CITY OF CONCORD

SPECIFICATIONS FOR FIBER OPTIC PROJECT

AUGUST, 2017

FIBER OPTIC SPECIFICATIONS

1.0 Fiber Optic Cable

1.01 Description of Work

Work under this section shall include the installation of fiber optic cable as indicated on the project plans.

1.02 Technical and Functional Requirements

288-Strand, 144-Strand, and 12-Strand Fiber Optic Cabling

The following requirements apply to all cable as shown on the project plans.

General

The Contractor shall furnish and install fiber optic cables with the fiber quantities and numbers shown on the project plans. The Contractor at his option and sole cost may propose to furnish and install fiber optic cables with higher numbers of fiber strands than shown on the contract plans which shall be subject to the approval by the Project Engineer.

All fiber optic cables shall be new and from the same manufacturer who is regularly engaged in the production of this material. Where an outside fiber cable that is not Plenum or Low Smoke Zero Halogen enters a building, the fiber shall be permitted to be installed within the building where the length of the cable within the building measured from its point of entrance does not exceed 50 feet, not including coiling. Fiber cables installed within buildings in ducts or other spaces used for environmental air shall be plenum-rated, low smoke zero halogen cables. The required fiber grade shall reflect the maximum individual fiber attenuation, to guarantee the required performance of each and every fiber in the cable.

The Contractor shall submit written certification from the fiber cable manufacturer that the fiber cables furnished fully comply with these special provisions.

The Contractor shall also provide the manufacturer's certification that the furnished fiber optic cables are listed with the Rural Utilities Service (RUS) Specification 1755.900 as currently amended; and qualified to the Telcordia/Bellcore GR-20-CORE Issue #3 requirements as set forth in these special provisions.

References

The following references are incorporated into these technical specifications for the fiber optic cable and all associated assemblies.

- Rural Utilities Service (RUS)
  - 7 CFR 1755.900, 1755.901, and 1755.902 (RUS Bulletin 1753F-601a), *Minimum Performance Specification for Fiber Optic Cables (For Backbone, Feeder and Distribution Plant)*

- International Telecommunications Union (ITU)
  - G.652, *Characteristics of Single-mode Optical Fibre and Cable*

- G.657, *Characteristics of a Bending-loss Insensitive Single-mode Optical Fibre and Cable for* the *Access Network*

- Insulated Cable Engineers Association, Inc. (ICEA)
  - ANSI/ICEA S-83-596, *Standard for Optical Fiber Indoor Plant Communications Cable*
  - ANSI/ICEA S-87-640, *Standard for Optical Fiber Outside Plant Communications Cable*
  - ANSI/ICEA S-104-696, *Standard for Indoor-Outdoor Optical Fiber Cable*

- Electronic Industries Association (EIA)
  - EIA-455-27A, *Method of Measuring (Uncoated) Diameter of Optical Waveguide Fibers*
  - EIA-455-28B, *Method for Measuring Tensile Failure Point of Optical Waveguide Fibers*
  - EIA-455-34, *Interconnection Device Insertion Loss Test*
  - EIA/TIA-455-82A, *Water Penetration Test*
  - EIA-455-95, *Absolute Optical Power Test for Optical Fibers and Cables*
  - EIA-455-103, *Buffered Fiber Bend Test*
  - EIA-359-A-1, Special *Colors*

- Fiber Optic Association (FOA)
  - FOA-1, *Testing Loss of Installed Fiber Optic Cable Plant*
  - FOA-2, *Testing Loss of Fiber Optic Cables, Single Ended*
  - FOA-3, *Measuring Optical Power*
  - FOA-4, *OTDR Testing of Fiber Optic Cable Plant*

- Telecommunication Industry Association (TIA) 568, *Telecommunications Standards*

Fiber Cable Characteristics

Each optical fiber shall be glass and consist of a doped silica core surrounded by concentric silica cladding; and meet ITU-T G.652, ”Characteristics of a Single-Mode Optical Fibre and Cable,” and ITU-T G657, “Characteristics of a Bending-Loss Insensitive Single-Mode Optical Fibre and Cable for the Access Network.”

All fibers in each buffer tube shall be factory tested and usable fibers, and shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical, and environmental requirements of these special provisions.

Fiber coating shall be layered, UV cured, acrylate. The coating shall be mechanically or chemically strippable without damaging the fiber.

Fiber optic cable shall comply with the optical and mechanical requirements over an operating temperature range of -40ºC to +70ºC.

Fiber optic strands within the finished cable shall meet the requirements listed in Table 1 (page 5).

Color Coding

In buffer tubes containing multiple fibers, each fiber shall be distinguishable from others in the same tube by means of color coding. The colors shall be targeted in accordance with the Munsell color shades and shall meet EIA/TIA-598 "Color Coding of Fiber Optic Cables."

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

Buffer Tubes

The loose buffer tubes shall provide clearance between the fibers and the inside of the tube to allow for thermal expansion without restraining the fiber. The fibers shall be loose or suspended within the tubes. The fibers shall not adhere to the inside of the buffer tube. Each buffer tub shall contain twelve (12) fibers.

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

Buffer tube shall contain a water-swellable yarn or hydrocarbon-based gel (with anti-oxidant additives) to prevent water intrusion and migration. The filling compound shall be non-toxic and dermatologically safe to exposed skin. It shall be chemically and mechanically compatible with all cable components, non-nutritive to fungus, non-hygroscope and electrically non-conductive. The filling compound shall be free from dirt and foreign matter and shall be readily removable with conventional non-toxic solvents.

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

TABLE 1: FIBER OPTIC REQUIREMENTS	
PROPERTY	**REQUIREMENT**
GEOMETRY	
Core Diameter	8.3 µm (nominal)
Cladding Diameter	125 µm ± 1.0 µm
Core to Cladding Concentricity	≤ 0.8 µm
Mode Field Diameter (Peterman II)	9.3 ± 0.5 µm at 1310 nm 10.5 ± 1.0 µm at 1550 nm
Coating Diameter	250 µm ± 15 µm
Cladding Non-Circularity Defined as: [1-(min. cladding Diam. / max. cladding diam.)]x100	≤ 1.0%
OPTICAL	
Type	**Step Index**
Attenuation @ 1,310 nm @ 1,550 nm	 ≤ 0.40 dB/km ≤ 0.30 dB/km
Attenuation at the Water Peak	≤ 2.1 dB/km @ 1383 + 3 nm
Chromatic Dispersion: Zero Dispersion Wavelength Zero Dispersion Slope	 1301 to 1321.5 nm ≤ 0.092 ps/(nm2*km)
Maximum Dispersion	3.3 ps/(nm*km) for 1285 - 1330 nm < 18 ps/nm*km) for 1550 nm
Cut-Off Wavelength	< 1,260 nm

Central Member

The central member which functions as an anti-buckling element shall be a glass reinforced plastic rod with similar expansion and contraction characteristics as the optical fibers. A linear overcoat of Low Density Polyethylene shall be applied to the central member of the main trunk fiber cable to achieve the optimum diameter to provide the proper spacing between buffer tubes during stranding.

Filler Rods

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

Stranding

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

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

The binders shall be non-hygroscopic, non-wicking, and dielectric with low shrinkage.

