice organizer trays that accept mechanical, fusion, or multi-fiber array splices. Use a splice closure that has provisions for storing fiber splices in an orderly manner, mountings for splice organizer assemblies, and space for excess or non-spliced fiber. Use splice organizers that are re-enterable and resealable.

Use only UL rated splice cases. Where high fiber count (144 to 432) splice cases are required, use cases that have an external pressurization port for optional pressurization.

Verify that closure re-entry and subsequent reassemble does not require specialized tools or equipment. Further, these operations cannot require the use of additional parts.

Provide a splice closure with provisions for controlling the fiber bend radius to a minimum of 1.5 in (38 mm).

All closures up to the 48-fiber size as shown in the Plans shall have maximum dimensions of 6.5 in. (165 mm) diameter and 23 in. (580 mm) length and shall provide entry of at least four cables of at least 0.75 in. (19 mm) diameter. These closures

shall allow for the storage and express of at least 12 unopened buffer tubes when configured for any number of splices up to 48.

All closures above the 48-fiber size and up to the 144-fiber size as shown in the Plans shall have maximum dimensions of 8.5 in. (216 mm) diameter and 30 in. (760 mm) length and shall provide entry of at least four cables of at least 1.0 in. (25 mm) diameter and at least two additional cables of at least 0.75 in. (19 mm) diameter. These closures shall allow for the storage and express of at least 24 unopened buffer tubes when configured for any number of splices up to 144.

3. Quality Assurance Requirements

Install only underground splice closures that pass the following factory testing:

a. Compression Test: Provide a closure that does not deform more than 10% in its largest cross-sectional dimension when subjected to a uniformly distributed load of 300 lbf (1.3 kN) at a temperature of 0 °F and 100 °F (-18 °C and 38 °C). Perform the test after stabilizing at the required temperature for a minimum of two hours. Place an assembled closure between two flat paralleled surfaces, with the longest closure dimension parallel to the surfaces. Place the weight on the upper surface for a minimum of 15 minutes. Take the measurement with weight in place.

b. Impact Test: Provide an assembled closure capable of withstanding an impact of 21 ft-lb (28 N•m) at temperatures of 10 °F and 100 °F (-12 °C and 38 °C). Perform the test after stabilizing the closure at the required temperature for a minimum of 2 hours. The test fixture shall consist of 20 lb (10 kg) cylindrical steel impacting head with a 2 in (50 mm) spherical radius at the point where it contacts the closure. Drop it from a height of 12 in (0.30 mm). Ensure that the closure does not exhibit any cracks or fractures to the housing that would preclude it from passing the water immersion test. There shall be no permanent deformation to the original diameter or characteristic vertical dimension by more than 5%.

c. Cable Gripping and Sealing Testing: The cable gripping and sealing hardware shall not cause an increase in fiber attenuation in excess of 0.05 dB/fiber at 1550 nm when attached to the cables and the closure assembly. Test by measuring six fibers, one from each buffer tube or channel, or randomly selected in the case of a single fiber bundle. Take measurements from the test fibers, before and after assembly to determine the effects of the cable gripping and sealing hardware on the optical transmission of the fibers.

d. Vibration Test:Provide splice organizers that securely hold the fiber splices and store the excess fiber. Use fiber splice organizers and splice retaining hardware tested per EIA Standard FOP-II, Test Condition I. The individual fibers shall not show an increase in attenuation in excess of 0.1 dB/fiber.

e. Water Immersion Test: Provide a closure capable of preventing a 10 ft (3 m) water head from intruding into the splice compartment for a period of 7 days. Ensure that testing of the splice closure has been accomplished by the placing of the closure into a pressure vessel and filling the vessel with tap water to cover the closure. Apply continuous pressure to the vessel to maintain a hydrostatic head equivalent to 10 ft (3 m) on the closure and cable. Continue this process for 7 days. Remove the closure and open to check for the presence of water. Any intrusion of water in the compartment containing the splices constitutes a failure.

H. Splice Closure - Aerial

1. Use

Design the closure for use in aerial applications and to conform to the requirements below:

2. Physical Requirements

Use a cylindrical closure or rectangular dome type closure with cable entry at one end only and a sealed one-piece high-density polyethylene dome body.

Design the closure for free breathing splice protection without the use of encapsulate.

Provide a closure with fully assembled weather tight closure design.

Ensure that the closure’s cable entry end has a flexible thermoplastic rubber end seal with pre-template cable ports.

The closure shall have corrosion resistant aluminum or stainless steel hardware. Design the aerial closure in such a way as to allow complete splice access after closure placement, without removal of the closure or electrical bonds from the cable. The closure shall be suitable for straight, butt or branch splices. Include provisions for strain relief, both around the cable jacket and to internal cable strength members. The aerial closure design shall eliminate the need for drip collars and sealing collars. Package the closure with all necessary hardware for aerial mounting.

The closure size shown in the Plans specifies the number of splices to be accommodated by the closure. With the closure, provide all materials to accommodate the number of splices specified by the closure size, including splice tray, storage, and organizing materials.

All closures up to the 48-fiber size as shown in the Plans shall have maximum dimensions of 6.5 in. (165 mm) diameter and 23 in. (580 mm) length and shall provide entry of at least four cables of at least 0.75 in. (19 mm) diameter. These closures shall allow for the storage and express of at least eight unopened buffer tubes when configured for any number of splices up to 48.

