

# DEPARTMENT OF TRANSPORTATION STATE OF GEORGIA

## ~~SUPPLEMENTAL SPECIFICATION~~ SPECIAL PROVISION

### Section 935—Fiber Optic System

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Replace Section 935 with the following:

#### 935.1 General Description

This section contains the requirements to furnish, install, test, and provide warranty and training for a fiber optic system comprised of equipment and materials as specified herein and shown in the Contract documents.

##### 935.1.01 Definitions, Acronyms, and Abbreviations

###### A. Definitions

Refer to Section 942.1 for a list of additional definitions and terminology used in this section.

1. **Drop Fiber:** a smaller-strand count fiber optic cable that provides the interconnection of network equipment inside a field cabinet and/or a hub building to the trunk or backbone fiber optic cable.
2. **Encapsulate:** A resin or other material to prevent ingress of moisture into the fiber optic closure.
3. **Fiber Interconnect Cable:** a 12 or 24 fiber factory-connectorized cable from the splice tray to the back of the bulkhead connector panel.
4. **Fiber Pigtail Cable:** a single-fiber factory-connectorized cable from the splice tray or splice holder to the back of the bulkhead connector panel.
5. **FPP/FDU:** Patch Panels or Distribution Units used for fiber termination at field cabinets and hub buildings to provide network connectivity for ITS devices. FPPs are defined as providing 6 to 36 connectors or ports, and FDU are larger, providing 48 to 288 connectors or ports.
6. **Trunk Fiber:** a multi-fiber count fiber optic cable that provides the network interconnection and transport between field cabinets, hub buildings, the TMC, and other facilities.

###### B. Acronyms and Abbreviations

Refer to Section 942.1 for a list of additional acronyms and abbreviations used in this section.

~~Refer to Sections 101.01 and 942.1.01.B for a list of acronyms, abbreviations, and terminology used in this section.~~

##### 935.1.02 Related References

###### A. Standard Specifications

~~Section 631—Dynamic Message Signs~~

Section 647 – Traffic Control Signal Installation

~~Section 682—Electrical Wire, Cable, and Conduit~~

~~Section 694—Weather Monitoring and Reporting System~~

~~Section 926—Wireless Communications Equipment~~

~~Section 936—Closed Circuit Television (CCTV)~~

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### ~~Section 939—Communications and Electronic Equipment~~

Section 942 – ITS General Requirements

#### B. Referenced Documents

Refer to Section 942.1.~~02-B~~ for a list of standards and documents referenced in this section.

#### 935.1.03 Submittals

Refer to Section 942.1.~~04~~ for submittal requirements. ~~Requirements for fiber optic cables, components, and materials are specified herein.~~

### 935.2 Materials

#### 935.2.01 Fiber Cable and Optical Requirements

##### A. General

1. Comply with ISO 9001 or Six Sigma quality manufacturing requirements.
2. Provide only fiber optic cables and components that are new (manufactured no more than one year prior to the Notice to Proceed) and provided by one manufacturer using the same model, part number, and revision. Provide the manufacturer date as part of the submittal process in Section 942.1.~~04~~.
3. Provide SM fiber optic cable that is splice-compatible with the Department's existing legacy G.652 SM fiber and requires no electronic equipment for dispersion compensation between new and existing fiber.
4. Provide fiber optic cables ranging from 6 strands to 288 strands as shown in the Contract ~~documents~~.
5. Provide cables that comply with NFPA 70.
6. Provide cables that comply with RoHS Directive 2011/65/EU.

##### B. Fiber Optical

1. Provide fiber optic cables that comply with ICEA S-87-640.
2. Provide fiber optic cables that comply with Telcordia GR-20-CORE.
- ~~3. Provide fiber optic cables that comply with USDA RUS 7 CFR 1755.900, 901, and 902 (PE-90).~~
4. Provide SM fiber optic cables that comply with ITU-T G.652.D.
5. Provide SM fiber optic cables that comply with ITU-T G.657.A1.
6. Provide SM fiber optic cables that comply with TIA-492-CAAB (OS2).
7. Provide fibers that are 100% usable.
8. Provide SM fibers that meet the optical performance requirements when tested according to TIA-455:
  - a. Provide a fiber section that has attenuation of  $\leq 0.35$  dB/km at 1,310 nm with a variability of  $\leq 0.03$  dB/km between 1,285 nm and 1,330 nm. Test according to FOTP-78-B.
  - b. Provide a fiber section attenuation of  $\leq 0.25$  dB/km at 1,550 nm with a variability of  $\leq 0.02$  dB/km between 1,525 nm and 1,575 nm. Test according to FOTP-78-B.
  - c. Provide fiber that has a mode field diameter of  $9.2 \mu\text{m} \pm 0.4 \mu\text{m}$  at 1,310 nm and  $10.4 \mu\text{m} \pm 0.5 \mu\text{m}$  at 1,550 nm. Test according to FOTP-191-B.
  - d. Provide fiber that has uniform attenuation with no point discontinuities  $> 0.05$  dB at both 1,310 nm and 1,550 nm.
9. Provide a mechanically strippable, dual-layer, UV acrylate, color-coded protective coating.
10. Provide microfiber cables that meet the optical requirements of Section 935 and the following conditions:

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- a. Be 288 strand single mode
  - b. Use a maximum of 48 fibers per buffer tube
  - c. Operational Temperature Range of -30 to 70 degrees C (-22 to 158 degrees F)
  - d. Installation Temperature Range of -10 to 40 degrees C (14 to 104 degrees F)
  - e. Maximum Attenuation of .35 dB/km
  - f. Have a maximum Weight of 56 lb/1000 ft.
11. Contractor may use “air-jetting” to install microfiber cables. The microfiber nominal outer diameter shall not exceed the maximum size requirements to be “Airjet” into a microduct.