Core and Cable Flooding

The cable core interstices shall be filled with water blocking tape or other method that is dry to the touch, to prevent water ingress and migration.

Tensile Strength Member

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

Outer Jacket

The outer jacket or sheath shall be marked with the manufacturer's name, the words "Fiber Optic Cable", date of manufacture, type of cable (i.e., single mode, OFNR, etc.) and sequential length markers. The markings shall be repeated approximately every three (3) feet.

The actual length of the cable shall be within 0 ± 1 percent of the length marking.

The marking shall be in a contrasting color to the cable jacket. The height of the marking shall be approximately 1/8”.

The cable shall contain at least one ripcord under the inner sheath for easy sheath removal.

Outdoor Fiber Cable Jacket

The outer jacket material shall be a medium density polyethylene (MDPE) or high density polyethylene (HDPE) applied directly over the tensile strength members and water blocking material and shall not

adhere to the armored strength material. The polyethylene shall contain carbon black to provide ultraviolet light protection and shall not promote the growth of fungus.

Indoor Fiber Cable Jacket

The outer jacket material for cables used in interbuilding and intrabuilding applications shall be plenum or low smoke zero-halogen. The jacket shall be chemical and UV resistant.

Cable Performance

Outdoor fiber optic cable shall comply with ANSI/ICEA S-87-640, *Standard for Optical Fiber outside Plant Communications Cable*. Indoor optic fiber cable shall comply with ANSI/ICEA S-104-696, *Standard for Indoor-Outdoor Optical Fiber Cable*, or ANSI/ICEA S-83-596, *Standard for Optical Fiber Indoor Plant Communications Cable*.
The Contractor shall submit certification from the manufacturer that the above requirements have been met by the cable supplied to the project. Documentation of factory results shall be submitted to the Engineer with the *Cable Reel Acceptance Test* outlined in these Special Provisions.

2.0 Fabric Innerduct

2.01 Description of Work

Work under this section shall include the installation of fabric innerduct as indicated on the project plans.

2.02 Technical and Functional Requirements

Innerduct
Innerduct must be installed as indicated on the plans. Innerduct consists of flexible fabric chambers that is installed inside conduit, and which in turn the fiber optic cable is installed. Innerduct within a conduit run must be continuous without splices or joints. Innerduct for this project must have a minimum of 3 cells as specified in the Project Plans. Innerduct size shall be per the following table:

Conduit Size	**Innerduct Size**	**No. of Cells**
2”, 2.5”	2”	3
3”, 4”	3”	3

Innerduct cells must include 1250lb minimum flat woven pull tape for installation. Innerduct shall be protected and installed per manufacturer specifications.

The innerduct must be shipped on reels marked with the manufacturer, the contract number, and the size and length of the innerduct. The material on reels must be covered with aluminized material to protect colors from UV deterioration during shipment and storage. Each innerduct must be one continuous unit within a conduit run. Each innerduct must comply with Caltrans Standard Specifications section 86-2.05A.

Tracer Wire
Tracer wire shall be installed within innerduct or conduit as shown on Project plans. Tracer wire shall be #12 AWG stranded copper conductor with orange THWN insulation, unless otherwise noted.

3.0 Fiber Optic Splice Enclosure

3.01 Description of Work

Work under this section shall include the installation of fiber optic splice enclosures as indicated on the project plans.

3.02 Technical and Functional Requirements

Underground fiber splice closures must be butt-end style, corrosion resistant, watertight, and meet the latest requirements of GR-771-CORE. Underground splice closures must seal, bond, anchor, and provide efficient routing, storage, organization, and protection for the fiber optic cables and splices that are installed within the closure.

The splice closures shall provide an internal configuration and end cap with a minimum of six ports, with each port having the capacity to accept up to a one (1) inch diameter fiber cable for entry and/or exit to/from the splice closure.

Splice closures shall have a reliable dual seal design with both the cable jackets and core tubes sealed, without the use of water-blocking material. The splice closures must be capable of being opened and completely resealed without loss of performance.

The fiber splice closures shall be equipped with splice trays that are designed specifically for housing single-mode fusion splices protected by heat-shrink sleeves, are easy to install and remove, and have provisions for a minimum number of fusion splices accommodated by the splice closure.

Unless otherwise noted on the contract plans, each splice closure shall accommodate a minimum of 288 fusion splices.

The splice closure maximum dimensions shall not exceed 20” in length by 12” in diameter.

4.0 Fiber Cable Assemblies & Installation

4.01 Description of Work

Work under this section shall include the installation of pigtails, patch cables, fiber splicing, and cable connections.

4.02 Technical and Functional Requirements

Cable Assemblies

Cable assemblies (pigtails, patch cords, and connectors) shall be products of the same manufacturer. The cable used for cable assemblies shall be made of fiber meeting the performance requirements of these Special Provisions for the fiber optic cable being connected.

Pigtails

Pigtails shall be of simplex (one fiber) construction, in 900 µm tight buffer form, surrounded by aramid for strength, with a PVC jacket with manufacturer identification information and a normal outer jacket with diameter of 0.12 inch.

All pigtails shall be factory terminated with connectors and factory tested, and shall be at least three (3) feet in length or as otherwise noted in the contract plans.

Unless otherwise noted on the contract plans, the connector type shall have a factory installed ST connector on one end, with the other end of the pigtail bare for splicing to a fiber strand.

Patch Cables

Patch cords shall be of simplex or duplex design. Duplex jumpers shall be of duplex round cable construction, and shall not have zip-cord construction.

The patch cord shall be terminated with a compatible super physical contact single-mode connector at both ends.

The fiber strands shall meet the specifications of the fiber cable and the connectors shall meet the specifications as specified elsewhere in these special provisions.

All patch cords shall be at least six (6) feet in length.

The outer jacket of duplex patch cords shall be colored yellow. The two inner simplex jackets shall be color coded white and slate, respectively, to provide easy visual identification for polarity.

Fiber patch cables shall meet the following requirements:

- 250 µm buffering of each fiber
- 900 µm buffering of each fiber applied after the initial 250 µm buffering
- Maximum factory measured insertion loss of 0.5 dB per EIA/TIA 455-171
- Less than 0.2 dB loss when subjected to EIA/TIA-455-1B, 300 cycles, 1.1 lbs.
- Aramid yarn strength member
- Rugged 0.12 inch (approximate) PVC sheathing
- Minimum bend radius of 12.5" following installation, 25" during installation
- Minimum tensile strength of 100 lbf
- Connectors shall be factory terminated with strain relief
- Comply with NEC requirements for indoor cable when used indoors
- Rated by the manufacturer for use in outdoor field cabinets

Provide permanent markings on duplex jumper cables that provide a visual distinction between the two fibers.

Provide strain relief for jumper cables at both ends and elsewhere as needed.

Unless otherwise noted on the contract plans, the fiber termination panel end of the patch cable shall be an ST connector and the equipment end of the patch cable shall be an LC connector.

Fiber Optic Splices

All fiber optic splices shall be in accordance with TIA/EIA-758, "Customer Owned Outside Plant Telecommunication Cabling Standard," and shall be measured in accordance with ANSI/ TIA/EIA-455-8, "Measurement of Splice and Connector Loss and Reflectance Using an OTDR".

All fusion splices shall not exceed a loss of 0.30 dB maximum.