All closures above the 48-fiber size and up to the 144-fiber size as shown in the Plans shall have maximum dimensions of 8.5 in. (216 mm) diameter and 30 in. (760 mm) length and shall provide entry of at least four cables of at least 1.0 in. (25 mm) diameter and at least two additional cables of at least 0.75 in. (19 mm) diameter. These closures shall allow for the storage and express of at least 12 unopened buffer tubes when configured for any number of splices up to 144.

3. Optical Fiber Organizer

The fiber organizer is a system that holds splice or organizer trays in such a way as to protect and support cable splices within an environmentally protected area. Provide organizer trays capable of storing all common splices; fusion and mechanical, in all configurations; butt, inline and branch (with up to four branch cables). All trays shall be completely re-enterable. Provide only trays able to accept both multi-mode or single mode fibers. The organizer itself shall accept a minimum of four trays, and offer bonding and grounding hardware. The organizer shall offer a simple one piece cable strapping system.

I. Mechanical Lab Splice

Insertion Loss:

Multi-Mode < 0.30 dB

Single Mode < 0.30 dB

Operating Temperature:

-23 °F to 77 °F (-31 °C to 25 °C)

J. Fiber Distribution Center (FDC)

Use rack-mount, wall-mount, or pre-terminated FDCs as specified in the Plans.

Use rack-mount and wall-mount FDCs and FDC splice cabinets with enclosures and mounting components of metallic construction. Use FDC interconnect cable for all OP cable terminations in rack-mount and wall-mount FDCs unless otherwise specified in the Plans.

Use rack-mount FDCs that fit standard 19 inch EIA equipment racks or cabinets.

Use rack-mount FDCs of specified sizes 6-fiber through 24-fiber that have front-opening swing-out drawers for access to the fiber splicing trays and the fiber termination couplers. When closed, the swing-out drawer shall provide a dust-tight seal that completely encloses the fiber splicing trays, fiber termination couplers, and the connecting ends of fiber patch cords connected to the couplers.

Use rack-mount FDCs of specified sizes 36-fiber through 96-fiber that have fixed-mounted front-facing fiber termination couplers accessible behind a removable transparent plastic dust cover.

Use rack-mount FDCs of specified sizes 6-fiber through 48-fiber that include fiber splicing trays integral to the FDC enclosure, accessible through the rear of the FDC or through the swing-out drawer. Use rack-mount FDCs of specified sizes 6-fiber through 48-fiber with a maximum horizontal depth of 24 in (0.61 m) and of the following maximum vertical heights:

- 6-fiber and 12-fiber: 1.75 in (44.5 mm)
- 24-fiber: 3.50 in (88.9 mm)
- 36-fiber and 48-fiber: 7.00 in (178 mm)

Use rack-mount FDCs of specified sizes 60-fiber through 96-fiber that include a separate FDC splice cabinet installed adjacent to the FDC. Alternately, rack-mount FDCs with splice cabinets integral to the overall FDC enclosure but contained in a separated compartment either above or below the FDC termination couplers. Use rack-mount FDCs of specified sizes 60-fiber through 96-fiber with a maximum horizontal depth of 24 in (0.61 m) and of the following maximum vertical height, combined FDC and FDC splice cabinet of 17.50 in (445 mm).

Provide rack-mount and wall-mount FDCs with the appropriate quantity of couplers, panels, splice trays, organizers, FDC interconnect cables, and ancillary materials to terminate the number of fibers as specified by the FDC size, regardless of the cable size to be terminated as shown in the plans. Where factory pre-terminated drop cable assemblies are permitted and to be used, do not provide splice trays.

Use Type A pre-terminated FDCs of specified sizes that are factory manufactured assemblies of fiber optic drop cable with factory-installed fiber connectors and integral ruggedized fiber connector enclosures. Use fiber optic drop cable in accordance with 935.2.B and 935.2.E. Use fiber optic connectors in accordance with 935.2.F. The size of the pre-terminated FDC is defined by the number of fibers in the drop cable, all of which shall be connectorized. Use ruggedized fiber connector enclosures of thermally stable rigid plastic housings fully potted with a thermally stable epoxy filling that encapsulates the drop cable fan out, fibers and connector bodies. Use permanent labels on the enclosure with contrasting color to identify each connector body by its associated fiber number. Provide a unique serial number permanently attached on each pre-terminated FDC. Provide a non-metallic cable strain-relief boot where the drop cable enters the fiber connector enclosure and that secures the cable and to the enclosure; the strain-relief boot shall fully encircle the cable for a minimum of 2 inches (51 mm) from the enclosure's outer surface. Use fiber connector enclosures that are no more than 2 inches (51 mm) wide and deep (the maximum dimension of the enclosure plus fiber connector body). Use 4 fiber and 6 fiber enclosures that are no more than 11 inches(280 mm) long and 12 fiber enclosures that are no more than 14 inches (356 mm) long. All fiber connectors shall be arranged on one of the long (vertical) faces of the enclosure. Provide an 0.125 in. (3.175 mm) thick aluminum mounting plate that secures to the fiber connector enclosure. The mounting plate shall have at least four mounting holes near the plate's corners that permit horizontal or vertical mounting flush to a panel, and are spaced appropriately for vertical mounting to an EIA equipment rack rail using two of the mounting holes.

For FDCs of all types, provide couplers with dust caps in accordance 935.2.F. Use only ST compatible couplers unless otherwise specified.

