804.01 Description. This work consists of furnishing and installing fiber optic cable and components. This specification describes the requirements for communication system cables, splicing, associated interface devices, and power cables.

804.02 General. Furnish new materials and equipment, being of first quality, of latest design and completely free of defects in material and poor workmanship.

All materials, cables, fiber and hardware shall be of the same type and manufacturer to assure uniformity, interchangeability of components, single responsibility and most satisfactory service.

Permanently attach to each major component, the manufacturer’s name, the type or style, model number and serial number on a weatherproof decal or tag.

All fibers in the cable shall be usable fibers and shall be free of surface imperfections, material and inclusions in order to meet or exceed one hundred percent (100%) of the optical, mechanical, and environmental requirements contained in this specification.
Applicable Documents
All work described in this section shall meet or exceed the applicable provisions of the following industry documents:
A. U.S Department of Agriculture, Rural Electrification Administration Specification for Totally Filled Optical Fiber Cable, PE-90
B. EIA/TIA-455-a, Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components
C. EIA/TIA-455-25a, Repeated Impact Testing Of Fiber Optic Cables and Cable Assemblies
D. EIA-455-28b, Method for Measuring Dynamic Tensile Strength of Optical Fibers
E. EIA-455-33a, Fiber optic cable tensile loading and bending test
F. EIA-455-34, Interconnection device insertion loss test
G. EIA-455-41, Compressive Loading Resistance of Fiber optic cables
H. EIA/TIA-455-81a, Compound flow (Drip) test for filled fiber optic cable
I. EIA/TIA-455-82b, Fluid Penetration test for fluid-blocked fiber optic cable
J. EIA-455-89a, Fiber optic cable jacket elongation and tensile strength
K. EIA-455-95, Absolute optical power test for optical fibers and cables
L. EIA-455-104, Fiber optic cable cyclic flexing test
M. EIA/TIA-598, Color Coding of Fiber optic cables
N. EIA/ANSI-472 Generic Requirement for Optical Fiber and Optical Fiber Cables
O. ANSI/ICEA S-87-640

804.03 Materials. Furnish materials conforming to: 904.01 and as listed on the QPL. Provide all materials required for the installation and splicing of the specified communications cables, power cables, and associated interface devices. All materials, cables, fiber and hardware shall be commercially-available items.

804.04 Manufacturer Warranties. Provide a three (3) year manufacturer’s warranty to all items contained in this specification with the exception of fiber optic cable, which shall be warranted by the manufacturer for a period of one (1) year. This one (1) year transferrable warranty shall cover the cable against significant degradation of the fiber caused by cable defects incurred either during the manufacturing or installation process.

804.05 Fiber Optic Cable. Fiber optic cable shall be loose tube, single-mode dielectric cable. In instances where new fiber optic cable is being spliced to existing fiber optic cable, match the existing type of fiber optic cable, unless it does not meet the following specifications:
1. ITU-T G.652 (Categories A, B, C and D)
2. IEC Specification 60793-2-50 Type B1.3
3. TIA/EIA 492-CAAB
4. Telecordia GR-20
Provide written manufacturer certification that the offered cable complies with all optical, electrical and mechanical requirements set forth in this and all referenced specifications.

Any deviation of the offered cable from the requirements set forth herein shall be conspicuously noted by colored highlights and/or callout bubbles in the submitted material documentation.

Ensure all cables are free of material or manufacturing defects and dimensional non-uniformity that would:
1. Interfere with the cable installation using acceptable installation practices.
2. Degrade the transmission performance and environmental resistance after installation.
3. Inhibit proper connection to interfacing elements.
4. Otherwise yield an inferior or inoperative installation.

Certain mechanical requirements such as central anti-buckling members and other items necessary to comply with the maximum bend requirements in 904.01 may be omitted, if approved by the Engineer.

A. Cable Wraps
Furnish and install cable wraps (markers) on the fiber optic cable installed in each pull box (median and round).

Provide wraps that:
1. Are 4 inches long “snap on type”, UV stabilized, and solid color throughout.
2. The wording shall include no advertising logo or message.

Provide wraps with color and text as follows:
1. For ODOT cable: yellow background with black print text “ODOT fiber optic cable – ITS 614-387-4113”.
   Include the fiber count of the appropriate fiber that the cable wraps is placed upon.