All fusion splices shall be tested in both directions and the average of the loss measured shall be used to determine the splice loss. Refer to the “Fiber Optic Testing” section elsewhere in these special provisions.

Fiber Optic Cable Connectors

All fiber optic cable connector types shall be compatible with the connection requirements of the communications end equipment (i.e., fiber switch), termination panel, or other communication equipment to which the cables are connected.

The fiber optic connectors shall meet or exceed the following:

- Operating temperature range shall be -40 °C to +70 °C.
- Insertion loss (i.e., connection loss) for a mated connector pair shall not exceed 0.75 dB in accordance to TIA/EIA-568-B.3.
- Connection durability changes shall be less than 0.2 dB per 500 mating cycles per EIA-455-21A (FOTP-21).
- All terminations shall provide a minimum 50 lb-force pull out strength.

All mated connector pairs shall be tested in both directions and the average of the loss measured shall be used to determine the connector loss. Refer to the "Fiber Optic Testing" section elsewhere in these special provisions.

The Contractor shall provide documentation of the manufacturer's factory test results and shall submit the documentation to the Engineer prior to installing any of the connectors.

Fiber Optic Cable Installation

The Contractor shall provide the Engineer with two copies of the cable manufacturer's installation instructions for fiber optic cable. The fiber optic cable manufacturer shall provide installation procedures and technical support concerning the items contained in this specification.

All fiber optic cable installations shall be in accordance with the manufacturer's best practices and procedures, unless otherwise shown on the contract plans, or as directed by the Engineer.

Any additional costs due to damage caused by the Contractor's neglect of the recommended procedures shall be the Contractor's responsibility.

All cable installation work shall be carried out in accordance and consistent with the highest standards of quality and craftsmanship in the communication industry with regard to the electrical and mechanical integrity of the connections, the finished appearance of the installation, as well as the accuracy and completeness of the documentation.

If the fiber optic cable is left outside overnight during installation, the Contractor shall provide twenty-four (24) hours a day and seven (7) days a week security for the cable.

The Contractor is responsible for any damage to the fiber-optic cable until the Engineer has accepted the project.

The Contractor shall make a physical survey of the project site for the purpose of establishing the exact cable routing and cutting lengths prior to the commencement of any fiber optic work or committing any fiber optic materials.

The manufacturer's recommended limits for cable pull lengths and pulling tension shall not be exceeded.

Cable ends shall be stored in pull boxes immediately adjacent to cabinets or as directed by the Engineer.

All fibers in cable buffer tubes shall also be installed in continuous runs.

Contractor shall be responsible for ensuring the cable length is sufficient to allow for connection between the communications equipment and the splice enclosures (if applicable) including provision for slack, vertical runs, cable necessary for splicing, wastage and cable to allow for the removal of the splice enclosure for future splicing.

Fiber Coiling and Slack

Where backbone or spur cable runs are left to be "dead ended," a minimum of 50 feet of cable shall be left coiled in the final cabinet, manhole, or pull box, unless otherwise called for in the contract plans.

In each pull box where a fiber optic cable is installed and where a splice closure is not being installed, a minimum of fifteen (15) linear feet of fiber cable slack shall be placed in the pull box unless otherwise noted in the contract plans.

In each pull box or vault where a fiber optic cable is installed and where a splice closure is to be installed, a minimum of fifty (50) linear feet of fiber cable slack shall be provided for each fiber cable that enters or exits a splice closure port (i.e., at each fiber cable entry point). This includes, but is not limited to, trunk cables, distribution cables, drop cables or lateral cables. For example, where there is a mid-span splice in a vault (i.e., trunk cable with drop cable), the trunk cable shall have a total of 100 feet of slack consisting of 50 feet of slack on the two entry points of the splice closure, and the drop cable shall have 50 feet of slack.

In a traffic signal cabinet where a fiber optic branch cable is installed, a minimum of twenty (20) linear feet of slack shall be provided at the base of the cabinet.

Fiber Bend Radius

During cable installation, the cable's minimum bend radius shall be maintained based on the manufacturer's specifications, or at a minimum of twenty (20) times the outside diameter of the fiber optic cable, whichever is greater.

In all pull boxes, the fiber cable shall be routed as needed to avoid violating the minimum bending radius.

After installation, the fiber cable's minimum bend radius shall be maintained based on the manufacturer's specifications, or at a minimum of ten (10) times the outside diameter of the fiber cable, whichever is greater.

During installation, the Contractor must keep a log that notes the meter marking on the cable at every pull box. This will help determine the exact location of problems along the cable run during the testing. The log shall present the information in sequential order and in table format listing the street and distance to the nearest cross street. This log shall be submitted to the Engineer after all the fiber optic cable has been installed and before performing any fiber optic cable testing.

Splicing

The Contractor shall disconnect all existing splices from existing fiber cables to be removed and make all new splices to the new fiber optic cable as shown in the contract plans.

The Contractor shall document any existing splices before making any new splices.

The Contractor shall keep accurate records of each new splice at each splice location. The Contractor shall immediately notify the City when there is a discrepancy between the documented existing splice(s) and the splice details shown on the Plans. Contractor shall not make any new splice(s) at the location with a discrepancy until the Engineer has resolved the discrepancy.

The Contractor shall perform all splicing and connectorization in the presence of the Engineer or his designee unless otherwise arranged for in advance, i.e., the Engineer allows the Contractor to proceed without his or his designee's presence.

The record of existing and new splices shall be submitted to the Engineer.

The fiber optic cable splices shall be fusion type. All splices shall be tested in accordance with the fiber testing specified in these special provisions.

Splices shall be housed in a splice tray in a splice enclosure in an underground pull box, or within a termination panel when splicing drop cables to pigtails. All splices shall be protected with a thermal shrink sleeve.

The Contractor shall perform all outdoor splices within a tent, truck or trailer. If the Contractor wishes to use another type of facility for splicing, it must be approved by the Project Engineer on a day-by-day basis.

Only those fibers that are to be spliced shall be removed from the cable and buffer tubes. All other fibers shall remain in their tubes and shall be suitably protected.

The Contractor shall seal all cables where the cable jacket is removed. The cable shall be sealed per the cable manufacturer's recommendation with an approved blocking material.

All technicians performing splices shall be certified as an Advanced Fiber Optics Technician or Certified Fiber Optics Specialist by the Fiber Optic Association (FOA).

Contractor shall submit to the Project Engineer for approval the resumes of people who will be performing splices along with proof of FOA certification. Splices shall be performed only by experienced personnel with experience including successful completion of no less than 2,000 fusion splices.

Only those individuals approved by the Engineer shall be allowed to make fiber optic splices.

Vehicles used for fiber splicing shall have their engine turned off during splicing.

Additional Splices

Fiber optic cable shall be installed in continuous runs without trunk splices except where specifically shown or allowed for in the contract plans. The Contractor may request additional fiber trunk splices to accommodate fiber cable reel length limitations. However, approval of any such request shall be at the sole discretion of the Engineer.

All costs associated with additional splices to accommodate the Contractor's fiber cable reel length limitations shall be borne by the Contractor and no additional compensation shall be allowed therefor.

If additional splices are approved by the Engineer, these additional splices shall be made in approved splice enclosures. Additionally, at these additional splices, all fibers shall be spliced and tested.