K. Transceivers

1. External Transceiver

Provide external transceivers that meet the following requirements:

- Daisy chained, linear multi-drop configuration.
- Asynchronous, full duplex RS 232 communication.
- Meet NEMA TS-1-1989 environmental standards for power interruption, temperature and humidity, power service transients, non-destruct transients, vibration and shock. Conformance with equivalent environmental standards by other entities may be submitted for consideration.
- External, female ST connectors with T1, R1, T2, R2 ports for fiber connection.
- External female DB-25, DB-9, or terminal block RS 232 connector.
- External indicator LEDs for power, transmit & receive (each channel).
- Multimode transceiver operates at 1300 nm (minimum 14 dB power budget).
- Single mode transceiver operates at 1310 nm (minimum 21 dB power budget).

- Receiver dynamic range that is a minimum of 2 dB greater than the manufacturer's specified power budget. The transceiver shall fully maintain all operational performance characteristics throughout the full receiver dynamic range, including a 0 dB path loss.

- Anti-streaming communications.

- Single mode transmitter units incorporate laser diode optical emitters.

- Internal, nickel-cadmium trickle charge battery for a minimum of six (6) hour backup operation. The battery shall be designed to have minimized degradation to reliability during extended periods of trickle charge operation. Use corrosion resistant battery contacts.

- Metal housing with maximum dimensions of 8" x 5" x 2" (200 mm x 130 mm x 50 mm). The metal housing shall have flanged mounting brackets to allow for permanent mounting with screws.

Do not use internal card-type units in field devices, such as traffic signal controllers, CCTV system controllers, and changeable message sign controllers.

Provide external transceivers in the control center or communications hub that meet the additional following requirements:

- Permanently rack mounted within a card cage with a self-contained rack power supply

- Card cage shall be provided per project requirements.

2. External Star Transceiver

Provide an RS232 data optical star transceiver meeting all requirements of the external transceiver in Subsection 935.2.K.1 with the following modifications:

The star transceiver shall be designed for multi-drop configuration with three optical data ports and one electrical equipment data connection port, to be applied in a drop-and-repeat optical three-way to "T" installation.

Verify that the star transceiver is fully compatible and operable with the linear drop-and-repeat transceiver specified in Subsection 935.2.K.1.

935.2.02 Delivery, Storage, and Handling

Package the cable for shipment on reels. Each package shall contain only one continuous length of cable. Construct the packaging so as to prevent damage to the cable during shipping and handling.

Seal both ends of the cable to prevent the ingress of moisture.

Include with each reel a weatherproof reel tag attached identifying the reel and cable that can be used by the manufacturer to trace the manufacturing history of the cable and the fiber.

Include with each cable a cable data sheet containing the following information:

- Manufacturer name

- Cable part number

- Factory order number

- Cable length

- Factory measured attenuation of each fiber

- Bandwidth specification (where applicable)

- Index of refraction

When the length of an order requires a reel greater than 3 ft (0.9 m) in diameter, apply a protective coating around the cable before shipment. Cover the cable with a thermal wrap. Securely fasten the outer end of the cable to the reel head so as to prevent the cable from becoming loose in transit. Project the inner end of the cable a minimum of 6.5 ft (2.0 m) into a slot in the side of the reel or into a housing on the inner slot of the drum, in such a manner to make it available for testing.

Plainly mark each reel to indicate the direction in which it is to be rolled to prevent loosening of the cable on the reel.

935.3 Construction Requirements

935.3.01 Personnel

A. Section deleted

935.3.02 Equipment

Furnish a portable fiber optic light source and power meter test set for testing the fiber optic cable. Provide a test set matched, calibrated and referenced to work as a synchronized test system. Include 850 and 1300 nm light sources by LED and 1300 and 1550 nm light source by laser. Provide a power meter capable of measuring the optical loss from all of the above sources. Provide a power meter capable of a resolution of at least 0.1 dB and a power range of at least +10 to –60 dB. Provide connectors and adapters for ST and duplex SC connectors. The light sources and power meter shall be capable of 120 VAC line power or rechargeable battery power. Provide a portable battery-operated printer for direct reports of test measurements, and provide PC software for uploading and storing test measurements on a computer. Provide protective padded carrying cases for all test set components, including test cables and adapters. Include complete instruction and training in the use of the test set in the training required in Subsection 935.3.08. This equipment shall remain the property of the Contractor.

935.3.03 Preparation

Not applicable

935.3.04 Fabrication

A. Fiber Optic Connectors

Furnish and install connectors with ceramic ferrules, with the fibers permanently secured within the ferrule with epoxy, heat set or air dried, as specified by the connector manufacturer.

Install connectors according to the manufacturers recommended practice.

935.3.05 Construction

A. OSP and IP Cable Installation

Submit for approval a detailed construction and installation procedure (SOP) covering all aspects of the construction and installation process for each and all specific cable to be used on this project. Secure from the cable manufacturer the construction and installation procedures to be used on the project. The SOP shall be submitted for review by the Engineer. Maintain traffic control that adheres to Section 150 of the Georgia Specifications.

B. Cable Installation Procedures and Standards

1. Safety Precautions

Follow all appropriate OSHA and industry standards related to safety when working in manholes or underground vaults and when handling optical fibers.

2. Cable Handling

Install all fiber optic cable according to the manufacturer’s recommended procedures and these specifications.

