1. **Description.** Furnish, install, splice, field terminate, and test the fiber optic cables.

2. **Materials.**

   A. **General Requirements.** Provide new corrosion resistant materials that comply with the details shown on the plans and the requirements of this Item.

   Provide splicing kits, fiber optic cable caps, moisture/water sealants, terminators, splice trays, fiber distribution housings, fiber distribution unit, fiber interconnect housing, fiber optic jumpers, and accessories to complete the fiber optic cable system. Furnish equipment for installation, splicing, and testing.

   B. **Cable Requirements.** Furnish fiber optic cable suitable for underground conduit environment. There are 2 fiber classifications: multimode and singlemode. Use multimode fiber optic cable for video, voice, and data communications between the building and the field cabinets. Use singlemode fiber optic cable for voice, data, and video communications between buildings.

   Splice or terminate fiber optic cables in field cabinets and buildings that comply with the details shown in the plans, and the requirements of this Item.

   Furnish two fiber optic cables; one composed of multimode dual window (graded index) glass fibers, the other composed of singlemode glass fibers. Use fiber optic glass from Corning, Lucent, or approved equal.

   Provide fiber optic cable from the same manufacturer.

   C. **Optical Requirements.**

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Optical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable Configuration:</strong></td>
<td>Singlemode</td>
</tr>
<tr>
<td>Core Diameter (microns)</td>
<td>8.3 ± 1</td>
</tr>
<tr>
<td>Cladding Diameter (microns)</td>
<td>125 ± 1</td>
</tr>
<tr>
<td><strong>Attenuation</strong> (dB/km):</td>
<td></td>
</tr>
<tr>
<td>850 nm</td>
<td>N/A</td>
</tr>
<tr>
<td>1300/1310 nm</td>
<td>0.4 or less</td>
</tr>
<tr>
<td>1550 nm</td>
<td>0.3 or less</td>
</tr>
<tr>
<td><strong>Bandwidth</strong> (MHz-km):</td>
<td></td>
</tr>
<tr>
<td>850 nm</td>
<td>N/A</td>
</tr>
<tr>
<td>1300 nm</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Dispersion</strong> (ps/nm-km):</td>
<td></td>
</tr>
</tbody>
</table>

2004 Specifications
<table>
<thead>
<tr>
<th></th>
<th>Singlemode</th>
<th>Multimode</th>
<th>Multimode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1310 nm</td>
<td>3.2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1550 nm</td>
<td>17</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

1. **Cable Configuration.** Provide a core/cladding size in accordance with Table 1 “Optical Requirements.”
2. **Attenuation.** Provide attenuation in accordance with Table 1, “Optical Requirements.”
3. **Bandwidth and Dispersion.** Provide bandwidth and dispersion in accordance with Table 1, “Optical Requirements.”

**D. Mechanical Requirements.**
1. **Fibers.** Provide the number of fibers as shown on the plans.
2. **Core/Clad Concentricity.** Provide an offset between the center of the core and cladding less than 0.8 microns for singlemode cable and less than 3.0 microns for multimode cable.
3. **Primary Coating.** Provide fiber with a coating diameter of 245 ± 10 microns.
4. **Tensile Strength.** Provide a cable withstand a pulling tension of 2700 N (600 lbf) without changing optical fiber characteristics or as directed.
5. **Bend Radius.** Provide a cable withstand a bending radius of 10 times its outer diameter during operation, and 20 times its outer diameter during installation without changing optical fiber characteristics.
6. **Buffering.** Use a buffering tube or jacket with an outer diameter of 1.0 to 3.0 mm containing 6 individual fiber strands.
7. **Color Coding.** Provide separate color codes for each fiber buffer tube and different color codes within unit tubes or sub-bundles. Use color codes in accordance with TIA/EIA-598.
8. **Cable Configuration.** Provide cables with a reverse oscillation or planetary stranding structure.

Group each cable in sub-bundles of 6 or 12. Jacket construction and group configuration should separate at splice points to cut and splice 1 set of fibers while the others remain continuous. Submit cable designs for approval.