Under no conditions shall any fibers be cut out or spliced at these additional splice points without written direction from the Engineer. Any unauthorized trunk splices performed by the Contractor will require the Contractor to replace the entire fiber cable segment between the authorized splices at his own expense.

Installation in Conduit

Fiber optic cables shall be installed in conduit or ducts in the field in accordance with the project plans. The conduit and duct ends shall have bell ends.

A stiff bristle brush shall be pulled through each section of conduit before pulling the fiber optic cable.

A manufacturer recommended lubricant shall be applied to the cable to reduce friction between the cable and duct or conduit.

The contractor shall provide a submittal of the proposed lubricant to be used for the Engineer's approval prior to use in the field.

During cable installation, the cable's minimum bend radius shall be maintained based on the manufacturer's specifications, or at a minimum of twenty (20) times the outside diameter of the fiber optic cable, whichever is greater.

Where fiber optic cables are to be installed in innerduct (fabric or rigid style), the Contractor shall secure each section of innerduct to prevent it from being pulled with the cables per the manufacturer's instructions.

A cable grip shall be attached to the cables so that no direct force is applied to the optical fibers. The cable grip shall have a ball-bearing swivel to prevent the cable from twisting during pulling. Cable rollers and feeders and winch cable blocks shall be used to guide the cable freely into the duct and at maintenance hole locations. Mechanical aids and pulling cables or ropes shall be used as required.

Whether pulling cable with mechanical aids or by hand, a tension measuring device and a break-away swivel shall be used on the end of the cable. When pulling cables, do not exceed 2225 N, or the manufacturer's maximum pulling tension value, whichever is less.

The Contractor shall set up and conduct a demonstration of the pulling cable grip and swivel assembly to demonstrate that it will operate as designed, i.e., disengage once the pulling tension reaches the user defined limit. No fiber cable installation will be allowed until such a demonstration has been conducted and the swivel assembly approved by the Engineer.

The Contractor shall keep a log of the measured maximum pulling tensions by fiber optic segment (i.e., between pull boxes). The pulling tension log shall be submitted to the Engineer for approval prior to conducting the post-installation testing or fiber splicing.

Should the pulling logs show that the maximum tension was exceeded during any pull and should any fiber tests reveal that any fiber strand or strands do not meet the maximum attenuation limits after one re-test, the Contractor shall replace the entire fiber optic cable run and conduct a new set of pulling logs.

The cable shall be taken up at intermediate pulling points with an intermediate cable take-up device as approved by the Engineer to prevent over-tension on the cable. Cable pulls shall be continuous and steady between pull points and shall not be interrupted until the entire run of cable has been pulled.

Cable Packaging and Shipping

All fiber optic cables that are delivered to the Contractor shall have been packaged for shipment on lagged wooden reels from the manufacturer. The cable and reel shall be wrapped in water resistant covering.

Each end of the cable shall be securely fastened to the reel to prevent the cable from coming loose during transport. Six (6) feet of cable length on each end of the cable shall be accessible for testing. Both ends of the cable shall be sealed to prevent the ingress of moisture.
Each cable reel shall have a durable weatherproof label or tag showing the following:

- Manufacturer's name
- The cable type
- The actual length of cable on the reel
- The Contractor's name
- The contract number and
- The reel number.

A shipping record shall be included in an attached weatherproof envelope showing the above information and shall include the date of manufacture, cable characteristics (size, attenuation, etc.), cable information number and any other pertinent information.

The diameter of the reel shall be at least thirty times the diameter of the cable. The fiber optic 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 should be rolled to prevent loosening of the cable.

Fiber Optic Cable Labeling

The fiber optic cable shall be clearly tagged and labeled as such at all pull box and vault locations and at all other locations where it is exposed. Labeling shall consist of a permanent plastic yellow tag with the words "Fiber Optic Cable." All labels shall be affixed to the cable per the manufacturer's recommendations and shall not be affixed in a manner that will cause damage to the fiber. Handwritten labels shall not be allowed. The Contractor shall submit the proposed fiber cable label to the Engineer for review and approval.

5.0 Fiber Optic Termination Panels

5.01 Description of Work

This section includes provisions for the central fiber optic termination panels in the City of Concord Traffic Signal Shop and the field fiber termination panels located at traffic signal cabinets, per project plans.

5.02 Technical and Functional Requirements

The Contractor shall furnish and install fiber optic termination panel that will be installed within an equipment rack in an indoor facility, or within a field cabinet.

For installations with an indoor equipment rack or facility, the fiber optic termination panel shall adhere to the following requirements:

- Mounts in standard 19" racks or cabinets

- Can be pre-loaded with adapter plates, adapters, pigtails, splice cartridges or splice trays
- Allows for adding adapter plates to expand the number of fiber ports
- Dual sliding tray system allows front panel slide-out access without straining rear mounted cable
- Front or rear accessibility to splice trays
- Front door locking option available
- Large cable management rings for enhanced jumper routing
- Stackable for custom sizing
- Front cable management saddles
- Side entry for trunk cable
- Enclosures are custom configurable
- Constructed of high-strength aluminum, powder-coated central office white
- Removable front door
- Rear door with key lock option
- Upper and lower patch cord bend radius brackets
- Flipcard for connector identification

For installations within a field cabinet for a drop cable installation, the fiber termination panel shall include all guard and dust proofing components and shall adhere to the following requirements:

- 1.75” in height (1RU) and 17.5” in width maximum
- Dual sliding tray system to allow front panel slide-out access without straining a rear mounted cable
- Shelf, wall or rack mountable (standard 19” racks or cabinets) styles
- Can be pre-loaded with adapter plates, adapters, pigtails or splice cartridges
- Front door locking available

The fiber splice cartridges shall adhere to the following requirements:

- From 6 to 24 fiber configurations
- Can include laser safety smoked polycarbonate cover, bulkhead adapters, color coded pigtails, splice sleeve holder and splice sleeves
- Pigtails can be either 900um tight or loose buffered
- Shall have a port ID chart to label up to 24 terminations
- Includes heavy duty cable clamp and waterfalls
- Includes a screw down metal cover

The termination panels shall have a sufficient number of connection panels and ports to handle the associated fiber terminations as shown in the contract plans.

Unless otherwise noted or shown in the contract plans, the fiber termination panels to be installed in outdoor cabinets shall be provided with a minimum of twelve (12) fiber ports, and the fiber termination panels to be installed in an indoor rack or facility shall be provided with a minimum of two hundred and eighty-eight (288) fiber ports.

The fiber termination panel (indoor and outdoor) shall be furnished with ST connectors, unless otherwise noted on the contract plans.

The capacity to secure and store the required splice trays, break out cables, pigtails and any other pertinent assemblies and components required for a complete termination panel assembly shall be provided by the contractor.

The termination panel housing shall have a front cover that shall be easily removed or opened by use of a hinge and/or fastened with thumbscrews to provide easy access for cable installation.

The bottom and/or back shall provide openings for cable entrance, and provide for strain relief at each entrance point.

The housing shall provide fixtures as required to maintain the fiber optic cables at more than the minimum bending radius without strain placed on the cable.

It shall be noted that regardless of the requirements set forth in these special provisions described above, the Contractor shall furnish and install all of the necessary assemblies, components, parts, and all relevant elements for a complete fiber optic termination panel assembly.