B. Cable Installation
Exercise extreme caution when ordering optical fiber cable in order to ensure that no additional splicing, beyond that indicated in the plans, is required.

If it is believed that additional splices are required, immediately bring this matter to the attention of the Engineer for resolution.

Certification is required by the cable manufacturer to perform installation with the cable manufacturers recommended procedures including, but not limited to the following:
1. Proper attachment to the cable strength elements for pulling during installation.
2. Cable tensile limitations and the tension monitoring procedures.
3. Cable bending radius limitations.
Submit documentation to the Engineer showing that one of the following certifications is held at the time of the contract letting date:

**Building Industry Consulting Service International (BICSI)** - All fiber installers must be Installer 2, Optical Fiber certified and at least one installer shall be BICSI Technician certified and the Technician shall oversee all fiber optic cable operations.

**Electronics Technician Association (ETA)** - All fiber installers must be FOI certified and at least one installer shall be FOT-OSP certified and all fiber optic cable operations shall be overseen by the FOT-OSP Technician.

**Fiber Optic Association (FOA)** - All fiber installers must be CFOT certified and at least one installer shall be CFOS certified and the CFOS shall oversee all fiber projects.

Present certification to the Engineer prior to installing any cable.

Comply with the cable manufacturer's specifications at all times. To accommodate long continuous installation lengths, bi-directional pulling of the optical fiber cable is permissible. Implement as follows:

1. From the midpoint of a pull station, pull the fiber optic cable into the conduit from the shipping reel in accordance with the manufacturer's specifications.
2. When this portion of the pull is complete, remove the remainder of the cable from the reel to make the inside end available for pulling in the opposite direction.
3. This is accomplished by hand pulling the cable from the reel and laying it into large "figure eight" loops on the ground. The purpose of the figure eight pattern is to avoid cable tangling and kinking.
4. Lay the figure eight loops carefully one upon the other (to prevent subsequent tangling) and in a protected area.
5. Make available for installation the inside reel end of the cable.
6. Should it be necessary to set up a winch at an intermediate manhole or pull box, pull the required length of cable to that point and bring out of the manhole and coil into a figure eight.
7. The figure eight is then turned over to gain access to the free cable end. This can then be reinserted into the duct system for installation into the next section.

Ensure that the minimum bending radius of the optical fiber cable is not compromised when preparing this stored cable slack.

Involve the placement of optical fiber cables in an inner duct during installation. Ensure that inner ducts are secured to prevent movement during the cable installation process.

Do not pull the sheath termination hardware on the optical fiber cables over any sheave blocks.

Do not exceed 100 feet per minute of pulling speed when power equipment is used to install optical fiber cabling.
Do not exceed the pulling tension and bending radii limitation for optical fiber cables under any circumstances.
Use large diameter wheels, pulling sheaves, and cable guides to maintain the appropriate bending radius.
Provide tension monitoring at all times during the pulling operation by using commercial dynamometers, load cell instruments, or shearing pins.

B.1. Air-blown/Pushable Fiber-optic Cable and Micro-duct Installation. Follow all manufacturer recommended procedures when performing installation of air-blown fiber. Have a manufacturer representative present for the installation of the first 2 complete runs of both the micro-duct pathway and air-blown fiber optic cable from pull-box to pull-box.
All micro-duct pathway shall consist of complete runs between pull-boxes with no pathway splices occurring in between.
Account for thermal expansion and contraction when installing pathway.
Micro-duct pathways may be installed by plowed-trench method, open-trench method, saw-cut in pavement, or by horizontally-directional boring method.
Perform BB and pressure testing per manufacturer recommendation on all micro-ducts following complete installation and in the presence of the ODOT Engineer or their representative and a manufacturer representative.

B.2. Slack Installation. Proper storage of slack cable, both long term and short term, will be required.
Do not leave slack cable lying free on the ground or floor of a building except during the actual pulling process.
Neatly coil the cable, adhering to the bend radius requirements, on racks or bays, as directed by the Engineer.
Submit certified shop drawings of the materials and installation of the anchored mounting channels to be installed in pull boxes and aerial hardware according to 625.06.
Include the cost for the fiber optic cable used in the slack installation (both aerial and underground) and mounting hardware. This shall be paid per location per cable.