### C. Fiber Optic Cable Construction

1. Provide OSP fiber optic cables with the following characteristics:
  - a. Provide cable suitable for underground (i.e., in conduit) and aerial installation.
  - b. Provide cable with a single jacket that is unarmored.
  - c. Provide cable with an outside diameter of no greater than one inch.
  - d. Provide all-dielectric (no metal or electrically conductive) materials.
  - e. Provide water-blocking materials that are gel-free, dry-type, non-nutritive to fungus, electrically non-conductive, and homogenous.
  - f. Provide loose tube design that is SZ-stranded around an anti-buckling central strength member.
  - g. Provide buffer tubes that contain 12 optical fibers placed inside each tube for cables 24 count and higher.
  - h. Provide fibers and buffer tubes that are color coded according to TIA-598-D.
    - (1) Colors shall be stable during temperature cycling and aging.
    - (2) Colors shall not fade or smear onto each other.
2. Provide cable outer jacket or sheath meeting the following minimum requirements:
  - a. Provide a minimum medium-density polyethylene black outer jacket as defined by ASTM D1248, Type II, Class C, Category 4 or 5 and Grades J4, E7, and E8.
  - b. Provide a track-resistant polyethylene black outer jacket if the fiber optic cable is installed in an aerial application and the space potential is >12 kV.
  - c. Provide jacket that is smooth; concentric; free from holes; consistent thickness; free of splits, blisters, and any other surface flaws; and contains carbon black to provide UV protection and prevent the growth of fungus.
  - d. Provide a method for removal of the sheath.
3. Provide labeling for the fiber optic cable meeting the following minimum requirements:
  - a. Label fiber optic cables (trunk and drop) using the following template, unless otherwise listed in the Contract:
    - (1) Manufacturer's name – Optical Cable – Year – Telecommunication Handset Symbol – GA DOT (or as required by the AHJ) – Description (which consists of XXX SM or MM, where XXX denotes the fiber count).
    - (2) Sequentially mark the cable length reflecting the distance from the cable origin point in English units every 2 ft (0.6 m). Cable length markings shall be within 1% of the actual length of the cable.
    - (3) Provide cable marking that is contrasting in color to the cable jacket. Marking font height shall be no less than 0.10 in (2.5 mm).

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b. Use cable marking that meets the following minimum requirements:

- (1) Use 2.5 in (64 mm) wide, 4 in (100 mm) long, wrap-around type cable markers suitable for underground and aerial use.
- (2) Use UV-stabilized marker material and printing inks to provide an aerial durability of at least five years.
- (3) Print text in bold black type on orange or yellow PVC markers.
- (4) Fabricate markers from PVC base material with a minimum thickness of 0.015 in (0.38 mm).
- (5) Pre-print the following text, or alternate text shown in the Contract documents, legibly on markers used for the cables:

Cable ID: XXXXXXXX

GA DOT

Optical Cable

Where XXXXXXX is the cable ID as defined in the Contract documents.

- (6) Print the text specified above twice on every cable marker with the text of the second image reversed and abutting the first image so that the text “reads right” when either short edge of the cable marker is held horizontally upright.

### D. Cable Performance

Provide fiber optic cable that has been tested in accordance with TIA-455 as shown in Table 1, resulting in no permanent change in attenuation, no signs of water leakage, no mechanical damage to the cable, and no adverse effects to the jacket or fibers. Upon the request of the Department, provide certification from an independent testing laboratory certifying the cable conforms to the following specifications and test procedures.

Table 1 – Fiber Optic Testing			
ID	Parameter	Test Performed	Test Condition/ Specification
<b>Testing requirements that apply to all fiber optic cable</b>			
1	Bend Test (Low and High Temperature)	<del>FOTP-37-A</del> TIA-455-37-A	Four full turns around mandrel of 20 times cable outer diameter at 4 hours of -22°F and +140°F (-30°C and +60°C)
2	Impact Resistance	<del>FOTP-25-D</del> TIA-455-25-D	25 impact cycles (at 4.4 nm) at different points along the sample
3	Compressive Strength (Crush Resistance)	<del>FOTP-41-A</del> TIA-455-41-A	125 lb/in (220 N/cm) (short)
4	Tensile and Fiber Strain (Macro-bending)	<del>FOTP-33-B</del> TIA-455-33-B	Maximum 600 lb (2,700 N) – during tensile load, Maximum 180 lb (800 N) – without tensile load
5	Cable Twist-Bend	<del>FOTP-85-A</del> TIA-455-85-A	10 cycles ±180 degrees of mechanical twisting
6	Cable Cyclic Flexing	<del>FOTP-104-B</del> TIA-455-104-B	25 times mechanical flexing cycles around a sheave of 20 times cable outer diameter
7	Temperature-Humidity Cycling	<del>FOTP-3-B</del> TIA-455-3-B	-40°F to +158°F (-40°C to +70°C)
8	Water (Fluid) Penetration	<del>FOTP-82-B</del> TIA-455-82-B	1 m static head for 1 hour
9	Cable Freezing	<del>FOTP-98</del> TIA-455-98	Frozen on ice
<b>Testing requirements that apply to aerial fiber optic cable</b>			
1	High Frequency (Aeolian) Vibration	IEEE P1222	100 million vibration cycles
2	Low Frequency (Galloping) Vibration	IEEE P1222	100 thousand vibration cycles