6.0 Ethernet Switches

6.01 Description of Work

This section includes provisions for the central Ethernet switch to be provided in the City of Concord Traffic Signal Shop and the Ethernet switches located at traffic signal cabinets, per plan.

6.02 Technical and Functional Requirements

Central Ethernet Switch

The Contractor shall furnish and install central Ethernet switch as shown on the Project Plans. The Ethernet switch shall include:

- A minimum of sixteen (16) Ethernet 10/100/1000 GE SFP (Gigabit Ethernet Small Form-factor Pluggable) ports and Service Module with two 10GE SFP+ interfaces. Switch shall be provided with the following SFP modules:
  1. XXX
  2. XXX
- Mount: 19” Rackmount (include rail kit)
- Media Access Control Security hardware-based encryption
- Fallback bridging
- Per port broadcast, multicast and unicast storm control
- VLAN Support and tagging
- Inter-VLAN IP routing for full layer 3 routing between VLANs.
- Non-Blocking
- Basic and advanced IP unicast routing protocols
- IEEE 802.1x with VLAN assignment, ACL assignment, voice VLAN and port security
- Spanning tree protocol (IEEE 802.1D) and Multiple Spanning tree protocol (IEEE 802.1s).
- VLAN trunking protocol (VTP).
- Supports up to 4000 VLANS IDs
- Management Console Port
- DRAM capacity: 4 Gb
- MTBF: 300,000 hours.
- Flash capacity: 2 Gb
- Switching fabric capacity: 92 Gbps
- Forwarding Rate: 68.4 Mbps
- Electrical: 100-240VAC, 50-60 Hz.

Field Ethernet Switch

The Contractor shall furnish and install field Ethernet switches at locations shown on the Project Plans.

The Fiber Optic Network Switch shall include the following items:

- 10/100/1000 Mbps Single Mode Rugged LC SFP (2 fibers per port)
- Field-hardened power transformer

The switch shall be a managed, environmentally hardened and intended for industrial applications and shall meet or exceed the NEMA TS2 - 2003 environmental requirements. The switch shall meet, at a minimum, the following requirements:

- A minimum of two (2) 10/100/1000 SFP ports (transmit and receive) capable of transmitting Ethernet data at up to 1000 Mb/s over single-mode fiber, full duplex (SFP ports)
- Minimum of Six (6) 10/100 Base-T fiber transceivers with RJ-45 connectors capable of transmitting Ethernet data at 10 or 100 Mb/s, full duplex.
- Switch shall be capable of operating using an input voltage of 120VAC at 60Hz with a maximum power consumption of 300 watts, or shall come equipped with power supplies capable of doing so.
- Switch ports shall comply with the following standards:
- IEEE 802.3 10Base-T
  - IEEE 802.3u 100Base-TX
  - IEEE 802.3u 100Base-FX
  - IEEE 802.3ab 1000Base-T
  - IEEE 802.3z 1000Base-SX and 1000Base-LX
  - IEEE 802.1P priority queuing
  - IEEE 802.3X flow control
- Wire speed switching on all ports simultaneously, non-blocking
- IEEE 802.1Q VLAN Tagging 4 port trunking groups with up to 2~4 ports per group with support for 256 VLANS
- Meets Bellcore GR-63-CORE vibration and shock specifications for NEBS Level III compliance (optional)
- Operating temperature = -34 to +74 degrees Celsius
- Relative humidity = 10% - 90%, non-condensing
- UL listed (UL1950), cUL, CE
- Emissions meet FCC Part 15, Class A
- Minimum MTBF of 8 years (Bellcore Method)
- Packet Filtering and Port Security Destination MAC
- MAC address learning with a minimum of 1028 MAC addresses and $\geq$ 1028 static MAC addresses
- IEEE 802.1p QoS Classification based on: Port based priority VLAN Priority field in VLAN tagged frame DS/TOS field in IP packet UDP/TCP logical ports
- IEEE 802.1w Rapid Spanning Tree Algorithm
- IP Multicast Filtering through IGMP Snooping
- Support Telnet, SNMP v1 & v2, RMON, Web Browser, Port Mirroring (RFC 1757, TFTP, FTP and CLI management tools
- MIB statistics counters for all ports
- Management and configuration shall be able to be performed through an integrated web interface
- Support remote reset and remote management
- Support remote turn on/off of 10/100 Base-T ports
- Ethernet switches shall be compatible with Actelis meta assist to view program

The switch shall have a minimum MTBF of 60,000 hours. The MTBF shall be calculated in accordance with the methods described in Mil-Std HDBK 217F for a temperature of 55ºC for naval sheltered.

7.0 Fiber Optic Testing

7.01 Description of Work

This section includes performance of fiber optic testing of the communication system as specified on the Project Plans.

7.02 Technical and Functional Requirements

The Contractor shall acknowledge that contractor-performed testing is a vital component of the work and required for acceptance of the fiber optic cables and all related assemblies.

The fiber optic testing shall be conducted at the following stages:

- Upon Cable Delivery Before Installation – Cable Reel Tests
- After Installation and Before Splicing – Post Installation/Pre-Splicing Tests
- After Splicing and Connectorizing – End-to-End/Post-Splicing Tests

Contractor shall submit a sample of the OTDR and power meter/light source data printouts to the Engineer for review and approval prior to conducting any testing.

All testing shall be performed in a manner that provides the time, space, set up, tools, and equipment for the Engineer or his designee to inspect and verify that all test setups and tests, including review of fiber connections, test equipment, device displays, and all related documentation. The tests shall quantitatively demonstrate that the fiber optic cable meets or exceeds the minimum requirements and specifications provided in these special provisions and the contract plans.

All technicians testing cable shall be certified as an Advanced Fiber Optics Technician or Certified Fiber Optics Specialist by the Fiber Optic Association (FOA). Contractor shall submit to the Project Engineer for approval proof of FOA certification for each of the technicians performing testing.

Vehicles used for fiber testing shall have their engine turned off during testing.

The Contractor shall use clean, well maintained testing equipment. The testing equipment shall have been calibrated within one (1) year prior to conducting the tests.

A 1,000-meter launch cable, or launch box tuned to the attenuation of a 1,000-meter launch cable, shall be used to overcome the dead zone of the OTDR inserted between the OTDR and the optical link.

The OTDR testing shall be done at a scale of at least 1 dB per division on the vertical scale.

All test measurements shall be measured at the wavelengths for the proposed equipment to use the fiber optic cable.

Contractor shall perform tests to verify that ports and fibers installed by others have end points indicated in the contract plans.

Short Fiber Cable Segments

A short fiber cable segment is defined as a cable measuring 1000 feet or less including all coiling and slack.

The contractor shall acknowledge that test results from short segments of fiber cable may require re-testing, and that there may be an issue where the OTDR results may appear inconsistent and do not meet the maximum attenuation limits required in these special provisions even after the re-tests. In these cases, the Contractor shall prepare link attenuation calculations and perform power meter/light source tests on the subject fiber cable and submit to the Project Engineer for review. Should the power meter tests show that the actual loss is less than the theoretical maximum loss for the fiber cable (all strands), the power meter/light source test results will be accepted instead of the OTDR tests.