3. Pulling Tension

Do not exceed the maximum recommended pulling tension during installation as specified by the cable manufacturer.

4. Allowable Bend Radius

Do not violate the minimum recommended bend radius during installation as specified by the cable manufacturer. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:

20 X Cable Diameter	Short Term - During Installation
10 X Cable Diameter	Long Term - Installed

5. Cable Installation Guidelines

Before the installation begins, carefully inspect the cable reels for imperfections such as nails that might cause damage to the cable as it is unreeled.

Take all necessary precautions to protect reeled cable from vandals or other sources of possible damage while unattended. Any damage to the cable sections may require replacement of the entire section.

Whenever unreeled cable is placed on the pavement or surface above a manhole, provide means of preventing vehicular or pedestrian traffic through the area in accordance with Section 150 of the Specifications.

Use the "figure-eight" cable lay configuration to prevent kinking or twisting when the cable is unreeled or backfed. Do not coil fiber optic cable in a continuous direction except for lengths of 100 ft (30 m) or less. The preferred size for the "figure-eight" is 15 ft (5 m) in length, with each loop 5 ft to 8 ft (1.5 m to 2.4 m) in diameter. When "figure-eighting" cable, exercise care to relieve pressure on the cable at the crossover of the eight. This may be done by placing cardboard shims at the crossover or by forming a second "figure-eight".

Keep the cable continuous throughout the pull. Cable breaks are allowed only at designated splice points.

Where messenger cable is required, as shown in the Plans, lash aerial fiber optic cable to a steel strand wire messenger cable of the size specified in the plans that conforms to Standard Specification 915.02.

6. Cable End Sealing

Where a cable ends without termination in a fiber optic closure, seal the end of the cable by re-using a cable end cap that is shipped with a cable reel. Use a cap that is size-matched to the cable to be sealed. Clean the end of the cable. Partly fill the cap with a waterproof silicone adhesive sealant and press the cap fully onto the cable end, rotating the cap to fully encapsulate the cable end with the sealant in the cap. Apply a full sealant bead between the end of the cap and the cable jacket.

C. Cable Storage

At designated intervals throughout the cable plant, pull and store excess cable for slack for future terminations or splicing.

1. Cable Storage Requirements - Underground (OSP) & IP

Unless otherwise noted on the plans, the following are the requirements for cable storage for underground and IP applications:

- Pull Box – (Type 1, 2, 3, 4, 4S, 5, 5S) Apply the following storage requirements for the indicated cable/closure situations.
    - Drop cable with no closure – 10 ft. (3 m)
    - One or more trunk cables with no closure – 110 ft. (34 m) of each cable
    - Two or more trunk cables with one closure – store 55 ft. (17 m) of each trunk cable so that the closure can be removed from the pull box approximately 55 ft. (17 m). If a drop cable is spliced to the trunk cable at this point, store 55 ft. (17 m) of each drop cable.

- One trunk cable with one closure – 110 ft. (34 m) Install closure in the center of the 110 ft. (34 m) cable loop, so that the closure can be removed from the ECB approximately 55 ft. (17 m). If a drop cable is spliced to the trunk cable at this point, store 55 ft. (17 m) of each drop cable.

- One trunk cable with one closure and trunk cable ends – 95 ft (30 m). Install closure on the trunk cable at 55 ft (17 m) from the pull box. If a drop cable is spliced to the trunk cable at this point, store 55 ft (17 m) of each drop cable.

- Trunk cable ends with no closure – 95 ft. (30 m)

- Hub Building *(interior)* – Do not store slack cable inside the hub building.

- Hub Building (exterior adjacent ECBs) – 180 ft (55 m)

- Traffic Control Center & Transportation Management Center (OSP splice vault) – 65 ft (20 m)

- Traffic Control Center & Transportation Management Center (IP at equipment room) – cable entrance to distribution panel bay plus 20 ft (6 m)

- Electrical Communication Box (ECB) (Type 1, 2, 3, 4, 5) Apply the following storage requirements for the indicated cable/closure situations. More than one situation may occur in a single electrical communication box, in which case apply each appropriate requirement.

  - Trunk cable with no closure – 110 ft (34 m)

  - Trunk cable with one closure – 110 ft (34 m). Measure the storage amount from the top of the ECB manhole opening. Install closure in the center of the 110 ft (34 m) cable loop, so that the closure can be removed from the ECB approximately 55 ft (17 m). If a drop cable(s) is spliced to the trunk cable at this point, store 55 ft (17 m) of each drop cable.

  - Trunk cable with one closure and trunk cable ends – 95 ft (30 m). Install closure at 55 ft (17 m) from the ECB on the trunk cable. If a drop cable(s) is spliced to the trunk cable at this point, store 55 ft (17 m) of each drop cable.

  - Trunk cable ends with no closure – 95 ft (30 m)

2. Minimum Cable Storage Requirements - Aerial Applications

Unless otherwise noted on the plans, the following are the minimum requirements for cable storage for aerial applications:

Install a minimum 150 ft (45 m) storage loop approximately one half the distance between every equipment drop or as shown in the Plans. Where equipment drops are greater than 1000 ft (300 m) apart, install a minimum 150 ft (45 m) storage loop for every 1000 ft (300 m)of uninterrupted cable length.

At aerial splice closures, install 75 ft. (23 m) of drop cable storage and 150 ft. (45 m) of trunk cable storage, unless otherwise noted in the Plans, to allow the fully assembled closure, including the trunk cable and drop cable, to be lowered to ground level for maintenance purposes.