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### E. Fiber Patch Cord

1. Provide the same glass type and performance requirements as the manufacturer of the backbone and drop fiber optic cable provided in the Contract
2. Provide factory pre-assembled, riser-rated, factory-tested, pre-terminated duplex patch cords with two fibers with connectors as described in Section 935.2.03.A on each end.
3. Provide patch cords that meet UL 94-V0 flammability requirements.
4. Provide lengths as listed in the Contract with a minimum of 1 ft (30 cm) slack between connected equipment.
5. Provide optical fiber within the body of fiber optic connectors that are mechanically isolated from cable tension, bending, and twisting.
6. Use yellow outer jackets for SM and orange for MM fiber optic cables.
7. Use connector boots of two colors for all duplex patch cords, zip cord, or round to distinguish between the two zip legs of the duplex cord.
8. Label duplex patch cords to distinguish between the two zip legs of the duplex cord. .
9. Provide protective dust caps on the connector ferrules.
10. No splices of any type shall be within a patch cord assembly.
11. Provide qualification or certification data from the manufacturer upon request by the Department.
12. Package each assembly individually within a plastic bag and clearly mark on the outside of that bag the submitted manufacturer's part number.

### F. Environmental

Provide fiber optic cables, connectors, and splice trays that meet Telcordia GR-20-CORE and ICEA S-87-640 temperature and humidity requirements.

## 935.2.02 Fiber Optic Components Requirements

### A. Fiber Optic Splice Closure

1. House optical fiber splices within a fiber optic splice closure, complete with fiber splice trays and expressed buffer tube organizer, dome, grommets, end plate, mounting hardware and bracket, cable restraint hardware, buffer tube storage, splice protection, sealant materials, and any other materials and components needed to provide a completely sealed fiber splice closure installation.
2. Provide splice closures, organizers, cable end preparation tools, and procedures that are compatible with the fiber optic cable.
3. Provide splice closures that are stand-alone.
4. Use splice closures that are either “cylindrical dome” or “rectangular dome” type with cable entries at one end only and sealed, one-piece, high-density black UV-resistant polyethylene (thermoplastic) dome bodies.
5. Provide splice closures that are designed and tested in accordance with Telcordia GR-771-CORE requirements.
- ~~6. Use only RUS listed splice closures.~~
7. Provide splice closures consisting of three types depending on the number of splices required that meet the following requirements:
  - a. Up to 48 fiber splice capacity (including both trunk and drop cable splices): determine the number and type of splice trays by the number of splices required in the Contract ~~documents~~. Provide splice closures that support up to four cable entries of at least 0.75 in (19 mm) diameter. These splice closures shall have



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5. Provide splice trays that include a cover with a locking mechanism to hold it in place.
6. Provide access to individual fibers without disrupting other fibers in the tray.
7. Provide fiber that is capable of being visually inspected.
8. Package and protect each fusion-spliced fiber housed within the splice tray with a minimum 1.5 in (40 mm) reinforced, heat shrink, and weathertight sleeve.

### C. Fiber Optic Connector

1. Provide certified LC fiber optic connectors for SFP optical transceivers for network switches and for FPPs and FDUs with greater than 12-port terminations.
2. Provide only ST-compatible, ceramic-insert couplers where barrel couplers are used in passive termination applications such as FPPs and FDUs with 6 and 12-fiber port terminations.
3. Provide connectors that comply with TIA-568-B.3.
4. Provide connectors that comply with TIA-604-10B (Type LC) and TIA-604-2B (Type ST) intermateability requirements.
5. Test connectors according to Telcordia GR-326-CORE.
6. Provide ceramic ferrule UPCs that are polished.
7. Mechanically isolate the optical fiber within the body of connectors from cable tension, bending, and twisting.
8. Provide connectors that are factory-assembled and tested. No field installed connectors are permitted.
9. Provide unmated connectors with protective dust caps installed. **Always provide dust caps for both sides of couplers at all times until permanent connector installation.**
10. Provide industry standard approved connector for optical fiber that meets or exceeds the applicable provisions of TIA-455-X related to fiber optic connectors and interfaces and meets the following requirements:
  - a. Insertion loss of  $\leq 0.25$  dB (typical) and  $\leq 0.5$  dB (maximum).
  - b. Return loss (back reflection)  $\leq -55$  dB (UPC) for SM and  $\leq -25$  dB (UPC) for MM, typical.
  - c. Mating durability  $\leq 0.2$  dB (typical) change, 500 mating cycles.