B.2.A. Underground Slack Installation. In underground installations, coil 150 feet of fiber slack in each 48” or 32” pullbox. Direction will be provided by the Engineer should the Contractor believe that this amount of slack is not capable of being stored.

B.2.B. Aerial Slack Installation. Where slack installation is designated, but a splice enclosure is not designated, provide a 100 feet in-line aerial mounted slack cable installation.
Where an aerial splice enclosure is shown, provide 50 feet of aerial mounted slack for each cable entering the splice enclosure.
Where the fiber cable is being brought aerially into an underground installation, provide 40 feet of slack for each cable run entering the designated pull box.
804.06 **Fan-Out Kit.** Only four (4) drop cable fibers are required for the full duplex daisy-chain fiber optic communication design; the remaining fibers are typically unused spares.

Fan out and apply connectors to all unused drop cable fibers and insert them into the termination panel. Color coded, Pre-connectorized, pre-tested pigtails may also be used. Connectors attached to fibers from the fan-out kit shall be incidental to the fan-out kit.

804.07 **Drop Cable.** Drop cables are used to connect the fiber trunk cable to termination point.

Leave unused drop cable fibers for future use.

Place spare drop cable fibers at the splice enclosure end inside of the enclosure with sufficient excess to provide two service loops.

Insert spare drop cable fibers at the device end into the fan-out kit, connectorized and inserted in the termination panel.

Provide drop cables routed down through a pole from aerial interconnect with strain relief (cable support assembly).

Cost of the cable support assembly shall be incidental to the bid item price of the drop cable.

Provide a minimum of 15 feet (4.5 meters) slack drop cable in each device cabinet or termination panel location.

 Coil slack drop cable and bind to the cabinet or wall via tie wrap or other approved means.

Any means of securing the slack cable shall NOT apply stress to the drop cable.

Loosely wrap tie wraps around the cable.

804.08 **Fiber Optic Patch Cord.** Equip patch cords for connections to/from fan-out kits and/or fiber termination panels with approved connectors on both ends of the patch cord.

The optical connectors on the other end of these patch cords shall be compatible with the connectors furnished on the optical device transmit and receive cards.

Patch cords shall be of a length that minimizes the amount of slack that needs to be stored in the cabinet.

804.09 **Fiber Termination Panel.** Provide a termination panel in a place that provides the most room for making connections, minimizes fiber bending, and does not subject fibers to interference from door openings or routine maintenance operations inside the cabinet space.

House in the termination panel all fiber optic pigtails, fiber optic connectors, fiber optic patch cords, and splice trays.

Mount termination panels in a location in ground mounted cabinets such that the bottom of the panel is 36” from the top of the cabinet riser or 48” from ground level.

All fiber optic pigtails, fiber optic connectors, fiber optic patch cords, splice trays, and pigtail fusion splices shall be incidental to the unit cost of the fiber optic termination panel.

Provide three meter patch cords of the appropriate fiber type and fiber connectors in a quantity that is half of the number of fiber optic connectors available on the termination panel, or as directed by the engineer.
A. NEMA Cabinet

Attach termination panel to the inside wall of the cabinet.

B. Caltrans Signal Cabinet (332, 336)

Utilize standard 19-inch rack mount panels for the termination panel.

C. Caltrans (334) or AASHTO/ITE/NEMA ITS Cabinet

Utilize standard 19-inch rack mount panels for the termination panel.

Provide a minimum of five 12-strand Splice Trays placed in the fiber termination panel.

Splice trays shall be incidental to the cost of the termination panel.

Splice trays shall be of the type that allows up to 12 splices. The buffer tubes of each fiber shall enter at opposite ends of the splice tray and shall have separate coils of fiber at opposite ends of the tray.

Install splice trays in the following manner:

- The splice trays have areas on each end for coiled fiber.

  - Coil the entering fiber buffer tube at one end and coil the exiting fiber buffer tube at the opposite end.

  - Secure the splice, with splice protector in the holder, located in the center of the splice tray.

  - Secure all splice trays in a separate 19 inch rack mount housing from the fiber optic connectors, so as to limit the amount of clutter located in the termination panel housing.

  - Make available enough fiber optic cable slack to allow each splice tray to be set flat on the ground outside of the cabinet, during any needed future fiber optic maintenance/repairs.