3. Cable Storage

Properly store all cable to minimize susceptibility to damage. Maintain proper bend radius, both short and long term, during cable storage.

a. Communication and Pull Boxes: Store the excess or slack cable in the pull box or communication box in accordance with the Plans details.

b. Hub/TMC/TCC: Properly store the cable in cable troughs and plenum applications which meet NEC requirements.

c. Aerial Installations: Store the excess or slack cable at storage loops in a “bow tie” configuration on the messenger strand using two fiber optic snowshoes (aerial fiber cable storage brackets) that maintain the proper bend radius in the fiber cable. Install one fiber optic snowshoe for drop cable and trunk cable storage at aerial splice closures to maintain the proper bend radius in the fiber optic cable.

D. Cable Splicing

Splice together each individual reel of fiber optic cable that makes up the continuous length of installed cable called for on this Project. Splice cable only at splice points designated on the plans. Make no splices within a patch cord assembly or drop cable.

E. Mid Span/Drop Access

At points where mid span/drop access is required, keep all fibers intact except those that are being accessed for the equipment drop. Use a suitable tool for removing fibers from the buffer tube to prevent damage to the fibers that will remain intact.

F. Connector Termination Procedures

Only use procedures for the termination of the connectors that meet the process set out in that connector manufacturer's standard operating procedure (SOP) for the field installation.

G. Cable Marking

1. Materials

Use 2-1/2" (63.5 mm) wide, 4" (100 mm) long, wrap-around type cable markers suitable for underground and aerial use. Use UV stabilized marker material and printing inks to provide an aerial durability of at least five years.

Print text in bold black type on orange or yellow PVC markers, as specified in Section 935.3.05.G.2. Use base material that is minimum 0.015" (0.38 mm) thickness PVC. Pre-print the following text legibly on markers used for all cables:

Cable ID: XXXXXXX
GA DOT
Optical Cable

Where XXXXXXX is the appropriate cable ID as defined in the Plans.

Print the text specified above twice on every cable marker with the text of the second image reversed and abutting the first image. The end result shall be text which “reads right” when either short edge of the cable marker is held horizontally upright.

2. Installation

Clean the installed cable of all dirt and grease before applying any marker. Follow the marker manufacturer’s recommended procedure for applying cable markers. Mark all cables in or at every communications hub, electrical communications box, pull box, handhole, equipment cabinet, aerial or underground splice closure, pole attachment, aerial storage bracket, and pole conduit riser entrance. At every trunk cable termination, reel end-to-reel end splice, electrical communications box, pull box, handhole, equipment cabinet, aerial splice closure, and aerial storage bracket, record the cable distance markings from the printline for the cable entry and exit, along with the exact location by Station Number or location name. Record the cable distance markings in a tabular format approved by the Engineer or on a documentation form provided by the Department.

Place cable markers in the following locations:

- within 18 in (460 mm) of every cable entry to a pull box, handhole, ECB and hub building
- within 6 in (150 mm) of every cable entry or termination in an equipment cabinet
- within 18 in (460 mm) of every splice closure at cable entry points
- within 6 in (150 mm) of every FDC or splice cabinet in a hub building in which a cable terminates or enters
- every 20 ft (6 m) for the length of a cable in maintenance coils in electrical communications boxes or pull boxes
- within 12 in (0.30 m) of every pole attachment, aerial storage bracket, and pole conduit riser entrance

Use orange markers at all locations, except as noted below:

- Where a trunk cable enters and leaves a closure (mid-span cable entry or end-to-end splice), use orange markers for one leg of the trunk cable and yellow for the other leg, placing corresponding color labels at the closure end of a leg and at the conduit entrance (underground installation) or span attachment (aerial installation).

- Where two drop cables terminate in a closure, use orange markers for one drop cable and yellow markers for the other drop cable, throughout the entire drop cable's length to its other termination.

H. Fusion Splicing

1. Use

Unless otherwise noted, fusion splice all fiber optic splices.

2. Procedure

Fusion splicing consists of aligning the cores of two clean, cleaved fibers or a group of such fibers and fusing the ends together with an electric arc. Position the fiber ends under a microscope or a high-resolution video monitor and then align them using precision movement micro-positioners. High-voltage electrodes contained in the splicer conduct an arc across the fiber ends as the fibers are moved together, thus fusing the fibers together. Verify maximum core alignment prior to splicing and estimate splice loss after the fusion process by the use of light injection and detection devices or profile alignment algorithms.

Install all splice enclosures according to the manufacturer's recommended guidelines.

3. Splice Protection

Adequately protect all fusion splices in splice trays or organizers in an enclosure. When splicing inside a building, use a splice center where rack or wall space is available.

Provide the splice with strain relief and protection of the stripped fiber splice in a manner recommended by the splice tray or organizer manufacturer. Use splice types compatible with the tray design.

Protect fusion splices with a heat shrink tubing that protects the splice and extends over the fiber coating. No bare fiber may be exposed.

I. Mechanical Splicing

1. Use

Where designated on the plans, splice fiber optic cable using a mechanical splice.

2. Procedure

Make all mechanical splices of the strain relief/locking type requiring no adhesive or polishing of the fiber ends. Ensure the fibers are self-aligning upon the closing of the mechanical splice. The splices shall have the capability of splicing multi-mode or single mode fiber, and with any combination of buffer coating (250 μm and 900 μm). The splice shall be of one piece construction. Ensure that there is no stress on the fiber in the alignment area.

