REVISION OF SECTION 614

FIBER OPTIC CABLE (SINGLE MODE) (install only)

Section 614 of the Standard Specifications is hereby revised for this project to include the following:

Subsection 614.08(o)  *Fiber Optic Cable (Single Mode)(InstallOnly)*, is hereby added to the Standard Specifications and shall include the following:

This work consists of removing, protecting, and re-installing existing single mode fiber optic cable at the locations shown on the plans.

## CONSTRUCTION REQUIREMENTS

The Engineer shall provide the contractor with two copies of the cable manufacturer’s installation instructions for all fiber optic cable. All installation shall be in accordance with these practices except as otherwise directed by the Engineer. Additional cable costs due to damage caused by the Contractor’s neglect of recommended procedures shall be the Contractor’s responsibility.

Fiber optic cable shall be installed in continuous runs. The manufacture’s recommended limits for cable pull lengths shall not be exceeded. If fiber installation operations meet the manufacturer’s recommended limits, the remaining cable shall be laid in a figure eight pattern prior to proceeding with installation.

**(a) Fiber Optic Cable Installation**. Fiber optic cable shall be cut at the intersection of SH 88 @ Chambers Road. Fiber optic cable shall be pulled back to a location west of the bridge construction. Once the new 2” conduit bored has been installed under the Cherry Creek, the Fiber optic cable shall be installed in a continuous run from pull box or manhole to each proceeding pull box or manhole to be spliced in the existing pull box in the existing splice enclosure at SH 88 @ Chambers Road. Under no conditions shall the fiber optic cables be cut or spliced at intermediate points without express written direction from the Engineer.

All installation shall be done in conformance with EIA/TIA standards and fiber optic cable manufacturer’s installation guidelines. The Contractor shall ensure that the cable bends maintain the proper radius during removal and installation. The fiber optic cable shall be pulled in the conduit with a split mesh cable grip designed to provide a firm hold on the exterior covering of the cable. The Contractor shall ensure that the tensile load on the cable does not exceed the manufacturer’s recommended maximum by using a pulley system with numerical readout of the actual tension on the cable and includes a means of alerting the installer when the pulling tension approaches the manufacturer’s maximum recommended pulling tension. The Contractor may supplement this procedure with a breakaway tension limiter set below the lowest recommended tensile limit of the cables being pulled. Blowing cable is an acceptable alternative. If the Contractor chooses to use this method, submittals for cable installation shall be submitted along with complete information on fiber installation equipment.

During pulling, the cable shall be continuously lubricated as it enters the conduit. The Contractor shall only use approved pulling lubricants as recommended by the cable manufacturer. Liquid detergent shall not be used.

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### **REVISION OF SECTION 614**

**FIBER OPTIC CABLE (SINGLE MODE) (INSTALL ONLY)**

If new fiber optic cable is installed within existing conduit, the Contractor shall be responsible for preventing damage to the existing equipment and circuitry, including fiber optic cables and wiring. The Contractor shall repair or replace any damaged circuitry at no additional cost the project and as approved by the Engineer. The Contractor shall perform operational tests to ensure the existing equipment and circuitry is in proper working condition after the installation of any new cable. This work shall be considered subsidiary to the installation of Fiber Optic Cable and no additional payment will be made. In no case, shall the number of cables and or wires within a conduit exceed the requirements of the National Electrical Code. The Contractor shall submit documentation to the Engineer supporting the conduit fill

Each conduit shall be equipped with pull tape in the final product. The pull tape shall have a minimum tensile strength of 1800 pounds. Each conduit shall be equipped with a copper tracer wire of at least 12 gage in the conduit.

Conduit plugs shall be supplied and installed in all conduit ends as soon as the conduit is installed. Conduit shall be plugged at all termination points such as pull boxes, manholes, controller cabinets, and node buildings. Conduits containing fiber optic cable shall be plugged with durable and reusable split type plugs, fabricated without metallic parts, and allow easy removal and reinstallation around in-place fiber optic cables. Split type plugs shall provide a water and air-tight seal of at least 50 psi and shall be installable by hand without using special tools and without damaging the cable. All plugs shall be correctly sized to fit the conduit being plugged. Empty conduits shall be sealed with removable mechanical type duct plugs that provide a watertight barrier and are equipped with a rope tie on the inside end for connection of the pull rope/tape. Contractor shall seal all conduits containing electrical wire (not fiber optic cable) with a sealing compound that shall be UL tested and approved for the use. Sealing compound shall be a permanently soft, fibrous, non-staining sealer easily applied and removed by hand at all working temperatures. Sealing compound shall be designed to seal out weather, moisture, dust rodents and atmospheric conditions both indoors and outdoors. No foam sealant will be allowed. All plugs and sealant shall be approved prior to construction.

All fiber optic cables shall include identification labels attached to the cable in each pull box, manhole or field equipment cabinet. The label shall be provided with information as shown in the ITS Pull Box project special detail.

