Section 935—Fiber Optic System

935.1 Fiber Optic System

This work includes the installation of fiber optic cable and equipment including but not limited to the following:

- Cable
- Interconnect
- Patch cords
- Pig tails
- Cable related hardware
- Connectors
- Splices
- Closures
- Temporary systems
- Testing
- Training
- Other fiber optic products specified on the Plans or in any other Section of these Specifications.

935.1.01 Definitions

General Provisions 101 through 150.

935.1.02 Related References

A. Standard Specifications

Section 150—Traffic Control

Section 639—Strain Poles for Overhead Sign and Signal Assemblies

Section 647—Traffic Signal Installation

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

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 Specifications, 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. 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. 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 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.

E. Fiber Optic Test Documentation

Provide the date, time and location of any tests required by this specification (see Subsection 935.3.06) to the Engineer at least 24 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. Cable & Fiber Identification
   - Cable ID
   - Cable Location - begin and end point
   - Fiber ID, including tube and fiber color
   - Operator Name
   - Date & Time
2. Setup Parameters
   - Wavelength
   - Pulse width Optical Time Domain Reflectormeter (OTDR)
   - Refractory index (OTDR)
   - Range (OTDR)
   - Scale (OTDR)
3. Test Results
   a. OTDR Test
      - Total Fiber Trace (mile or kilometer)
      - Splice Loss/Gain (dB per mile or km)
      - Events > 0.10 dB
      - Measured Length (Cable Marking)
      - Total Length (OTDR) (mile or km)
      - Also provide traces on a diskette to the Engineer.
   b. End – To – End Attenuation Test

- Length, number and type of splices and connectors
- Link attenuation

F. As-Built Documentation

Submit as built documentation of all work provided in accordance with this specification prior to Final Acceptance of the Project. 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.

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.

4. As Built Drawings

   Provide the Department with drawings that detail the final installation route of all cable.

   Except for standard bound materials, bind all 8.5"x11" (A4) documentation, including 11" x 17" (A3)drawings folded to 8.5"x11" (A4), 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:

1. 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.
2. 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.
3. Use only cable that is new and of current design and manufacture.
4. Ensure that multimode optical fiber used in cables meets EIA/TIA-492AAAA, "Detail Specification for 62.5µm Core Diameter/125µm 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.
5. 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.
6. 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."
7. Ensure that all optical fibers in the cable are usable fibers.

8. Ensure that all optical fibers are free of surface imperfections and occlusions to meet the optical, mechanical, and environmental requirements of this specification.
9. 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.
10. 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
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

* 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 2 feet (600 mm) if marking the cable in English units (every meter if using metric 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 (183 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.

7. Pulling Tension

   Ensure that the cable can withstand a maximum pulling tension of 600 lbf (2669 N) during installation (short term) and 200 lbf (890 N)) long term installed.

8. Temperature Range

   Provide only OSP cable with shipping, storage, and operating temperature range of –40 ^{o}F to +160 ^{o}F (-40 ^{o}C to +71 ^{o}C). The installation temperature range of the cable shall be -20°F to +160 ^{o}F (-30 ^{o}C to +71 ^{o}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.

   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 Subsection 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 three feet with the manufacturer's name or UL file number, date of manufacture, fiber type, flame rating, UL symbol, and sequential length marking every one meter (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. SBJ Buffered Fiber

Use this special cordage when there is a need to splice a preconnectorized "pig tail" on to a cable end, routing that fiber within a splice shelf, and mounting the connector within the build-out panel of the distribution shelf. Construct SBJ cordage of 250 μm coated fiber (single mode or multi-mode optical fiber) surrounded with U.S. manufactured aramid fibers, and jacketed with flame retardant jacket material. Set the maximum diameter SBJ fiber to be 900 μm ±50μm and to have a coloration of orange for multi-mode and yellow for single mode. Ensure that the optical fiber is proof tested to 100 kpsi and that it meets all the optical fiber requirements of this Specification.

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 ^{o}C to + 71 ^{o}C). The operating temperature range for riser cables shall be 0 °F to +160 °F (-18 ^{o}C to +71 ^{o}C). The operating temperature range for plenum cables shall be 32 °F to +160 °F (0 ^{o}C to +71 ^{o}C).