### D. FPP and FDU

1. Provide FPPs (6 to 36 connectors) and FDUs (48 to 288 connectors) that meet the requirements presented in this section.
- ~~1. Provide FPPs and FDUs that comply with TIA-310-D standard 19-in rack-mounted applicable to both or wall or panel-mounted installation~~
- 2. Provide FPPs that comply with TIA-310-D standard 19-in rack-mounted applicable to wall or panel mounted installation.**
- 3. Provide FDUs that comply with TIA-310-D standard 19-in rack-mounted applicable to wall mounted installation.**
4. For 6 to 36 connectors, use FPP enclosures that integrate the splice trays and connector modules into one compartment within one enclosure. For 48 connectors and larger, use FDU enclosures as one integrated compartment or house the splice trays and connector modules in separate compartments integrated into one enclosure.
5. Provide splice trays for storing the number of fusion splices as listed in the Contract **documents**. For FPPs with 12 connectors or less, splice holders within the FPP compartment may be used in lieu of splice trays.
6. Provide FPPs and FDUs that meet UL 94-V0 flammability requirements.
7. Provide wire management system at every FPP and FDU location for fiber optic cables and patch cords.

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8. Provide access to fiber splicing trays and fiber termination couplers meeting the following minimum requirements:
  - a. Provide access from the front or rear with removable, fold-down or swing-out doors, drawers, and covers.
  - b. Provide physical protection when doors, drawers, and covers are in the closed position that encloses the fiber splicing trays, fiber interconnection cables, fiber pigtail cables, and fiber termination couplers.
  - c. Provide storage space to house and protect the number of splice trays required to splice and terminate the fibers.
  - d. Provide rubber grommets or similar material to prevent the cable from ~~coming in~~ contacting ~~with~~ bare metal.
  - e. Provide radius guides and strain relief for the incoming fiber optic cable(s) to maintain bend radius and protect the fibers.
  - f. Provide bulkhead-mounted, termination coupling connectors that include locknuts for mounting the connectors in predrilled or punched holes in the connector panel.
  - g. Provide bulkhead-mounted coupling connectors with dust caps.
9. Provide fiber interconnect cables and fiber pigtail cables meeting the following minimum requirements:
  - a. Provide 12-fiber interconnect cables for FDUs with 12-splice capacity trays, and 24-fiber interconnect cables with FDUs with 24-splice capacity trays.
  - b. Use only fiber-interconnect cables for FPPs and FDUs with 24 connectors or more.
  - c. Provide single fiber pigtail cables or fiber interconnection cables for FPPs with less than 24 connectors.
  - d. Provide cables with factory installed connectors in accordance with Section 935.2.03.A.
  - e. Provide fiber pigtail cables with ~~900-micron~~900-micron tubing or 0.12 in (3 mm) fan out tubing as required for the application.
  - f. Use fiber pigtail cables with 900-micron tubing only when fully enclosed within the FPP from splice tray to the back of the bulkhead connector panel.

### E. Aerial Cable Lashing Materials

1. Provide minimum 0.038 in (0.96 mm) diameter lashing wire to attach aerial fiber optic cable to the messenger or strand.
2. Provide lashing wire, attachment, and mounting hardware with sufficient tensile strength for the application and meeting the requirements of ASTM F593/F594 for corrosion resistance.
3. Use Type 302 stainless steel lashing materials in non-coastal regions and Type 316 along coastal regions within 5 miles (8 km) of the ~~coastline~~ ~~coast-line~~.

### F. Aerial Snowshoe Storage

1. Provide a factory-manufactured, UV-stabilized, snowshoe fiber storage unit that is designed to store excess or slack fiber optic cable or fiber optic cable and a splice closure in the span.
2. ~~Provide fiber optic snowshoe that is constructed with plastic or aluminum bodies.~~ Provide fiber optic snowshoes utilizing corrosion resistant aluminum or stainless-steel hardware, including attachment between and to the snowshoe body case and the aerial support strand that maintain the minimum cable bend radius and have integral cable lashing strap slots or holes to secure cable attachments to the storage bracket. ~~Do not use non-metallic attachment hardware.~~
3. Provide galvanized or ~~stainless-steel~~ stainless-steel hanging and attachment hardware (bolts, nuts, washers) and strand clamps for attachment to messenger or strand according to ASTM A135 and ASTM B695.
4. Provide cable protection bracket that minimizes cable abrasion and organizes cable against the pole.

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5. Provide cable channel to secure the cable that minimizes ice and leaf loading.
6. Provide snowshoe design that minimizes the number of cable ties needed.
7. Provide weathertight, UV-resistant cable ties designed for continuous outdoor use.
8. Store the maintenance cable length for closure ground access with one fiber optic snowshoe and the aerial cable length attached to the same messenger ~~strand~~ that strand to which the splice closure is attached.

### G. Environmental

Provide fiber splice closures that meet Telcordia GR-771-CORE temperature and humidity requirements.

### 935.2.03 MM Fiber Optic Cable Requirements for Legacy Systems Only

#### A. General

1. Meet the fiber optic cable and environmental requirements as specified herein.
2. Provide fiber optic cable that is splice-compatible with the Department's existing legacy 62.5/125  $\mu\text{m}$  MM fiber optic cable as required.