Strand loose buffer tubes around a dielectric central anti-buckling strength member. Provide dielectric aramid and/or fiber glass yarn strength members with specified strength for the cable. Provide cable with a water-blocking material, which is non-hygrosopic, non-nutritive to fungus, non-conductive, non-toxic, and homogeneous. Apply a polyethylene inner jacket over the cable core, and enclose entire cable with a polyethylene outer jacket.
Demonstrate crush and abrasion resistance of final cable design, and conduit installation under tensile loads and multiple bends.

9. **Diameter.** Provide a maximum 19 mm outer diameter for each cable or as directed.

10. **Environmental Requirements.** Provide cable that functions in a temperature range from -40°F to 158°F, and when immersed in water for indefinite periods of time.

3. **Construction.** Install fiber optic cable without changing the optical and mechanical characteristics of the cables.

Utilize available machinery, jacking equipment, cable pulling machinery with appropriate tension monitors, splicing and testing equipment, and other miscellaneous tools to install cable, splice fibers, attach connectors and mount hardware in cabinets employed with the above “Mechanical Requirements.” Avoid jerking the cable during installation. Adhere to the maximum pulling tensions and bending radii as specified by the manufacturer.

Use installation techniques and fixtures that provide for ease of maintenance and easy access to all components for testing and measurements.

A. **Installation in Conduit.** Install fiber optic cable in conduits. If required, relocate existing cable to allow new fiber optic cable routing in conduits.

When pulling the cable, do not exceed the bending radius. Use rollers, wheels, or guides that have radii greater than the bending radius. Provide separate grooved rollers for each cable when simultaneously pulling multiple cables. Use a lubricating compound to minimize friction. Use fuse links and breaks. Measure the pulling tension. Do not exceed a pulling tension of 2700 N (600 lbf).

Seal conduits with a 2 part urethane after installation of cable.

B. **Cable Installation between Pull Boxes and Cabinets/Buildings.** Do not break or splice a second interconnect cable to complete a run when pulling the cable from the nearest ground box to a cabinet or building. Pull sufficient length of cable in the ground box to reach the designated cabinet or building. Pull the cable through the cabinet to coil, splice, or terminate the cable in the cabinet or building. Avoid bending the cable beyond its minimum bend radius.

Coil and tie cable inside cabinet, building, or boxes for future splicing or termination as shown in the plans. Coat the open end of the coiled cable with protective coating and provide a dust cap.

C. **Splicing Requirements.** Splice fibers as shown on the plans, in accordance with TIA/EIA-568, TIA/EIA-758, or as directed.

Use the fusion technique on all splices. Use fusion splicing equipment recommended by the cable manufacturer. Clean, calibrate, and adjust the fusion splicing equipment at the start of each shift. Use splice enclosures, organizers, cable end preparation tools, and procedures compatible with the cable furnished.
Package each spliced fiber in a protective sleeve or housing. Re-coat bare fiber with a protective 8 RTV, gel or similar substance, prior to application of the sleeve or housing.

Perform splices with losses no greater than 0.10 dB for singlemode cable and 0.30 dB for multimode cable. Use an Optical Time Domain Reflectometer (OTDR) to test splices in accordance with Article 5.A.1. Record splice losses on a tabular form and submit for approval.

D. Termination Requirements. Provide matching connectors with 900 micron buffer fiber pigtails of sufficient length and splice the corresponding optical fibers in cabinets where the optical fibers are to be connected to terminal equipment. Buffer, strengthen, and protect fiber pigtails with dielectric aramid yarn and outer PVC jacket to reduce mishandling that can damage the fiber or connection. Use epoxy style connectors and not the crimp on connectors. Terminate multimode fiber optic cable with ST connectors and singlemode fiber optic cable with FC connectors, unless otherwise shown on the plans.

The connector pigtails/splice loss for complete connection at the patch panel in front of the terminal equipment shall not exceed a mean of 0.4 dB mated pair with a maximum loss of 0.75 dB. Maintain this loss characteristic for a minimum of 500 disconnections and reconnections with periodic cleanings. Qualify and accept connectors by the connector-to-connector mating using similar fibers.