Install all splice closures according to the manufacturer's recommended guidelines.

3. Lab Splice

Use a mechanical fiber optic lab splice when a temporary joining of two fibers is required, such as in the testing of non-terminated fiber. These splices may be used on single mode or multi-mode optical fiber. Ensure the lab splice is re-usable for up to 50 matings. The lab splice shall accommodate optical fibers with cladding diameters between 120 and 145 μm.

J. Fiber Optic Cable Fan Out

1. Inside Plant

Provide all inside plant cable with a fan out in accordance with the manufacturer's recommended guidelines. In protected environments such as a splice case, protect the fiber with a minimum 900 μm jacket. In all other instances, protect the fiber with 3 mm fan out tubing. Install only connectors meeting the requirements for connectors set forth in Subsections 935.3.04.A and 935.2.F.

2. Outside Plant

Up-jacket individual 250 or 900 micron fibers to 3 mm using fan out tubing. Include in the fan out tubing aramid yarn strength members and an outer protective jacket. The individual leg length shall be 3 ft +/- 2 in (0.9 m +/- 50 mm).

K. Temporary Fiber Optic Cable

Furnish and install one continuous temporary fiber optic cable system as shown in the Plans. Terminate the cable and patch cords as required in the Plans, splice the cable along cable route at the points indicated in the Plans.

L. External Transceivers

Shelf mount external transceivers in a manner that does not restrict the replacement of other components in the cabinet housing. In Type 170 traffic cabinets mount the transceiver on an aluminum shelf permanently attached to the EIA 19" cabinet rack in the rear of the cabinet.

M. Fiber Distribution Center (FDC)

Do not install mechanical splices or field installed connectors. Equip unused panel slots with blank panels. Provide inter-cabinet and inter-bay bend radius and jumper management on each side of the FDC. Install all hardware according to the manufacturer's recommended procedures and Department standards. Determine specific hardware sizing from the project documents.

For rack-mount and wall-mount FDCs, array connectors in a vertical pattern with number one being at the top left position.

Prior to manufacture of pre-terminated FDCs, verify the final installed location of all portions of each drop cable route from the splice closure to the equipment cabinet (including but not limited to the cabinet location, all conduit and pullboxes, and the splice closure location) to determine the required length of drop cable, including all splice closure and storage coils, to be factory manufactured with each FDC. In Type A Equipment Cabinets, mount pre-terminated FDCs on the side panel in a vertical position, as shown in the equipment cabinet details. Mount the pre-terminated FDCs with the connectors horizontal or facing downward, and route the drop cable up or down as necessary. Route and secure the drop cable beside or behind the cabinet side panel such that it is fully strain-relieved, does not violate the manufacturer's recommended bending radius, and does not interfere with the operation of or access to any cabinet equipment or electrical components.

935.3.06 Quality Acceptance

A. Underground Splice Closures

Ensure that an independent testing laboratory has performed all tests described in Subsection 935.2.G. Provide certification from an independent testing laboratory as required in Subsection 935.3.1.

B. Fiber Optic Cable

1. Installation Test

Test the fiber optic cabling installed on this project according to the fiber's assigned use as shown in the plans and as defined below:

- Terminated Fibers: terminated fibers are defined as fibers that are terminated on both ends, providing an end-to-end link from the hub to a device or between devices

- Spare Fibers: spare fibers are defined as fibers not being connected with this project to a device and that may be terminated at one end and stored at the other end, or stored at both ends. Spare fibers may or may not be spliced through two or more different trunk cables.

Upon completion of the cable installation, splicing, and termination, and a minimum of fourteen days before equipment hookup, test all terminated fibers and spare fibers for continuity, events above 0.10 dB, and total attenuation of the cable. In the event that fiber optic cable installed on this project is connected to existing fiber optic cable, perform installation testing on both terminated fibers and spare fibers of the new cable and existing fibers to which the new fibers are spliced or connected. Submit both printed and electronic (diskette) OTDR traces as specified in Subsection 935.1.03. Submit copies of the cable distance marking documentation as required in 935.3.05.G.2.

2. Test Requirements

a. OTDR Test: For all single mode and multi-mode fiber links, test and document the installation using OTDR testing.

A certified technician (See 935.3.01) shall conduct the installation test using an optical time domain reflectometer (OTDR) and optical source/power meter. The technician is directed to conduct the test using the standard operating procedure as defined by the manufacturer of the test equipment. The OTDR to be used shall be capable of performing standard OTDR functions, including the ability to display individual loss/gain in dB per km, as well as display all 2-point dB loss cursors to allow isolating and viewing any and all points along a given fiber distance.

Use a factory patch cord of a length equal to the "dead zone" of the OTDR to connect the OTDR and the cable. Optionally, the Technician can use a factory "fiber box" of 325 ft (100 m) minimum with no splices within the box.

Conduct the tests at 1300 nm for multimode cable and at 1310/1550 nm for single mode cable.

b. Attenuation Test: For all single mode and multi-mode fiber links, test and document attenuation by a standard power-meter test.

For every fiber installed or connected to under this Contract, perform end-to-end attenuation test. For the test, use a calibrated optical source and power meter using the standard three-stage procedure. Determine acceptable link attenuation by the cumulative value of standard losses based on length, number and type of splices and connectors.