There shall be no additional cost for the additional calculations and testing for short fiber cable testing including the power meter/light source tests and link attenuation calculations. The contractor shall bear the entire cost of the re-tests and calculations, and no additional compensation shall be allowed therefor.

Test Plan

The Contractor shall prepare and submit a Test Plan to the Engineer for review and approval that provides a detailed description of the tests that will be conducted, the steps required to conduct the testing, and the specific locations where the tests will be conducted.

The Test Plan shall cover all stages of the fiber testing and shall include the following at a minimum:

1. Stage of Test (i.e., Cable Reel, Post Installation or End-to-End)
2. Contractor staff who will be conducting the tests
3. Test equipment to be used
4. The setup for the testing including all of the equipment connections
5. The detailed process for the testing including, but not limited to:
    a) recording/capturing of the test data;
    b) file format and organization of the test data that will be submitted;
    c) direction of the test (OTDR and power meter/light source); and
    d) test data that will be collected and reported
6. Sample test printouts including all graphic and tables
7. A tabular and narrative summary of all of the fiber optic segments that will be tested which shall include all start and end points noted by intersection name, facility name, stationing, or other means for the Engineer to be able to verify the location

Contractor shall submit a sample of the OTDR and power meter/light source data printouts to the Engineer for review and approval as part of the Test Plan.

If the Engineer rejects the submitted Test Plan, the Contractor shall submit a revised Test Plan within five (5) working days for review and approval by the Project Engineer. No testing shall be performed until Contractor's test plan has been approved by the Project Engineer.

Submittal of the test equipment user’s manual does not constitute any part of the Test Plan, and should the Test Plan contain such documentation, it shall be rejected in its entirety.

The Contractor shall notify the Engineer of his intent to proceed with testing forty-eight (48) hours prior to commencement of each test. It is noted that regardless of the advance notification, there shall be no testing until the Test Plan is approved by the Project Engineer. In addition, the Contractor shall be able to commence testing a minimum of 48 hours after the Test Plan has been approved.

The approval of the formats for the test printouts shall be attained prior to conducting any testing. Any tests that are conducted prior to the Engineer's approval of the Test Plan and the test document format shall be considered as not acceptable and the Contractor shall re-test all fibers as a result.

Link Attenuation Calculations

The Contractor shall prepare Link Attenuation Calculations for each fiber segment. The calculations shall be shown in a table clearly indicating the following:

- Fiber cable segment – note the two end points
- Length of the segment tested
- Direction – note which direction the calculation is being conducted for
- Splices – note the number and locations of the splices
- Connectors – note the number and locations of the connectors.

The results of the calculations will provide the theoretical attenuation limits for each segment. This will be used to compare the results of the power meter and light source testing.

The Contractor shall submit the Link Attenuation Calculations to the Engineer for review and approval prior to conducting any power meter/light source tests.

The approval of the Link Attenuation Calculations shall be attained prior to conducting any power meter/light source testing.

Any power meter/light source tests that are conducted prior to the Engineer's approval of the Link Attenuation Calculations shall be considered as not acceptable and the Contractor shall re-test all fibers as a result.

Cable Reel Test

After delivery of the fiber optic cable to the project site prior to field installation (Cable Reel Acceptance Test). This test is intended to verify that the fiber received from the supplier is in sound condition and without manufacturing defects.

The Cable Reel Test shall be performed within ten (10) working days from the delivery of the fiber optic cable to the project site, or when the cable is received by the Contractor from the supplier, whichever is sooner.

The Contractor shall notify the Engineer of his intent to proceed with the cable reel testing forty-eight (48) hours prior to commencement of the test. However, no tests shall commence until the Project Engineer has approved the Test Plan that shall be submitted to the Engineer (refer to the "Test Plan" section elsewhere in these special provisions).

The fiber cable shall be tested with an Optical Time Domain Reflectometer (OTDR), and only one direction needs to be tested.

Any fiber optic cable that does not meet the requirements described in the section "Fiber Cable Characteristics" and any applicable and relevant section in these special provisions shall be replaced at shall be at the sole cost of the Contractor, and no additional compensation shall be allowed therefor.

At the time of testing, the Contractor shall inspect the fiber optic cable and record any visible signs of defects.

The Contractor shall compare the test results to the manufacturer's specifications and note any discrepancies.

If the attenuation level measured from the tests conducted by the Contractor is 5% or more higher than the attenuation reported from the manufacturer's factory tests, *or* 5% or more higher than the maximum attenuation values allowed as shown in Table 1, the fiber cable reel will be considered as unacceptable at this stage regardless of the number of fibers that deviate from the manufacturer's test results.

The Contractor shall replace the unsatisfactory reels of cables at no expense to the City, and no additional compensation shall be allowed therefor.

The Contractor shall install heat shrink or other protective covering to the fiber optic cable end to prevent the entry of moisture or other contaminants.

Installation of new fiber optic cable shall only occur once the fiber optic cable reel acceptance test has been reviewed and approved by the Engineer.

The Cable Reel Test results including the manufacturer's factory test results shall be summarized and submitted to the Engineer for review and approval. The test results shall be documented and submitted to the Engineer based on the requirements contained in section "Test Documentation" contained herein these special provisions.

Post Installation/Pre-Splicing Testing

The installation of new fiber optic cable shall only occur once the fiber optic cable reel acceptance test has been reviewed and approved by the Engineer.

At the time of testing, the Contractor shall inspect the fiber optic cable and record any visible signs of damage.

The Post Installation/Pre-Splicing Test shall be performed within ten (10) workings from the time the fiber optic cable is installed, and before any splices are conducted or connectors installed on the fiber cable segment.

The fiber cable shall be tested with an OTDR, and shall be conducted in both directions along each fiber cable segment.

Any fiber optic cable that does not meet the requirements described in the section "Fiber Cable Characteristics" and any applicable and relevant section in these special provisions shall be replaced at shall be at the sole cost of the Contractor, and no additional compensation shall be allowed therefor.

If the attenuation level for a fiber strand measured from the tests conducted by the Contractor is 5% or more higher than the attenuation reported from the cable reel tests, *or* 5% or more higher than the maximum attenuation values allowed as shown in Table 1, the fiber strand shall be considered as an unacceptable fiber having failed the test.

The Contractor will be allowed one re-test to mitigate any failed test(s).

Should the results from any re-tests continue to yield test failures, the entire fiber cable shall be considered as unacceptable and shall be replaced by the Contractor, regardless of the number of fibers that have failed the test.

The Contractor shall replace the unacceptable fiber cables at no additional cost, and no additional compensation shall be allowed therefor.

Test results shall be summarized and submitted to the Engineer. If the cable installation test results are found unsatisfactory by the Engineer, the fiber optic cable segment will be judged as unacceptable. The Contractor shall replace the unsatisfactory segment of cable with new fiber, without additional splices, at no expense to the City. Conduct cable installation acceptance test for the new segment of cable to demonstrate proper installation.

Any and all connectorizing that is necessary to conduct the post-installation testing shall be considered as part of the fiber optic testing costs, and no additional compensation shall be provided therefor.

The test results shall be documented and submitted to the Engineer based on the requirements stated in section “Test Documentation” contained herein these special provisions.

End-to-End/Post-Splicing Testing

After the post installation testing has been approved by the Engineer and after the splicing and connectorizing of the fiber cable per the contract plans is completed, the Contractor shall conduct the End-to-End/Post Splicing Testing.