#### B. Fiber Optical

1. Provide standard 62.5/125  $\mu\text{m}$  graded index MM fiber optic cables that comply with TIA-492AAAA-A (OM1).
2. Comply with IEC EN 60793-2-10, Type A1b product specifications.
3. Provide MM fibers that meet the optical performance requirements when tested according to TIA-455:
  - a. Provide a fiber section attenuation of  $\leq 3.5$  dB/km at 850 nm. Test according to FOTP-78-B.
  - b. Provide a fiber section attenuation of  $\leq 1.0$  dB/km at 1,300 nm. Test according to FOTP-78-B.
  - c. Provide fibers that have uniform attenuation with no point discontinuities  $> 0.2$  dB at both 850 nm and 1,300 nm.
4. Provide an OFL bandwidth  $\geq 200$  MHz/km at 850 nm and  $\geq 500$  MHz/km at 1,300 nm.

## 935.3 Construction

The construction and installation of fiber optic cabling and components as specified herein shall meet the requirements in this section and the cable manufacturers' installation requirements and recommendations.

### 935.3.01 Construction Requirements

#### A. General Construction

1. Fiber Optic Installation Plan
  - a. Develop a fiber optic installation plan for review and approval by the Department prior to fiber optic cable installation, splicing, and termination work. Include at a minimum the following components:
    - (1) Fiber running path line (route). Where not specifically shown in the Contract ~~documents~~, show proposed trunk fiber and existing fiber (if any) to identify trunk to trunk fiber splice points, coordination of fiber allocation and associated splice details, and as-built drawings of the complete fiber system.
    - (2) Vendor and part numbers for proposed materials and equipment (i.e., fiber optic trunk and drop cables, splice closures and splice trays, splicer equipment, fiber patch panels, connectors and other materials required or needed).
    - (3) Location of fiber drop cables and proposed splice locations.
    - (4) Location of fiber terminations.
    - (5) Fiber splice details for each location, showing buffer/strand utilization and allocation plan.

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2. Pack the cable and wrap in weathertight and temperature resistant covering to prevent damage during shipment, to facilitate unloading, and to allow for outdoor storage as approved by the Department.

### B. Cable Installation Guidelines

1. Before installation begins, inspect the cable reels for imperfections such as nails that might cause damage to the cable as it is unreeled.
2. When 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.
3. Comply with the manufacturer's recommended procedures and these specifications for cable handling.
4. Comply with the maximum recommended pulling tension during installation as specified by the cable manufacturer.
5. Comply with the minimum recommended bend radius during installation as specified by the cable manufacturer. Use large diameter wheels, pulling sheaves, and cable guides to maintain the bend radius. **Always provide tension monitoring at all times during the pulling operation.**
6. Unless the manufacturer's recommendations are more stringent, use the following guidelines for minimum bend radius:
  - a. 20 times the outside cable diameter during installation
  - b. 10 times the outside cable diameter after installation
7. If a mechanical pulling machine is used, equip the machine with a monitored or recording tension meter. At no time shall the manufacturer's recommended maximum pulling tension be exceeded. Submit the method of monitoring cable stress during installation to the Department for review and approval. The allowable pulling tension shall be the lesser of either of the two values below:
  - a. Cable manufacturer's recommended pulling tension from the outer jacket for the cable
  - b. 80% of the cable manufacturer's maximum pulling tension from the outer jacket
8. When using lubricants, comply with the cable manufacturer's recommendations for type, amount, application tools and method, and removal of the lubricant from the exposed cable. Pre-lubrication of cable is acceptable to provide uniform lubrication.
9. Use rollers and sheaves for difficult pulls to eliminate damage when entering and existing the conduit system.
10. During the installation of the fiber optic cable, record as-built fiber optic cable footage at riser locations, hand-holes, and slack storage locations.
11. Where messenger cable is required, as shown in the Contract **documents**, lash aerial fiber optic cable to a steel strand wire messenger cable of the size specified in the Contract **documents** that conforms to Section 647.
12. Select fiber optic cable installation method that meets the following requirements:
  - a. If pulling is utilized:
    - (1) Install the fiber optic cable by hand and/or by using a mechanical pulling machine.
    - (2) Attach the central strength member and aramid yarn directly to the pulling eye during cable pulling. Use pulling attachments such as "basket grip" or "Chinese finger" type so that the optical and mechanical characteristics are not degraded during the fiber optic cable installation.
    - (3) Coil excess cable in a figure eight and feed manually when pulling through pull boxes by hand.
    - (4) Provide a continuous section of cable throughout the pull. Cable breaks are permitted only at designated splice points.
  - b. If air assisted/blowing is utilized:
    - (1) Use either the HASB method or the Piston method.

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- (2) When using the HASB method, the volume of air passing through the conduit shall not exceed 600 ft<sup>3</sup>/min or the conduit manufacturer's recommended air volume, whichever is more restrictive.
- (3) In cold temperatures, an air dryer accessory is recommended to avoid introducing water condensation into the HASB air inlet chamber or conduit/duct system. Condensation may result in frost. In hot temperatures, an air cooler is recommended to avoid excessive temperatures at the conduit/duct and cable.
- (4) When using the Piston method, comply with the conduit manufacturer's recommended air volume or limit to 300 ft<sup>3</sup>/min, whichever is less.