3. Fiber Optic Cable Acceptance

Use the following criteria for acceptance of the cable:

Provide test results demonstrating that the dB/km loss does not exceed +3% of the factory test or 1% of the cable's published production loss. Consider the error rate for the test equipment in the test.

No event can exceed 0.10 dB. If any event is detected above 0.10 dB, replace or repair that event point.

The total dB loss of the cable, less events, cannot exceed the manufacturer's production specifications as follows:

Cable Type	Max. Attenuation dB/km	Test Wavelength
Singlemode	0.30	1550 nm
	0.40	1310 nm
Multimode	1.0	1300 nm

If the total loss exceeds these specifications, replace or repair that cable run and assume all expenses, both labor and materials. Elevated attenuation due to exceeding the pulling tension during installation will require the replacement of the cable run at no expense to the Department for either labor or materials.

NOTE: The Department may allow the "bi-directional/averaging" process of OTDR testing, particularly when splice losses are being unfavorably affected by "mode field diameter misalignment," "core off-set" or "core misalignment."

C. Fusion Splicing

Ensure that the maximum splice loss for any fusion splice does not exceed 0.10 dB.

D. Mechanical Splicing

Ensure that the maximum splice loss for mechanical splices does not exceed 0.70 dB.

E. Fiber Distribution Center (FDC)

Test all completed and assembled pre-terminated FDCs at the point of manufacture and provide two copies of the manufacturer test documentation. Test each connecterized fiber in the pre-terminated FDC to demonstrate compliance with all requirements for cables and connectors as detailed in other subsections of these specifications. Include in the test documentation the location station number where the FDC is to be installed, the serial number of the pre-terminated FDC, the drop cable footage markings at each end of the drop cable, and the total drop cable distance. Place one copy of the manufacturer test documentation in the equipment cabinet drawer where the pre-terminated FDC is installed, and submit the other copy to the Engineer.

935.3.07 Contractor Warranty and Maintenance

Provide a Manufacturer support (usual and customary warranties) period for all fiber optic cable materials furnished and installed as part of the fiber cable system. Include in warranty and support all contractor or manufacturer activities related to maintenance, removal and replacement of cabling, closures and other fiber optic system materials during the period of support. Begin the Manufacturer warranty support period upon successful completion of the Fiber Optic Quality Acceptance testing as outlined in Subsection of 935.3.06. All Manufacturer warranties shall be continuous throughout the period and state that they are subject to transfer to the Department.

935.3.08 Training

Provide both installation and maintenance training on fiber optic cable to selected Department personnel. Personnel trained by the manufacturer of the fiber optic cable furnished on this project and authorized by said manufacturer shall perform the training. Furnish a training notebook in a labeled 3-ring binder to each trainee.

Provide a location to hold the courses that is an acceptable indoor and comfortable location near the project area. If requesting that the training be conducted away from the project area, pay all costs associated with travel and accommodation of all students.

Provide installation and maintenance training for up to eight (8) people. Include in this training both classroom training and hands-on training. All training shall be conducted in half-day sessions. Two half-day sessions may be held on the same day. The training will consist of classroom instruction and field training applications. The contractor shall provide and schedule training at least 5 working days prior to fiber cable being installed on the project The total of the installation and maintenance training shall consist of at least forty (40) clock hours of training for each participant. Cover all aspects of inside plant and outside plant fiber optic cable installation, maintenance, and trouble-shooting including the use of all recommended test equipment. Ensure that all equipment, materials, and procedures used in the training comply with the requirements of Section 935.

As a minimum, include in the fiber optic training the following:

THEORY

- Light
    - Light transmission through fiber cable with discussion on effect of cable composition.
    - Theory definitions
- Electromagnetic spectrum
    - Composition of light
    - transmission of differing spectrums of light
- Refraction/reflection (Effects of light within fiber cable and relationship of light against core and cladding materials)
- Attenuation (Effects of fiber cable on transmission speeds of light)

- Signal wavelength selection (single-mode, multi-mode)
    - Selection of cable based on application
    - advantages of each cable
- Signal transmission form
    - Analog, digital
    - Bandwidth

SAFETY

- Working with optical fibers
    - Handling precautions
    - Working with lasers
    - Chemicals used in preparation, maintenance, splicing

ADVANTAGES/DISADVANTAGES

- Comparison of fiber optic cable to copper cable

COMPARISONS

- Fiber optic cable sizes and characteristics (capacities, weights, single-mode, multi-mode)

FIBER

- Types of propagation
- Multi-mode - characteristics and applications MM fiber spools
- Single-mode - characteristics and applications SM fiber spools
- Fiber cross sections, 250 μm and 900 μm fiber
- Fiber characteristics and specifications
- Fiber manufacturing

CABLE

- Loose tube designs, sample cable
- Tight buffer designs, cable samples
- Selection of cable to environment
- Cable for strip/prep for fan-out kit installation

CONNECTORS/COUPLINGS

- Connector designs, connectors/couplings samples
- Connectors in fiber systems
    - Installation of 900 μm fan-outs on loose tube cable, buffer tube fan-out
    - Installation of 3.0 mm fan-outs on central core cable, 3.00 mm fan-out tubing

- Installation of Spider fan-out on loose tube cable, spider fan-out.
- Field installation of MM/SM connectors (attendees terminate ends of cables with connectors)