Install all fiber optic cable, buffer tubes, pigtails, patch cords, and splice trays in a neat and orderly fashion and secured to eliminate any interference with the removal, replacement, operation, and maintenance of all other items located in the cabinet.

Perform all permanent splicing based on Fiber Termination Drawings found in plan set.

Provide an emergency restoration kit with each fiber termination panel to perform temporary splices. This kit shall include all necessary materials to perform a minimum of 5 mechanical splices. Tools, such as cleavers, strippers, etc., shall be provided by the owning agency. Each mechanical splice kit shall be capable of achieving not more than 0.5dB loss at any wavelength and contain LC/SC/ST type connectors. This kit shall be incidental to each termination panel. The emergency restoration kit shall be of the same manufacturer as the cable being installed.

804.10 Fusion Splicing. Ensure that all permanent optical splices are of the core alignment fusion type method.

- Splice only at locations identified in the plans or approved by the Engineer.

  - The splicing of fibers shall be between fibers of identical color contained in fiber buffer tubes of identical color (splice through in-kind fibers inside of in-kind buffer tubes), or as specified in the plans.

  - Ensure all splicing equipment is in good working order, properly calibrated, and meets all industry standards and safety regulations.

  - Accomplish cable preparation, closure installation, and splicing in accordance with accepted and approved industry standards.

  - Upon completion of the splicing operation, deposit all waste material in suitable containers, removed from the job site, and disposed of in an environmentally acceptable manner.
No individual splice loss measured in a single direction shall exceed 0.05 dB.

804.11 Fiber Optic Connectors. In the event that particular components proposed in the system are not compatible or cannot fit within the cabinets with the proposed type connectors, detail a plan to use other connectors for the Engineer’s approval.

Include in the plan the type of connector, except for the pigtails connecting to the components requiring different connectors, and new proposed cabinet layout.

The contractor shall be compensated for any change in materials and any labor involved.

Optical fiber connectors shall satisfy all of the interface parameters of equipment components as may be defined by the transmission equipment specifications.

Pigtails shall have sufficient length to extend from the fiber splice closure to the termination panel, allowing for routing, securing, and slack.

The connector shall be pre-terminated on the fiber cable or pigtail and core-aligned fusion spliced to the fiber trunk cable.

No-epoxy, no-polish quick mount single-mode UPC connectors shall be provided.

804.12 Splice Enclosure. Use a ring cut methodology at splice locations, as described below.

Cut back trunk cable jacketing at a sufficient distance to allow unused trunk fiber tubes to be stored uncut/unopened with two service loops inside the enclosure.

Open the trunk cable tube that contains the interconnect fibers to expose the inner fibers.

The remaining trunk cable fibers in the opened tube shall remain uncut and stored in the splice tray with a minimum of two service loops.

The only trunk cable fibers that are to be cut are the trunk cable fibers being spliced into the drop cable.

Cost for the splices shall be incidental to the fiber optic cable being spliced. If all fiber optic cable is existing, then splices will be itemized separately.

If the contractor must cut the cable at the splice enclosure location, the additional splices for through fibers shall be included in the cost of the splice enclosure.

804.13 Fiber Optic Media Converter. Equip traffic signal controllers and/or cabinets and ITS cabinets with media converters.

Install and activate each media converter in the controller housing or cabinet.

804.14 Testing. All testing listed below shall be incidental to the cost of the fiber optic cable and shall be completed and approved, prior to acceptance of the fiber optic cable by the Engineer.

A. Optical Fiber Cable Factory and Reel Testing. Obtain a factory test data sheets for each reel of optical fiber cable delivered.

The tests shall be performed by the factory at 1550 nm and shall include directional Optical Time Domain Reflectometer (OTDR) traces and test data for each fiber in the cable.

Test each fiber on the reel at 1550 nm prior to installation to ensure no damage occurs to the fiber in transit and that the length of cable is correct.

Provide these two test results to the Engineer prior to installation as part of final acceptance of the section of cable for payment.

Attenuation test all cabled optical fibers > 1000 meters in length. Provide the attenuation of each fiber with each cable reel.
Supply the Engineer with the factory, and pre-installation test results documenting that the cables meet all relevant EIA specifications.