4. Crush Resistance Requirements

Ensure that the cable can withstand a minimum compressive load of 89 N/cm 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.

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 3mm 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 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 central core design 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. Provide a drop cable with a maximum pulling tension of 300 lbs (1334 N)) unless the manufacturer’s requirements are more stringent.

2. Assembly Construction

Provide a drop cable assembly meeting the following requirements. Drop cables may be factory pre-terminated or may use splice-on factory-connectorized pig tails.

a. Pre-terminated Drop Cable Assembly

Install pre-terminated drop cable assemblies with central core 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 3mm 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 central core 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 - Central Core 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, 3mm 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 except for connectors installed on outside plant drop cables in traffic signal cabinets. 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	.70 dB	N/A	N/A
Single-mode	Field	.70 dB	.35 dB	>35 dB
Multimode	Factory	.50 dB	N/A	N/A
Single-mode	Factory	.50 dB	.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
   a. The closure shall handle up to eight cables in a butt configuration.
   b. Ensure that the closure prevents the intrusion of water without the use of encapsulate.
   c. 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. Splice cases shall hold a minimum of 2 splice trays to a maximum of 18 splice trays with each tray housing 12 or 24 splices depending on splice type.
   d. 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.
   e. 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.
   f. Provide a splice closure with provisions for controlling the fiber bend radius to a minimum of 1.5 in (38 mm).

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 (1334 N)at a temperature of 0 °F and 100 °F (-18 °C to 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 (28.5 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 (9 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 (300 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 foot (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 feet (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
   a. Ensure that the closure has the capacity to accommodate up to 144 fibers using six 24 fiber capacity trays.
   b. The closure shall allow for the storage of at least twelve unopened buffer tubes and/or fiber ribbons.
   c. Design the closure for free breathing splice protection without the use of encapsulate.
   d. Provide a closure with fully assembled weather tight closure design.
   e. The closure shall have flexible thermoplastic rubber end seals with pre-template cable ports.
   f. Ensure that the closure has a high density polyethylene body.

g. 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.

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 ^{o}C to 25 ^{o}C)

J. Fiber Distribution Center (FDC)

Use rack-mount and wall-mount FDCs and FDC splice cabinets with enclosures and mounting components of metallic construction.

Use rack-mount FDCs that fit standard 19 inch (483 mm)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 inches (600 mm) and of the following maximum vertical heights:

- 6-fiber and 12-fiber: 1.75 in (45 mm)
- 24-fiber: 3.50 in (90 mm)
- 36-fiber and 48-fiber: 7.00 in (175 mm)

Where splice-on fiber pigtails are to be used, provide 900 micron tubing or 3mm fan out tubing from the splice trays to the connectors.

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 inches (600 mm) and of the following maximum vertical height, combined FDC and FDC splice cabinet of 17.50 inches (445 mm). Where splice-on fiber pigtails are to be used, provide only 3mm fan out tubing from the splice trays in the splice cabinet to the connectors in the FDC.

Provide couplers with dust caps according to Subsection 935.2.F. Use only ST compatible couplers unless otherwise specified.

Provide rack-mount and wall-mount FDCs with the appropriate quantity of couplers, panels, splice trays, organizers, pig tails, 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.

K. Transceivers

1. External Transceiver

   Ensure the transceiver meets the following requirements:

   The transceiver shall be designed for daisy chained, linear multi-drop configuration.

   The transceiver supports asynchronous, full duplex RS 232 communication.

   The transceiver meets 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.

   The connectors shall be external, female ST connectors with T1,R1,T2,R2 ports for fiber connection.

   The equipment data connector shall be a female DB-25, DB-9, or terminal block RS 232 connector.

   The transceiver shall have external indicator LEDs for power, transmit & receive (each channel).

   A multimode transceiver operates at 1300 nm (minimum 14 dB power budget).

   A single mode transceiver operates at 1310 nm (minimum 21 dB power budget).

   Transceivers shall have a 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.

   The transceiver communications shall be anti-streaming.

   A single mode transmitter shall incorporate laser diode optical emitters.

   The transceiver shall have an 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.

   The transceiver shall have a metal housing with maximum dimensions of 8" x 5" x 2" (200 x 125 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.