SPLICING

- Fiber preparation and cleaving
- Factors effecting splice loss
- Splice trays
- Splices
  - Fusion and mechanical
  - Mechanical splice installation, mechanical splice demo
  - Fusion splicing class demonstration

DISTRIBUTION HARDWARE

- Distribution equipment (FDC)
- Wall and rack mount distribution equipment
- Field connecting, pigtails
- Field installation of connectors, demonstrate loose tube cable

INSTALLATION/MAINTENANCE

- Installation of outside plant cable (OSP) and closures
- Installation of inside plant cable (ISP)

TESTING AND TROUBLESHOOTING

- Power meter and light source usage, demonstration and test
- Visual fault locator usage, demonstration and test
- OTDR usage, demonstration and explanation of trace results with samples of multi-mode and single mode fiber
- Interpretation of OTDR reports on single and multi-mode fiber

FIBER IN ITS AND TRAFFIC SIGNAL CLOSED LOOP APPLICATIONS

- Typical architectures course book
- Closed loop traffic interconnect, trunk and drop/point to point connection
- CCTV/VDS trunk and drop/point to point
- Overall GDOT system architectures

935.4 Measurement

Fiber optic system, temporary fiber optic system, testing and training that is complete, in place, accepted and of the kind, size, and type specified is measured as follows.

A. Fiber Optic Cable

Fiber optic cable is measured for payment by the actual number of linear feet installed, complete, functional, and accepted.

B. Pig Tails

Pig tails are measured for payment by the actual number of linear feet installed, complete, functional, and accepted. Factory-connectorized pigtails associated with drop cable assembly and FDCs, in accordance with Section 935.2, will not be measured separately for payment.

C. Closures

Underground splice closures, aerial splice closures, and FDCs are measured for payment by the actual number of units installed, complete, functional and accepted.

D. Fiber Optic Splice

Fiber optic splices, whether fusion, mechanical, or lab, are measured for payment by the actual number of splices made, complete, and accepted. Fiber optic splices associated with the use of factory-connectorized pigtails on drop cables, in accordance with Section 935.2, will not be measured separately for payment.

E. Fiber Optic Cable Fan Out

Fan out kits are measured for payment by the actual number of units installed, complete, functional and accepted.

F. Fiber Optic Connectors

Fiber optic connectors are measured for payment by the actual number of units installed, complete, functional and accepted. Fiber optic connectors associated with the use of factory-connectorized pigtails, in accordance with Section 935.2, will not be measured separately for payment.

G. Patch Cords

Patch cords are measured for payment by the actual number of units installed, complete, functional and accepted.

H. Fiber Optic Snowshoe

Fiber optic snowshoes are measured for payment by the actual number of units installed, complete, functional, and accepted.

I. Temporary Fiber Optic System

Payment for work on the Temporary Fiber Optic System will be a lump sum project bid price and will be considered full compensation for all installed materials and labor associated with the Temporary Fiber Optic System. Specific items include but are not limited to timber poles, guys, anchors, lashing, messenger cable, conduit directional boring, conduit, fiber optic cable, fusion splicing, hardware attachments, splice enclosures, equipment rentals, and disposal of materials.

J. Transceivers

External drop and repeat transceivers and external star transceivers are measured for payment by the number actually installed, complete, functional, and accepted.

For each unit installed, furnish and install all mounting and interconnection materials, including but not limited to card cages, hardware, fiber and RS-232 jumper cables, RS232/485 converters, and power supply cables at no separate cost to the Department.

K. Testing

Testing is measured as a lump sum for full delivery of testing and acceptance requirements. Measurement of testing includes subsistence necessary to conduct the testing.

L. Training

Training is measured as a lump sum for all supplies, equipment, materials, handouts, travel, and subsistence necessary to conduct the training.

935.4.02 Limits

Not applicable

935.5 Payment

Fiber optic cable, pig tails, closures, splices, fiber optic cable fan out, fiber optic connectors, patch cords, fiber optic snowshoes, temporary fiber optic system, and testing are paid for at the Contract Unit Price for the various items. Payment is full compensation for furnishing and installing the items complete and in place according to this Specification, with the exception of Training.

Training is paid for on a partial payment basis as follows:

The Department will pay 25% of the total contract bid amount for this item upon approval of the Training Plan. The Department will pay the remaining 75% after completion of all training as described in Subsection 935.3.08. The total sum of all payments cannot exceed the original contract amount for this item. Payment for all items of this Section is as follows:

Payment will be made under:

Item No. 935	Outside Plant Fiber Optic Cable (type, mode, size)	Linear Feet
Item No. 935	Inside Plant Fiber Optic Cable (type, mode, size)	Linear Feet
Item No. 935	Fiber Optic Pigtail (mode, size)	Linear Feet
Item No. 935	Fiber Optic Closure	Per Each
Item No. 935	Fiber Optic Splice	Per Each
Item No. 935	Fiber Optic Fan Out Kit	Per Each
Item No. 935	Fiber Optic Connectors (mode)	Per Each
Item No. 935	Fiber Optic Patch Cord (mode)	Per Each
Item No. 935	Fiber Optic Snowshoe	Per Each
Item No. 935	Temporary Fiber Optic System	Lump Sum
Item No. 935	External Transceiver (mode)	Per Each
Item No. 935	External Star Transceiver (mode)	Per Each
Item No. 935	Testing	Lump Sum
Item No. 935	Training	Lump Sum

935.5.01 Adjustments

Not applicable