This test stage is intended to verify that the end-to-end fiber optic paths have been completed per the contract plans, and that all of the splices and connectors have been performed to the highest standard of care that meets all of the requirements in these special provisions.

The End-to-End/Post Splicing Test shall be performed within ten (10) working days from the completion of all the splices and connectorizations.

The Contractor shall notify the Engineer of his intent to proceed with the end-to-end testing forty-eight (48) hours prior to commencement of the test. However, no tests shall commence until the Engineer has approved the Test Plan that shall be submitted to the Project Engineer (refer to the “Test Plan” section elsewhere in these special provisions).

The end-to end/post-splice tests shall consist of performing OTDR and power meter/light source testing.

Both the OTDR and power meter/light source tests shall be conducted in both directions along each fiber segment.

All fusion splices shall be tested in both directions and the average of the loss measured shall be used to determine the splice loss.

All mated connector pairs shall be tested in both directions and the average of the loss measured shall be used to determine the connector loss.

The tests shall document total end-to-end loss, splice and connector loss and backreflection, and overall reflectance levels.

Should the power meter tests show that the actual fiber loss is less than the theoretical maximum fiber loss for the fiber cable (for all strands), the fiber cable will be considered as acceptable. Refer to the “Test Documentation” section elsewhere in these special provisions.

If the attenuation level for a fiber strand measured from the tests conducted by the Contractor is 5% or more higher than the maximum attenuation values allowed as shown in Table 1, or the theoretical maximum as calculated from the Link Attenuation Calculations, the fiber strand shall be considered as an unacceptable fiber having failed the test.

The Contractor will be allowed one re-test to mitigate any failed test(s).

Should the results from any re-tests continue to yield test failures, the entire fiber cable shall be considered as unacceptable and shall be replaced by the Contractor, regardless of the number of fibers that have failed the test.

The Contractor shall replace the unacceptable fiber cables at no additional cost, and no additional compensation shall be allowed therefor.

Any and all connectorizing that is necessary to conduct the end-to-end testing shall be considered as part of the fiber optic testing costs, and no additional compensation shall be provided therefor.

Test Documentation

All tests shall be saved on Compact Disc (CD) or portable media stick (USB flash drive) and shall be submitted to the Engineer for review and approval. All electronic copies of the test results shall be submitted in portable document format (pdf).

A three-ring binder with hardcopies of the test results shall also be provided. All test result printouts (OTDR and Power Meter/Light Source) shall contain the following:

- Maximum specified loss at specified wavelengths
- Test location (e.g., intersection name or facility name)
- Date and Time of test
- Test crew (names)
- Test Equipment manufacturer and model
- Direction of the test
- Length of fiber segment tested
- Buffer tube and fiber color
- Attenuation result (in dB or dB/km)

OTDR Test Results

The OTDR test result printouts shall provide a ***graphical representation*** of the test of each fiber strand that clearly shows the following information at a minimum:

- The launch cable length
- The cable length
- Cable ID
- Fiber strand number or color
- Start location (where the OTDR is located)
- End or Far location
- Total End to End Loss (dB)
- Start point and end point for each OTDR trace
- Indications where losses or other events occur along the fiber

The start point and end point shall be used to determine the direction of the test. The graphical representation shall provide enough information for the Engineer to determine where splice and connector losses are located along the fiber segment. If this information is not readily apparent on the graphical representation, it will be rejected.
In addition to the test result printouts and graphical representations, the Contractor shall provide a summary table that documents the test results of each fiber strand that is tested on each fiber cable segment. The table shall indicate the fiber number or color, buffer tube (color), wavelength (in nm), and attenuation (in dB/km).

All printouts shall bear the signature or initials of the Contractor's representative who has reviewed the tests.

The Contractor shall place a check mark on all traces that satisfy the requirements identified herein.

The Contractor shall highlight any discrepancies that may exist in the test results. If more than 20% of the tests have any discrepancies, abnormalities or failures, the tests will be rejected and the Contractor shall be required to conduct a complete re-test and re-submit the documentation for the Engineer's review and approval.

Any subsequent re-testing, re-splicing, or revision of the test documentation shall be at the sole cost to the Contractor and no additional cost shall be allowed therefor.

Power Meter and Light Source Test Results

The Power Meter/Light Source test results shall be submitted with the following at a minimum:

- Contractor staff tester (name)
- Cable ID
- Start point (intersection or facility name)
- End point (intersection or facility name)
- Fiber number and color
- Fiber buffer tube
- Direction of test
- Length of cable tested (feet)
- Splice locations (name)
- Connector locations (name)
- Wavelength (nm)
- Theoretical loss limit (from Attenuation Calculations)
- Measured loss
- Headroom loss (theoretical loss minus actual loss)

The optical testing using a light source and power meter shall meet the following minimum requirements:

Optical fiber light source

- Single mode fiber
- Provide dual laser light sources with central wavelengths of 1310 nm (±20 nm) and 1550 nm (±20 nm).
- Output power of –10 dBm minimum.

Power Meter

- Provide 850 nm, 1300nm, 1310 nm, and 1550 nm wavelength test capability.
- Power measurement uncertainty of ± 0.25 dB.

Single-mode OTDR

- 1. Wavelengths of 1310 nm (± 20 nm) and 1550 nm (± 20 nm).
- 2. Event deadzones of 2 m maximum at 1310 nm and 2 m maximum at 1550 nm.

- 3. Attenuation deadzones of 15 m maximum at 1310 nm and 15 m maximum at 1550 nm.
- 4. Distance range not less than 10,000 m.
- 5. Dynamic range at least 10 dB at 1310 nm and 1550 nm

The OTDR used for testing shall be provided with certification of its most recent calibration which shall be within twelve (12) months from the date of the testing.

The OTDR operator shall hold a current operators certificate for the equipment used. This certificate shall be provided to the Engineer prior to any use of the OTDR for testing, and shall represent not less than sixteen (16) hours of training from the equipment manufacturer.

The OTDR shall have a distance measurement accuracy of ± 0.01%.

8.0 Conduit

8.01 Description of Work

Work under this section shall include the installation of conduit as indicated on the project plans.

8.02 Technical and Functional Requirements

Conduit shall be per Section 86-2.05 “Conduit” of the State Specifications except as modified herein.

Conduit shall be installed by directional drilling or jacking and boring methods unless otherwise noted. The work shall include trench backfill and restoration as required. Furthermore, regardless of which method is chosen, the Contractor shall pothole as needed to locate existing utilities. The Contractor shall assume all risk associated with chosen method of installation, and shall fully locate and verify utilities prior to conduit installation. No additional compensation shall be allowed due to delays or changes in installation method. The contractor shall repair any infrastructure damaged during the installation of conduit in kind.

Conduit runs shall have no more than 180° of bends, unless authorized by the Engineer, and shall enter the pull box vertically within +/-30°. When trenching for conduit installation, the top of the installed conduit shall be a minimum of 24 inches below finished grade in the street section. Where the asphalt concrete (AC) portion of the roadway cross section is greater than 24 inches in depth, the finished height of the conduit shall be two (2) inches below the AC section. The trench shall be back filled with two inches of commercial grade sand with the remainder being 2% red oxide concrete.