Single-mode fibers utilized in the cables specified herein shall be subjected to and successfully pass a tensile proof stress test equivalent to 100 kpsi (0.70 gN/m²) for 1.0 second.

Fibers shall contain no factory splices.


Testing procedures shall utilize – one jumper reference.
Perform bidirectional testing of optical fibers.
Coordinate with the Engineer for specific locations for the testing.
Provide the Engineer written notification a minimum 14 calendar days before testing the fiber optic cable.
Do not begin testing until written authorization and fiber locations and test points have been received from the Engineer.

Perform tests as described below:

1. Test all single mode fiber cables at both 1310 nm and 1550 nm after installation.
   Fibers will be considered acceptable if the Optical Time Domain Reflectometer (OTDR) trace for that fiber shows an end to end loss of less than $xx \text{ dB} + yy (0.05) \text{ dB} + zz (0.2) \text{ dB}$ (where $yy$ is the number of splices (a number to be provided by the Engineer), $zz$ is the number of connector pairs and $xx$ is calculated using the following formula: $xx = distance \times fiber \text{ attenuation/}unit \text{ distance at the required wavelength}$). In addition, no splice may show a loss of greater than 0.05 dB and no connector pairs may show a loss of greater than 0.2 dB, regardless of the total accumulated end-to-end loss.
   Perform any additional tests required by the ANSI/TIA/EIA standard and include in the written test report.

2. Test each fiber strand from both ends of the fiber utilizing an OTDR at the wavelengths specified above.
   Overall, the OTDR test results shall be made up of the wavelength of the conducted test, the link length, attenuation, cable identification, and the locations of the near end, the far end and each splice point or points of discontinuity.
   Electronic format results for each fiber strand shall be submitted as part of the final documentation, prior to acceptance.
   Submit to the Engineer all test results in electronic format provided by the manufacturer of the test equipment used by the contractor to perform the tests.
   Those results must be provided such that they can be viewable without the use of special software or additional equipment, unless the software or equipment is also delivered to the Engineer.
   If software is provided, a separate pdf document showing all fiber test results must be submitted to be placed in the project file.
   Any software or equipment so delivered will become the permanent property of the maintaining agency and will not be returned.
3. If the cable fails to meet the above requirements, it shall be replaced by the Contractor at the Contractor’s expense. Test results shall include a record of wavelength, fiber type, fiber and bundle number, test equipment and model number, date reference setup, and operator (crew members). In the event that test results are not satisfactory, make adjustments, replacements, and changes as necessary and then repeat the test or tests that disclosed faulty or defective material, equipment, or installation method. Additional tests shall be performed as the Engineer deems necessary. Tests related to connected equipment of others shall be done only with the permission and presence of the Contractor involved. Perform only that testing required to prove that the fiber connections are correct.

804.15 Packaging and Shipping. Package the completed cable for shipment on wooden reels. Wrap the cable and reel in a water resistant covering. Securely fasten each end of the cable to the reel to prevent the cable from coming loose during transit. At least six feet of cable length on each end of the cable shall be accessible for testing. Seal both ends of the cable to prevent the ingress of moisture. Provide on each cable reel a durable weatherproof label or tag showing the manufacturer's name, the cable type, and the actual length of cable on the reel, the Contractor's name, the contract number, and the reel number. Include a shipping record in a weatherproof envelope showing the above information and also include the date of manufacture, cable characteristics (size, attenuation, etc.), cable identification number and any other pertinent information. The minimum diameter of the reel shall be at least thirty times the diameter of the cable. The optical fiber cable shall be in one continuous length per reel with no factory splices in the fiber. Each reel shall be marked to indicate the direction the reel shall be rolled to prevent loosening of the cable. Installation procedures and technical support information shall be furnished at the time of delivery.

804.16 Fiber Optic Training. Provide both formal classroom and "in-field" operations and maintenance training for up to twenty (20) designated personnel on the fiber optic cable system and its components. Coordinate all training at a mutually agreed upon time and location. All training material generated for each course shall contain "hand-outs" for each attendee. These hand-outs shall serve not only as subject guidance, but as quick-reference material for future use. Deliver all course material, in reproducible form, to the Engineer immediately following course completion. Provide two (2) DVD copies of the training program. Submit for Engineer’s approval at least two (2) weeks prior to the proposed starting date, the schedule for such training.