Connectors shall meet the TIA/EIA-568 fiber optic test procedures for multimode and singlemode specifications. Test connections at the patch panel and splices made between cables to pigtails with the OTDR to verify acceptable losses.

Remove 5 ft. of unused optical fibers at the ends of the system from the buffer tube(s) and place coiled fibers into a splice tray. Clean the water blocking compound from all fibers destined for splice tray usage.

E. Fiber Optic Accessories.

1. Rack Mount Splice Enclosures. Provide a 19 in. rack mounted splice enclosure module to hold spliced fibers as shown in the plans.

Splice or terminate fibers inside rack mounted fiber optic splice enclosures. Provide an enclosed unit enclosure designed to support a minimum of 4 cables, with each cable having 36 fibers. Provide enclosures that support up to 72 fiber optic connectors in bulkheads.

Provide splice enclosures containing mounting brackets with 4 cable clamps. Install cable according to manufacturer standards for the cable distribution panel.

2. Fiber Distribution Housings. Install the cables according to manufacturer standards for the rack mount splice enclosure, fiber distribution housing, and splice trays.

Coil and protect a maintenance loop of at least 5 ft. of buffer tube inside the rack mount, fiber distribution housing, or splice tray. Allow for future splices in the event of a damaged splice or pigtails.
a. **Cabinet.** Terminate or splice fibers inside the compact and modular fiber distribution housing in the cabinet. Provide a 9 in. x 17 in. x 11 in. (h x w x l) housing, each housing having 4 snap-in simplex connector panel modules, each module having 6 fiber termination/connection capabilities. Use a pre-assembled compact modular unit snap-in simplex connector panel module, with a removable cover having 6 pre-connectorized fiber pigtails, interconnection sleeves, and dust caps installed by the manufacturer. Provide a 12 fusion splice tray capability housing, each tray holding 12 fusion splices as shown in the plans. Stack splice trays on a rack to permit access to individual trays without disturbing other trays. Locate the rack on a pull-out shelf. Protect the housing with doors capable of pivoting up or down and sliding into the unit. Document the function of each terminated/spliced fiber, along with the designation of each connector on labels and charts on the housing door. Provide each housing with strain relief. Terminate multimode fiber optic cable with ST connectors and singlemode fiber optic cable with FC connectors, unless otherwise shown on the plans.

Install the fiber distribution housing as an integral unit as shown in the plans.

b. **Building.** Provide a fiber distribution unit with a modular design allowing interchangeability of connector panel module housing and splice housing within the rack, as shown on the plans.

Provide the number of multimode and singlemode fibers, connector panel module housings, and splice housings for the fiber distribution unit in the building as shown on the plans.

Provide a fiber distribution unit less than 7 ft. in height, capable of housing 8 connector panel module housings or 8 splice housings. Protect the housing with doors capable of pivoting up or down and sliding into the unit.

Provide 12 snap-in simplex connector panel modules with each connector panel module housing, each module having 6 fiber termination/connector capabilities. Use a pre-assembled compact modular unit with a removable cover for the snap-in simplex connector panel module having 6 pre-connectorized fiber pigtails, interconnection sleeves, and dust caps installed by the manufacturer. Provide each connector panel module housing with a jumper routing shelf, storing up to 5 ft. (minimum) of cable slack for each termination within the housing. Provide the fiber distribution unit with strain relief.

Provide splice enclosure with 24 fusion splice tray capabilities, each splice tray holding 12 fusion splices. Stack splice trays on a rack to permit access to individual trays without disturbing other trays. Locate the rack on a pull-out shelf.

Document the function of each terminated/spliced fiber, along with the designation of each connector on labels and charts on the housing door.

Allow terminations only in the fiber interconnect housings placed in the cabinets as shown in the plans or as directed.
3. **Splice Trays.** Use splice tray and fan-out tubing for handling each fiber. Provide a splice tray and 6 fan-out tubing with each housing for use with the 245 microns coated fiber. The fan-out will occur within the splice tray (no splicing of the fiber required). Allow each tube to fan out each fiber for ease of connectorization. Provide fan-out tubing with 3 layers of protection consisting of fluoropolymer inner tube, a dielectric strength member, and a 2.9 mm minimum outer protective PVC orange jacketing.