Schedule 80 High Density Polyethylene (HDPE) shall be used throughout the “Fiber Optic Project”, except on bridge crossings or other locations, where Galvanized Rigid Steel (GRS) or PVC Schedule 40 shall be used.

For all new signals and modified traffic signals (where new cabinet and controller will be installed), three (3) – 4 inches conduit shall be installed between the controller cabinet base to the adjacent home run pull boxes. Out of three conduits, one conduit shall exclusively be dedicated to run fiber optic cable only through a separate interconnect pull box. Splicing shall not be allowed in any of the home run pull boxes.

The ends of conduits in pull boxes shall have Bell Bushings and be a minimum of two inches above the surface of the rock, and between eight and ten inches below the top of the pull box.

9.0 Pull Boxes and Vaults

9.01 Description of Work

Work under this section shall include the installation of pull boxes and fiber optic vaults as indicated on the project plans.

9.02 Technical and Functional Requirements

No. 6E Pull Boxes

No. 6E pull boxes shall conform to pull box requirements of Section 86 “Signals, Lighting, and Electrical Systems” of the Standard Specifications and shall be the size and type as noted on the Project Plans. The lids of pull boxes and vaults shall be inscribed as indicated in the Project Plans.

N48 Fiber Optic Pull Box

Fiber optic vaults shall conform to pull box requirements of Section 45 “Signals, Lighting, and Electrical Systems” of the Standard Specifications and shall be the size and type as noted on the Project Plans. The lids of pull boxes and vaults shall be inscribed as indicated in the Project Plans.

24” x 36” Traffic Signal Pull Box

24” x 36” traffic signal pull boxes shall be of the Quazite “PG” style construction or approved equivalent prior to bid, and shall be installed at locations as shown on the Project Plans. Pull boxes shall be gray in color unless otherwise specified.

17” x 30” Traffic Signal Pull Box

All home run pull boxes adjacent to the controller cabinet (minimum two with new installation only) shall be quazite flared wall style (17”*30”) or approved equal with no hold down bolts. No splicing shall be allowed in these pull boxes.

Materials

All No. 6E and N48 Fiber Optic pull boxes shall be Christy concrete boxes or approved equivalent prior to bid. Pull box lids shall have a non-skid surface and shall have lockjaw lid. Tracer wire shall be connected to the lockjaw lid and shall run continuously between signalized intersections. Contractor shall provide the City with one (1) lockjaw opening key for every ten (10) pull boxes installed.

Grounding

Bonding and grounding shall conform to the provisions in Section 86-2.10, "Bonding and Grounding," of the State Standard Specifications and these Specifications.

Within all conduits, a #12 stranded copper conductor with orange THWN insulation shall be installed. It shall be connected to the ground rod to be installed in pull boxes as indicated on the Project plans. Tap splices at pull boxes shall be made using either split bolts or c-taps.

Cover Markings

All pull boxes and vaults containing fiber optic cables, shall be supplied with pull box lids that accurately reflect their contents as indicated in the details in the Project Plans. All lids damaged or scuffed from construction shall be immediately rejected and be replaced by the Contractor at his/her own expense.

Installation and Use

Pull boxes and vaults in non-paved or asphalt areas shall be constructed with a minimum 4 inch deep x 12 inch wide concrete apron. Attention is also directed to Section 86 "Pull Boxes" of the State Standard Specifications and the requirements for stub modification shown in the Project Plans, and described herein.

A minimum of six inches of 0.75-inch round aggregate shall be placed under each pull box. Place a layer of roofing paper on the aggregate and place grout over the layer of roofing paper. Install a 1" drain hole in the center of the drain hole through the grout and the roofing paper. All pull boxes shall be inspected and approved prior to pulling any conductors.

Contractor shall clean all pull boxes (new and existing) entered for installation of conduit or wire of all dirt and debris. All pull box lids damaged by Contractor operations shall be replaced at their own expense. The wiring in these pull boxes shall be neatly bundled, recoiled and reinstalled in the pull box.

Appropriate number of Conduit stub-outs shall be provided as indicated on the plans and/or to match existing conditions, and as part of any pull box modifications (installation, removal, or replacement).

10.0 PAYMENT

The contract price paid for each type of "**Fiber Optic Cable"** per linear feet (288 Strand Single Mode Fiber Optic Cable, 144 Strand Single Mode Fiber Optic Cable, 12 Strand Single Mode Fiber Optic Cable), price paid for per linear foot of "**Fabric Innerduct"** with tracer wire and price paid for per linear foot of "**Conduit**" (HDPE Schedule 80, PVC Schedule 40) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in installing and testing fiber optic cables, installing fabric innerduct with tracer wire, installing conduit and all other work required to install cable complete in place, as shown on the plans, as specified in the Standard Specifications and these Special Provisions, and as directed by the Project Engineer and no additional compensation will be allowed therefor.

The contract price paid per each for **"Fiber Optic Splice Closure"** shall be considered full compensation for furnishing all labor, materials, tools, equipment and incidentals; for all of the work required for installing fiber optic splice closure per manufacturers specifications, as shown on the plans, as detailed in the Standard Specifications, these Special Provisions, and as directed by the Engineer and no additional compensation will be allowed therefor.

The contract price paid per each for **"Fiber Splicing and Testing"** shall be considered full compensation for furnishing all labor, materials, tools, equipment and incidentals; for splicing fibers, testing, and for performing all of the work required for fiber optic splicing and testing as shown on the plans, as detailed in the Standard Specifications, these Special Provisions, and as directed by the Engineer and no additional compensation will be allowed therefor.

The contract price paid per each for **"Central Fiber Termination Panel"** and each for **"Field Fiber Termination Panel"** shall be considered full compensation for furnishing all labor, materials, tools, equipment and incidentals; for all of the work required for installing the central fiber termination panel and for all of the work required for installing the field fiber termination panel per manufacturers

specifications, as shown on the plans, as detailed in the Standard Specifications, these Special Provisions, and as directed by the Project Engineer and no additional compensation will be allowed therefor.

The contract price paid per each for **"Central Ethernet Switch"** and per each for **"Field Ethernet Switch"** shall be considered full compensation for furnishing all labor, materials, tools, equipment and incidentals; for all of the work required for installing the central Ethernet switch per manufacturers specifications and the field Ethernet switch per manufacturers specifications as shown on the plans, as detailed in the Standard Specifications, these Special Provisions, and as directed by the Engineer and no additional compensation will be allowed therefor.

The contract price paid per linear foot for **GRS Conduit"** shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in installing, mounting, and securing galvanized rigid steel (GRS) conduit to the bridge structure, and any other work required to install the GRS conduit complete in place, as shown on the plans, as specified in the Standard Specifications and these Special Provisions, and as directed by the Engineer and no additional compensation will be allowed therefor.

The contract price paid per each for **"No. 6E Pull Box", "No. 48 Fiber Optic Pull Box" and "24" x 36" Traffic Signal Pull Box"** shall be considered full compensation for furnishing all labor, materials, tools, equipment and incidentals; for installing pull box, connecting to conduit, aggregate base rock beneath inlet, concrete installation, lockable cover, and for performing all of the work required for drainage inlet as shown on the plans, as detailed in the Standard Specifications, these Special Provisions, and as directed by the Engineer and no additional compensation will be allowed therefor.