A. Classroom Training. Train personnel to install, splice, and test fiber optic cable. This training shall be a minimum of 32 hours. The 32 hours of fiber optic training shall be a four (4) day course taught by personnel from the manufacturer of the fiber optic cable. Topics in the course shall include: safety, theory, fiber types, cable placement
techniques, fiber optic sheath removal, hardware types, fault location with an Optical Time Domain Reflectometer (OTDR), Dense Wave Division Multiplexing (DWDM), splicing and termination methods and applications, theory and principles of splicing, fusion splicing, mechanical splicing, cable preparation procedures for installing optical connectors, installing connectors, mocking up a typical traffic control system, cable system testing and documentation, attenuation test procedures, and overall cable system maintenance. This course shall include lectures, demonstrations, and hands-on experience with the equipment. Students shall be given hand-outs to use as guides for field applications.

B. Field Training. Provide field training. This training shall consist of the following as a minimum: eight (8) hours of fiber optic communications plant trouble shooting including fault location using an optical power meter/light source and using an Optical Time Domain Reflectometer (OTDR) cable tester, four (4) hours of field splicing (which shall include re-enterable rotary mechanical splicing (for emergency temporary repair) and fusion splicing techniques), and four (4) hours of training on the installation, maintenance, and replacement of fiber interconnect centers.

C. Course Outline and Workbooks. For both types of training, four (4) copies of all proposed training material shall be submitted for approval, which shall include course curriculums, draft manuals, and resumes of instructors. Make submittals to the Engineer at least four (4) weeks prior to the scheduled starting date. For the classroom training, provide for each participant a course workbook, which shall be provided in loose-leaf format in a three (3) ring binder.

804.17 Method of Measurement. The Department will measure Fiber Optic Cable by the number of feet, excluding slack, and will include the costs for equipment, fusion splices, labor and miscellaneous materials.

The Department will measure Fiber Optic Cable, Airblown / Pushable by the number of feet, excluding slack, and will include the costs for equipment, fusion splices, labor and miscellaneous materials.

The Department will measure Micro-duct Pathway by the number of feet and will include the costs for equipment, splices, labor and miscellaneous materials.

The Department will measure Fan-Out Kit by the number of each, and will include all costs for material, equipment, tools and labor to provide and install the fan-out kit.

The Department will measure Drop Cable by the number of each, and will include all costs for material, equipment, tools and labor to provide and install the drop cable.

The Department will measure Fiber Optic Patch Cord by the number of each, and will include supplying and installing connectors on all ends of the patch cord.

The Department will measure Fiber Termination Panel by the number of each, and will include all materials, MTP Module, splice trays, pre-terminated MTP cables, patch cables, emergency restoration kit, tools and labor to provide and install a termination panel.

The Department will measure Fusion Splice by the number of each, and will include all costs for equipment, material and labor to provide a permanent fused splice including splice protection.

The Department will measure Fiber Optic Connector by the number of each.
The Department will measure Splice Enclosure by the number of each, and will include fusion splices and aerial or pull box wall mounting brackets as required.

The Department will measure Slack Installation by the number of each, and will include all materials, equipment and labor to provide a slack installation.

The Department will measure Fiber Optic Media Converter by the number of each.

The Department will measure Fiber Optic Fusion Splicer by the number of each.

The Department will measure Fiber Optic Optical Time Domain Reflectometer (OTDR) by the number of each.

The Department will measure Fiber Optic Cleaver by the number of each.

The Department will measure Fiber Optic Power Meter by the number of each.

The Department will measure Fiber Optic Visual Fault Locator by the number of each.

The Department will measure Fiber Optic Training by the number of each.

804.18 Basis of Payment. The Department will pay for accepted quantities at the contract prices as follows:

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<tr>
<th>Item</th>
<th>Unit</th>
<th>Description</th>
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<td>804</td>
<td>Foot</td>
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<td>804</td>
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<td>Fiber Optic Cable, Airblown / Pushable, _____ Fiber</td>
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<td>Drop Cable, _____ Fiber</td>
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<td>Fiber Optic Patch Cord, _____ Fiber</td>
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<td>Fiber Optic Training</td>
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</table>
Designer Note: This specification shall be used for any project that contains Intelligent Transportation System (ITS) Devices and Components.