### C. Cable End Sealing

1. Where a cable ends without termination in a fiber optic closure, seal the end of the cable by reusing a cable end cap shipped with a cable reel, or use a cap that is size-matched to the cable to be sealed.
2. Clean the end of the cable. Partly fill the cap with a weathertight 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.
3. Apply a full sealant bead between the end of the cap and the cable jacket.

### D. Cable Slack Storage

1. For aerial installations, meet the following requirements.
  - a. Where messenger strand or cable is required, as shown in the Contract documents, lash aerial fiber optic cable to a steel strand wire messenger cable of the size specified in the Contract documents that conforms to Section 647.
  - b. 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 optic cable storage brackets) that maintain the proper bend radius in the fiber optic cable.
  - c. Install one fiber optic snowshoe for drop cable and trunk cable storage at aerial splice closures to maintain the bend radius in the fiber optic cable.
  - d. Use tie-wraps or tape for securing the cable to the snowshoe. Tie wraps and tape must be UV-resistant and designed for continuous outdoor use.
2. For underground applications, meet the following requirements.
  - a. Pull Box Types 4, 4S, 5, 5S, 6, and 7: Apply the following storage requirements for the indicated cable/splice closure situations.
    - (1) Drop cable with no splice closure: 10 ft (3 m).
    - (2) One or more trunk cables with no splice closure: 110 ft (34 m) of each cable.
    - (3) Two or more trunk cables with one splice closure: Store 55 ft (17 m) of each trunk cable so that the splice closure can be removed from the pull box 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.
    - (4) One trunk cable with one splice closure: 110 ft (34 m). Install splice closure in the center of the 110 ft (34 m) cable loop so that the splice closure can be removed from the ECB 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.
    - (5) One trunk cable with one splice closure and trunk cable ends: 95 ft (30 m). Install splice 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.
    - (6) Trunk cable ends with no closure: 95 ft (30 m).
  - b. Hub Building (interior): Do not store slack cable inside the hub building.

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- c. Hub Building (exterior adjacent ECBs): 180 ft (55 m).
- d. Mini-Hub (exterior adjacent ECBs): 180 ft. (55 m).
- e. Traffic Control Center and TMC (OSP splice vault): 180 ft (55 m).
- f. Traffic Control Center and TMC (Inside plant at equipment room): Cable entrance to distribution panel bay plus 20 ft (6 m).
- g. ECB Types 3, 4, 5, and 6: Apply the following storage requirements for the indicated cable/closure situations. More than one situation may occur in a single ECB, in which case apply each requirement.
  - (1) Trunk cable with no splice closure: 110 ft (34 m).
  - (2) Trunk cable with one splice 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 splice closure can be removed from the ECB 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.
  - (3) Trunk cable with one splice 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.
  - (4) Trunk cable ends with no closure: 95 ft (30 m).
- 3. Unless otherwise noted in the Contract **documents**, the following are the minimum requirements for cable storage for aerial applications.
  - a. Install a minimum 150 ft (45 m) storage loop one-half the distance between every equipment drop or as shown in the Contract **documents**.
  - b. Where equipment drops are >1,000 ft (300 m) apart, install a minimum 150 ft (45 m) storage loop for every 1,000 ft (300 m) of uninterrupted cable length.
  - c. 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 Contract **documents**, to allow the fully assembled splice closure, including the trunk cable and drop cable, to be lowered to ground level for maintenance purposes.

### E. Cable Splicing

- 1. Splice together each individual reel of fiber optic cable to provide a continuous length of installed cable.
- 2. Splice cable only at splice points shown in the Contract **documents**.
- 3. Make no splices within a fiber patch cord assembly or fiber drop cable.
- 4. Use the fusion technique for splices and terminations. Use a fusion splicing machine (fusion splicer) to splice optical fiber. Mechanical splicing is not permitted.
- 5. Provide fusion splicing equipment supported by calibration records indicating a factory calibration within three months preceding their use.
- 6. Clean and calibrate fusion splicing equipment per the manufacturer's specifications, and specifically adjust the fiber and environmental conditions at the start of each splicing shift.
- 7. Comply with the cable manufacturer's and fusion splicer's procedures, accepted standards, codes, and practices. Do not install mechanical splices.
- 8. To prevent splice loss, meet the following requirements.
  - a. Splice SM optical fibers using the fusion splice method. The mean (average) splice loss shall not exceed 0.1 dB for new fiber to new fiber and 0.3 dB (per TIA-568.3-D) for new fiber to existing (legacy) fiber.
  - b. Splice MM optical fibers using the fusion splice method. The mean (average) splice loss shall not exceed 0.3 dB for new fiber to new fiber and for new fiber to existing (legacy) fiber.

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- c. Obtain the mean splice loss by measuring the loss through the splice in both directions and then averaging the resultant values.
9. To protect splices, meet the following requirements.
- a. Protect fusion splices in splice trays or organizers in a splice closure.
  - b. 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.
  - c. Protect fusion splices with heat shrink tubing that protects the splice and extends over the fiber coating.
  - d. Do not leave bare fiber exposed.
  - e. Do not use silicone in any splice tray.