2. External Star Transceiver

   Provide an RS232 data optical star transceiver meeting all requirements of the external transceiver in Subsection 935.2.B.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 the star transceiver is fully compatible and operable with the linear drop-and-repeat transceiver specified in Subsection 935.2.B.1

935.2.01 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 feet (1 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 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. Technician Requirements

Employ only fiber optic technicians that are listed on the Department's "Approval Listing - Fiber Optic Technician" for all termination, splicing and testing.

Technicians not previously approved by the Department will be considered for approval upon submission of a qualifications package to the TMC Manager, 935 East Confederate Avenue, Building 24, Atlanta, Georgia 30316. Include in the qualifications package documentation showing that the technician meets the following requirements:

1. Education Requirement

   The technician shall have attended and successfully completed at least one four day "Installation of Fiber Optic Products School." This school shall be conducted by a major manufacturer of fiber optic products or a Department approved independent generic four-day school that encompasses all aspects of fiber optic technician certification.

2. Work History Requirement

   Employ only technicians demonstrating a minimum of two years work experience with the splicing, termination, and testing of fiber optic cable.

   To apply for approval (see application form), the applicant shall submit a resume providing a summary of qualifications and a general description of professional experience, education and training in fiber optic installation

techniques (termination, splicing and testing). The applicant shall also provide a work record for the previous two years detailing specific projects, types of installations, testing and a customer reference for each project.

B. Certification Compliance

The approved technician shall carry evidence of his/her Department provided approval on their person at all times while working on the project. The Department reserves the right to revoke the approval of any technician not demonstrating the skill and knowledge to perform at accepted industry standards or to the quality required in this spec.

C. Certification Cancellation

An approved certification is subject to cancellation upon determination by the Department that the technician's work does not meet the Department's requirements or common industry standards.

D. Certification Renewal

The certification issued is for two years. For renewal, submit a work history to the Department for that two-year period, no less than thirty days prior to expiration, for review. Include in the history the type and duration of each project and a reference for each. Include as much additional detail as reasonable to facilitate approval.

STATE OF GEORGIA

DEPARTMENT OF TRANSPORTATION

FIBER OPTIC TECHNICIAN

APPLICATION

_____ _____

Name (Last) (First) (Middle) (Social Security Number)

_____

Address (Street) (City) (State) (Zip)

Section I (Identification)

Identification: (Must Supply Copy of Two) Drivers License Must Include Picture.

Drivers License Required

Social Security Card _____

Birth Certificate _____

Passport _____

Other (Specify) _____

2 Passport Pictures For I.D. Card _____

Section II (Proof of Technical Training)

Attach a photocopy of course completion certificate from an approved fiber optic school or manufacturer of fiber optic equipment and cable training school.

Section III (Experience)

In resume form, starting with the most recent: List all projects, the beginning and ending dates of the project, the contractor you worked for, the supervisor on said project and a complete description of the fiber optic work performed by you on said project.

Section IV

I, _____, do hereby certify that all the above information is correct, and further give permission for a representative of the Department of Transportation to verify any part of the information which I have included on this application and/or attachments which I have made to this application.

_____ _____

Signature Date

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

General Provisions 101 through 150.

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 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 (4.5 m) in length, with each loop 5 ft to 8 ft (1.5 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 Section 915.

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:

   a. Pull Box – 20 ft (6 m)
   b. Hub Building – 65 ft (20 m)
   c. Traffic Control Center & Transportation Management Center (OSP splice vault) – 65 ft (20 m)
   d. Traffic Control Center & Transportation Management Center (IP at equipment room) – cable entrance to distribution panel bay plus 20 ft (6 m)
   e. 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. (33.5 m)
      - Trunk cable with one closure – 110 ft.(33.5m). Measure the storage amount from the top of the ECB manhole opening. Install closure in the center of the 110 ft. (33.5 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 (29 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 (29 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 65 ft (20 m) storage loop approximately one half the distance between every equipment drop. Where equipment drops are greater than 1000 ft (300 m) apart, install a minimum 65 ft (20 m) storage loop for every 1000 ft (300 m) of uninterrupted cable length.
   - Additionally, at aerial splice closures, install enough cable slack 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 splice closures and storage loops in a “bow tie” configuration on the messenger strand. Install a device (a “snowshoe”) that maintains the proper bend radius in the fiber cable in the bow tie configuration.