4. **Jumpers.** Provide fiber optic jumper cables to cross connect the cable distribution panel to the fiber optic transmission equipment as shown in the plans or as directed. Match the core size, type, and attenuation from jumper to the cable. Use orange jumpers for multimode fiber, and a yellow for singlemode fiber, provide strain relief on the connectors. Provide fiber with a 900 micron polymer buffer, Kevlar strength member, and a PVC jacket with an outer jacket of 2.4 mm in diameter.

Provide 10 ft. long jumpers, unless otherwise shown on the plans. One end of each jumper shall have an ST connector and the other end shall be a connector that is suitable to be connected to the fiber optic transmission equipment selected.

Provide each cabinet with eight, 1 ft. each, 62.5/125 multimode fiber jumpers with ST connectors for testing purposes. After test completion, the 1 ft. jumpers will remain property of the Department.

**F. Electronic Components.** Provide electronic components in accordance with Special Specification, “Electronic Components.”

**G. Mechanical Components.** Provide stainless steel external screws, nuts and locking washers. Do not use self-tapping screws unless approved. Provide corrosion resistant material parts and materials resistant to fungus growth and moisture deterioration. Separate dissimilar metals with an inert dielectric material.

4. **Documentation Requirements.** Provide 10 complete sets of operation and maintenance manuals with the following:
   - Complete and accurate schematic diagrams showing the fiber optic cable system.
   - Complete performance data of the cable system showing the losses at each splice joint and each terminal connector.
   - Installing, splicing, terminating and testing procedures.
   - Complete parts list including names of vendors.
   - Complete maintenance and trouble-shooting procedures.

**A. Installation Practice.** Submit for approval 10 copies of the Contractors Installation Practices thirty working days prior to installation. Submit practices for approval, which includes practices, list of installation equipment and splicing and test equipment. Detail field quality control procedures and corrective action procedures.

**B. Manufacturer’s Certification.** Accompany each reel of fiber optic cable with the manufacturer’s test data showing the conformance to the requirements in this Item.
5. **Testing.** Perform tests in accordance with testing requirements in this Item.

A. **Test Methods.**

1. **Optical Time Domain Reflectometer (OTDR) Tests.** Use the OTDR to measure fiber optic cable for overall attenuation (signal loss dB/km), fiber cable length, and identify fiber optic cable anomalies such as breaks. Perform 4 OTDR tests. They are follows:
   - Acceptance test
   - Post installation test
   - Post termination test
   - Final end to end test

   **OTDR Settings:**
   
   a. Use the file name of the fiber scan to indicate the location or direction the test was run from, as well as the fiber number being tested.
   
   b. Set the “A” cursor at the beginning of the fiber trace and set the “B” cursor at the end of the fiber trace. The distance to cursor “B” indicates the length of the fiber cable segment being measured.
   
   c. Match the index of refraction to the index of the factory report.
   
   d. Set the loss indicator to dB’s/km for the acceptance test.
   
   e. The reflectance is automatically set internally by the OTDR.
   
   f. Set the pulse width at a medium range. Change the pulse width to a slow pulse width when an anomaly occurs on the fiber trace so that it can be examined closely.
   
   g. Set the average at medium speed. Change the average to slow when an anomaly appears on the fiber trace to allow for closer examination of the anomaly.
   
   h. Set wavelength at 850 nm and then at 1300 nm for multimode cable, set at 1310 nm and 1550 nm for singlemode cable so the cable is tested at both windows for each type of cable.

   Show all settings on test result fiber scans.

2. **Pre-installation Tests.** Test and record the fiber optic cable at the site storage area prior to installation.