### F. Mid Span/Drop Access

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

### G. Connector Termination Procedures

Comply with procedures for the termination of the connectors as required by the connector manufacturer's fiber optic installation standard operating procedure for the field installation.

### H. Cable Marking Installation

1. Clean the installed cable of dirt and grease before applying any marker.
2. Follow the marker manufacturer's recommended procedure for applying cable markers.
3. Mark cables in or at every hub building, ECB, pull box, hand-hole, field cabinet, aerial or underground splice closure, pole attachment, aerial storage bracket, and pole conduit riser entrance.
4. At every trunk cable termination, reel end-to-reel end splice, ECB, pull box, hand-hole, field cabinet, aerial splice closure, and aerial storage bracket, record the cable distance markings from the print-line for the cable entry and exit, along with the exact location by station number or location name.
5. Record the cable distance markings in a tabular format approved by the Department or on a documentation form provided by the Department.
6. Place cable markers in the following locations:
  - a. Within 18 in (450 mm) of every cable entry to a pull box, hand-hole, ECB, and hub building
  - b. Within 6 in (150 mm) of every cable entry or termination in a field cabinet
  - c. Within 18 in (450 mm) of every splice closure at cable entry points
  - d. Within 6 in (150 mm) of every FPP/FDU or splice cabinet in a hub building in which a cable terminates or enters
  - e. Every 20 ft (6 m) for the length of a cable in maintenance coils in ECBs or pull boxes.
  - f. Within 12 in (300 mm) of every pole attachment, aerial storage bracket, and pole conduit riser entrance
7. Use orange markers at all locations, except as noted below:
  - a. 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).

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- b. 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 drop cable's length to its other termination.

### I. Splice Closures

1. Install splice closures according to manufacturer's recommendations.
2. Install splice closures where shown in the Contract ~~documents~~, and in the approximate center of fiber optic cable storage coils.
3. Mount splice closures in ECBs or pull boxes to cable rack hooks or mounting brackets.
4. Mounting hardware for closures must be aluminum, galvanized, or stainless steel.

### J. FPP/FDU

1. Do not install mechanical splices or field installed connectors.
2. Equip unused panel slots with blank panels.
3. Provide inter-cabinet and inter-bay bend radius and jumper management on each side of the FDU.
4. Install hardware according to the manufacturer's recommended procedures and approved by the Department.
5. Determine specific hardware sizing from the Contract ~~documents~~.
6. For rack-mount and wall-mount FPPs/FDUs, array connectors with fiber number one being at the top left or leftmost position.
7. Route and secure the drop cable beside or behind the field 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 field cabinet equipment or electrical components.

## 935.3.02 Equipment Configuration and Integration Requirements

Not Applicable

## 935.3.03 Testing and Acceptance Requirements

Refer to Section 942.3-~~04~~ for testing requirements.

## 935.3.04 Training Requirements

Refer to Section 942.3-~~05~~ for training requirements.

## 935.3.05 Warranty and Maintenance Support Services

### A. Warranty Requirements

1. Provide a minimum warranty length of two years for fiber optic cable and associated components. If the manufacturer's warranties for the components are for a longer period, those longer period warranties shall apply.
2. Refer to Section 942.3-~~02~~ for general warranty requirements.

### B. Maintenance Support Services

Refer to Section 942.3-~~02~~ for maintenance support services requirements.

## 935.4 Measurement

The fiber optic system and training that are complete, in place, accepted, and of the kind, size, and type specified will be measured as follows:

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### A. Outside Plant Fiber Optic Cable, Loose Tube, Single Mode, No. Fibers

OSP fiber optic cable, loose tube, SM fiber will be measured in units of actual linear feet and paid for at the Contract price per linear feet, including cable slack. The price bid will include the length in feet of actual cable installed and tested as measured from the cable sequential length markings, cable print-lines, aerial snowshoes for storage (aerial segments), ancillary and incidental materials, documentation, and labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in the Contract documents.

### B. Fiber Optic Closure, Underground or Aerial, No. Splices

Underground and aerial sealed fiber optic splice closures will be measured for payment by the number of units installed, complete, functional, tested and accepted. Fiber optic closures will be measured in units of each and paid for at the Contract unit price each, which will include, but not be limited to, splice closure, splice trays, splices, splice protection, organizer, dome, end plate, cable port sealing grommets, sealant material, cable end preparation tools, mounting hardware within the pull box or on the messenger strand, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### C. Fiber Patch Panel or Fiber Distribution Unit, Rack or Wall Mount, No. Ports

FPPs and FDUs will be measured for payment by the number of units installed, complete, functional, tested and accepted. The number of ports is equal to the number of fibers. FPPs and FDUs will be measured in units of each and paid for at the Contract price each, which will include, but not be limited to, housing, splice trays or splice holders, fiber interconnect cables, fiber pigtail cables, splices between the incoming cable fibers and fiber interconnect/pigtail cables, splice protection, connector modules, connectors, wire management, mounting hardware within field cabinet/hub rack and wall mounting hardware, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### D. Fiber Optic Splice, Fusion