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.

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" (65 mm) wide, 4" (100 mm) long, wrap-around type cable markers (ACP International, Part No. DN33-2.5; UTICOM Systems Inc., Part No. U2540-GADOT; William Frick & Co., Part No. SA1- GADOT; or approved equal).

   Print text in bold black type on orange PVC marker. Use base material that is minimum 0.015" (0.4 mm) thickness PVC. Pre-print the following text legibly on labels used for trunk cables:

   Cable ID: XXXXXXX
   GA DOT
   Optical Cable

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

Pre-print the following text on labels used for drop cables:

Cable ID: _____
GA DOT
Optical Cable

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.

Use only permanent marking pens, as recommended or provided by the manufacturer, for labels requiring a handwritten cable ID. Per manufacturer's recommended procedure, apply an optically clear protective 2" x3" (50 x 75 mm) Mylar (polyester) overlay to the marker, covering the written text.

2. Installation

Clean the installed cable of all dirt and grease before applying any label. Follow the label manufacturer's recommended procedure for applying cable labels. Label all cables in every communications hub, electrical communications box, pull box, handhole, and equipment cabinet.

Place cable labels in the following locations:

- Within 18" (450 mm) of every cable entry to a box
- Within 18" (450 mm) of every splice enclosure at cable entry points
- Within 6" (150 mm) of every FDC or splice cabinet in which a cable terminates or enters
- Every 10 ft (3 m) for the length of a cable in maintenance coils in electrical communications boxes or pull boxes

Label drop cables to devices within 18" (450 mm) of the splice enclosure where spliced to a trunk cable. Use cable labels with pre-printed cable ID numbers when labeling trunk cables. For drop cable applications, legibly print the drop cable ID number as shown in the Plans with a permanent-marking pen as recommended by the label manufacturer and seal with a laminate covering.

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 Subsection 935.3.04.A and Subsection 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 (1 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

Mount external transceivers on a shelf in a manner that does not restrict the placement of other components in the cabinet housing. In Type 170 cabinets mount the transceiver on an aluminum shelf permanently attached to the EIA 19" (475 mm) cabinet rack in the rear of the cabinet.

M. Fiber Distribution Center (FDC)

Array connectors in a vertical pattern with number one being at the top left position. 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.

935.3.06 Quality Acceptance

A. Underground Splice Closures

Ensure that an independent testing laboratory has performed all tests described in Subsection 935.2.K. Provide certification from an independent testing laboratory as required in Subsection 935.3.01.

B. Fiber Optic Cable

1. Installation Test

   Upon completion of the cable installation, splicing, and termination, and a minimum of fourteen days before equipment hookup, test all 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 the new cable and existing fibers to which it is spliced or connected.

   Submit both printed and electronic (diskette) OTDR traces as specified in Subsection 935.1.03.

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 (Subsection 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.

      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 (99 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.

935.3.07 Contractor Warranty and Maintenance

Provide a manufacturer's support (usual and customary warranties) period for all equipment and materials furnished and installed as part of Fiber Optic System. Transfer Manufacturer's and Contractor's warranties or guarantees to the agency or user responsible for the device or system maintenance. The warranties and guarantees shall be continuous throughout their duration, and state that they are subject to transfer.

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.

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

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 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.

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 (meters) installed, complete, functional, and accepted. Factory-connectorized pigtails associated with drop cable assembly, in accordance with Subsection 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, in accordance with Subsection 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 Subsection 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 lump sum 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 actual number of transceivers installed, complete, functional, and accepted.

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.

935.4.01 Limits

General Provisions 101 through 150.

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.

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 will be made under:

Payment will be made under:

Item No. 935	Outside plant fiber optic cable (type, mode, size)	Per linear foot (meter)
Item No. 935	Inside plant fiber optic cable (type, mode, size)	Per linear foot (meter)
Item No. 935	Fiber optic pigtail (mode, size)	Per linear foot (meter)
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	Per lump sum
Item No. 935	External transceiver (mode)	Per each
Item No. 935	External star transceiver (mode)	Per each
Item No. 935	Testing	Per lump sum
Item No. 935	Training	Per lump sum

935.5.01 Adjustments

General Provisions 101 through 150.