   Test each optical fiber in the cable from 1 end with an OTDR compatible with wavelength and fiber type. Check testing for length, point discontinuity, and approximate attenuation. Record each measurement by color, location, and type of fiber measured. Perform a measurement from the opposite end of that fiber in case a measurement cannot be made from 1 end. Wait for notification if loss per Km
exceeds manufacturer’s test data by more than 0.5 dB/km or point discontinuity greater that 0.2 dB.

Perform this test within 3 days from receipt of the fiber optic cable. Test overall attenuation (dB/km), total cable length, anomalies, or cable problems. Test cable at both windows (850 nm and 1300 nm for multimode and 1310 nm and 1550 nm for singlemode cable).

Compare factory test results with test results and return if test results are not identical to factory test results. If identical, document the test results. Deliver documentation for future reference.

3. **Post-installation Tests.** Re-test and re-record each optical fiber in the cable after installation, before termination, for loss characteristics. Test both directions of operations of the fiber.

Immediately perform the post installation test after the fiber optic cable has been installed. Test cable for overall attenuation, cable segment length, and damage with the OTDR in accordance within this Item. Replace any cable segment that is damaged during the test and document test results. Deliver tests results for future reference.

Use the same OTDR settings for Post Installation Test as the Pre-Installation Test.

4. **Subsystem Tests.** Perform Network Subsystem Tests after integration to the fiber optic network. Test the capability of the fiber optic cable to transmit video and digital information. Complete and submit approved data forms for review and rejection or acceptance.

Correct and substitute components in the subsystem if the Subsystem Tests fail and repeat the tests.

Prepare and submit a report if a component was modified as result of the Subsystem Test failure. Describe in the report the failure and action taken to remedy the situation.

**B. Test Procedures.** Submit test procedures and data forms for the pre-installation, post-installation, subsystem, and system integration test for approval. Test procedures will require approval before performing tests. Submit 1 copy data forms containing data and quantitative results, as well as an authorized signature. Submit a copy of the OTDR results as a hard or electronic copy; supply original software packages and PC for OTDR results interpretation.

**C. Post Termination Test.** Perform the post termination test as the cable is terminated or spliced, whether there is termination of fiber cable to fiber cable or fiber cable to fiber pigtail. Check attenuation, fusion or termination point problems, and overall fiber cable segment. Determine if the attenuation and quality of the termination meets the specification; if not, repeat the termination until it meets specification requirements.

Test the fiber segment for attenuation and anomalies after termination acceptance. Document and submit test results as stated in this Item after fiber segment acceptance.
Test the splices at 1300 nm for multimode and 1310 nm for singlemode and provide printouts of the splice tests. Take tests in both directions and record the average.

Use a launch reel of the same type of fiber to test the fusion splices on pigtails.

Use the same OTDR settings for Post Termination Test as the Post Installation Test and Pre-Installation Test, except move the “B” cursor to the middle of the termination or splice point. After the termination, return “B” cursor to the end of the fiber segment and measure overall length and attenuation.

**D. Final End to End Test.** Perform Final End to End Test after fiber cable segments of the system are terminated. Use the OTDR test as specified in this Item.

Perform the Final End to End Test:

1. Measure the overall fiber cable system length.
2. Measure the overall system attenuation.
3. And check for anomalies.

Document and submit results as stated in this Item, after test acceptance.

**6. Training.** Perform training in accordance with Article 3, Special Specification, “Testing, Training, Documentation, Final Acceptance, and Warranty.” Include the following training material: code compliance, pulling and installation techniques, use of installation tools, splicing and terminating equipment and test instruments, and methods of recording installation and test data. Furnish 10 copies of training material 30 days before training begins for approval.


**8. Measurement.** This Item will be measured by the foot of cable furnished, installed, spliced, connected, and tested.

**9. Payment.** The work performed and materials furnished in accordance with this Item and measured as provided under “Measurement” will be paid for at the unit price bid for “Fiber Optic Cable System” of the type, and number of fibers as applicable. This price is full compensation for furnishing and installing all cable; for relocating cables as required; for pulling through conduit or duct; testing; splicing; connecting; and for materials, equipment, labor, tools, documentation, warranty, training and incidentals.