Fiber optic fusion splices will be measured for payment by the number of splices made, complete, tested and accepted. Fiber optic fusion splices will be measured in units of each and paid for at the Contract unit price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work. Fiber optic splices associated with the use of fiber interconnector cables and fiber pigtail cables, in accordance with Section 935.2.03, will not be measured separately for payment. The price bid

### E. Fiber Optic Patch Cord, SM

Fiber optic patch cord, SM will be measured for payment by the number of patch cords provided, installed, tested and accepted. Patch cords will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### F. Fiber Pigtail Cable, SM

Fiber pigtail cables, SM will be measured for payment by the number of pigtails provided, installed, tested and accepted, and only when separately denoted by pay item in the Contract. Fiber pigtail cables will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### G. Fiber Interconnect Cable, SM

Fiber interconnect cable, SM will be measured for payment by the number of interconnect cables provided, installed, tested and accepted, and only when separately denoted by pay item in the Contract. Fiber interconnect cables will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### H. Fiber Optic Connectors, SM

Fiber optic connectors, SM will be measured for payment by the number of connectors provided, installed, tested and accepted. Fiber connectors will be measured in units of each and paid for at the Contract price per each, which will

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include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### I. Outside Plant Fiber Optic Cable, Loose Tube, Multi-Mode, No. of Fibers

OSP fiber optic cable, loose tube, MM fiber will be measured in units of actual linear feet and paid for at the Contract price per linear feet, including cable slack. The price bid will include the length in feet of actual cable installed and tested as measured from the cable sequential length markings, cable print-lines, aerial snowshoes for storage (aerial segments), ancillary and incidental materials, documentation, and labor and equipment necessary to complete the work. No measurement for payment will be made for cable storage amounts in excess of that required in the Contract documents.

### J. Fiber Optic Patch Cord, MM

Fiber optic patch cord, MM will be measured for payment by the number of patch cords provided, installed, tested and accepted. Patch cords will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### K. Fiber Pigtail Cable, MM

Fiber pigtail cables, MM will be measured for payment by the number of pigtails provided, installed, tested and accepted, and only when separately denoted by pay item in the Contract. Fiber pigtail cables will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### L. Fiber Interconnect Cable, MM

Fiber interconnect cable, MM will be measured for payment by the number of interconnect cables provided, installed, tested and accepted, and only when separately denoted by pay item in the Contract. Fiber interconnect cables will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### M. Fiber Optic Connectors, MM

Fiber optic connectors, MM will be measured for payment by the number of connectors provided, installed, tested and accepted. Fiber connectors will be measured in units of each and paid for at the Contract price per each, which will include, but not be limited to, ancillary and incidental materials, testing, documentation, and labor and equipment necessary to complete the work.

### N. Training

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

## 935.5 Payment

### 935.5.01 Fiber Optic System

Fiber optic cable, splice closures, fiber splices, interconnect cables, pigtails, fiber patch cords, and fiber optic connectors will be paid for at the Contract unit price. This price will include full compensation for labor, materials, equipment, tools, test equipment, incidentals, installation, testing, and providing warranty necessary to complete the fiber optic system.

#### Payment Notes:

##### *Submittal*

Submittal requirements are included in Section 942.1-04 and will not be paid for separately. It will be considered incidental to the fiber optic system pay item.

##### *Testing*

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Testing is defined in Section 942.3.04 and will not be paid for separately. It will be considered incidental to the fiber optic system pay item.

Payment for the fiber optic system will be made under:

Item No. 935	Outside Plant Fiber Optic Cable, Loose Tube, Single Mode, __ Fiber	Linear feet
Item No. 935	Fiber Optic Connectors, SM	Per each
Item No. 935	Fiber Optic Patch Cord, SM	Per each
Item No. 935	Fiber Interconnect Cable, SM	Per each
Item No. 935	Fiber Pigtail Cable, SM	Per each
Item No. 935	Fiber Optic Splice, Fusion	Per each
Item No. 935	Fiber Optic Closure, Underground, __ Splice	Per each
Item No. 935	Fiber Optic Closure, Aerial, __ Splice	Per each
Item No. 935	Fiber Patch Panel, Rack Mount, __ Port	Per each
Item No. 935	Fiber Patch Panel, Wall Mount, __ Port	Per each
Item No. 935	Fiber Distribution Unit, Rack Mount, __ Port	Per each
Item No. 935	Fiber Distribution Unit, Wall Mount, __ Port	Per each
Item No. 935	Testing	Lump Sum

The following pay items are eligible for use to maintain a legacy communication network that has existing multi-mode fiber-optic cable. The pay items shall be used only when required and approved by the Department.

Item No. 935	Outside Plant Fiber Optic Cable, Loose Tube, Multi-Mode, __ Fiber	Linear feet
Item No. 935	Fiber Optic Connectors, MM	Per each
Item No. 935	Fiber Optic Patch Cord, MM	Per each
Item No. 935	Fiber Interconnect Cable, MM	Per each
Item No. 935	Fiber Pigtail Cable, MM	Per each

### 935.5.02 Training

Payment for training will be made under:

Item No. 935	Training	Lump sum
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### 935.5.03 Adjustments

Refer to General Provisions 101 through 150.