1) Splices and Splice Closures:

The Contractor shall splice lateral cables into the backbone cable at the locations shown on the plans. The Contractor shall splice the cut backbone fibers to the lateral cable fibers as shown in the project plans. All splices shall be enclosed within a splice closure as approved by the Engineer. Following successful splicing, the splice closure shall be placed inside the pull box or manhole. The Contractor shall perform the work using splicing tools and hardware recommended by the cable manufacturer.

2) Lateral Fiber Optic Cable:

The Contractor shall install lateral fiber optic cable in continuous runs from the backbone cable to the field equipment cabinet. The Contractor shall leave 10 feet of slack cable in the control cabinet and 25 feet of slack cable in both the backbone cable manholes and in the intermediate pull boxes. Strain relief shall be provided for the lateral cables within the equipment cabinets at a maximum of three locations.

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### **REVISION OF SECTION 614**

FIBER OPTIC CABLE (SINGLE MODE) (INSTALL ONLY)

3) Backbone Fiber Optic Cable:

The Contractor shall install backbone fiber optic cable in continuous runs from pull box to pull box. The Contractor shall leave 50 feet of slack cable in all the pull boxes.

4) Buffer Tube Fan-Out:

The Contractor shall terminate the loose-tube lateral cable at the field equipment cabinet using a buffer tube fan-out kit. Fanned-out cables shall be terminated in a termination block with connectors to match the connectors on pre-connectorized patch cords.

Subsection 614.13 shall include the following:

## METHOD OF MEASUREMENT

Fiber Optic Cable (single mode) (Install Only) shall be measured by the Linear Foot for lateral cable and shall include all labor and materials required to install, splice and terminate the cable (and make it operational) including the following items:

* Identification labels shall be provided for each connector supplied in the patch panels and splices.
* All pull tape and copper tracer wire.
* All conduit plugs
* Splices
* Termination
* All other work necessary to complete the item

Payment for Fiber Optic Cable (single mode) (Install Only) will be made according to the following schedule:

* 50% upon completion of the installation
* 50% upon the completion of successful integration and testing of each fiber strand installed and testing with the existing devices show at each termination point.

Subsection 614.14 shall include the following:

**BASIS OF PAYMENT**

Payment will be made under:

# Pay Item Pay Unit

Fiber Optic Cable (Single-Mode) (96 Strand) (Install Only) Linear Foot

REVISION OF SECTION 614

TEST FIBER OPTIC CABLE

Section 614 of the Standard specifications is hereby revised for this project as follows:

Subsection 614.08 shall include the following:

Test fiber Optic Cable. For this project this work shall consist of the testing of Single Mode fiber optic cable as shown and tabulated in the plans. The testing procedures involve an OTDR test and an Optical Power Meter Test.

The guidelines for fiber optic cable testing include:

1. Test jumpers and patch cords must be of the same fiber core size and connector type as the cable system:
	1. Single Mode fiber 8.3/125 μm
2. The light source and OTDR must operate with the range of 1310±10 nm or 1550±20 nm for Single Mode testing in accordance with ANSI/EIA/TIA-526-7.
3. The power meter and the light source must be set to the same wavelength during testing.
4. The power meter must be calibrated and traceable to the National Institute of Standards and Technology (NIST).
5. All system connectors, adapters and jumpers must be cleaned as per manufacturer’s instructions before measurements are taken.

A) Fiber Optic Cable Testing Equipment. The following is required to perform fiber optic cable tests:

1. An OTDR
2. A test reel, of at least 900 feet
3. A light source at the appropriate wavelength
4. Optical Power Measurement Equipment
5. Test Jumpers as specified below
	1. Single Mode Fiber Testing
		1. CPR Test Jumper-1 and Test Jumper-2 shall be 1-5 meters long with connectors compatible with the light source and power meter and have the same fiber construction as the link segment being tested.

B) Optical Fiber Cable Testing with OTDR.The Contractor shall perform an OTDR test of all fibers in all tubes on the reel prior to installation of the fiber. The test results shall be supplied to the Engineer prior to installation of the cable.

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**REVISION OF SECTION 614**

**TEST FIBER OPTIC CABLE**

If the fiber is specified as “Install Only”, the Contractor shall test the fiber on the reel and provide the test results to the Engineer prior to accepting the cable. After installation, if there are unused portions of cable remaining on the reel, the Engineer may request the Contractor or other qualified technician to perform a reel test. The Contractor shall provide the Engineer the test results prior to delivering the cable to the Engineer. Any cable damaged while in the Contractor’s possession shall be replaced at the Contractor’s expense.

All fiber testing shall be performed on all fibers in the completed end-to-end system. Testing shall consist of a bi-directional end-to-end OTDR trace performed per TIA/EIA-455-61. The system margin loss measurements shall be provided at 1310 nm and 1550 nm for Single Mode fibers. If the Plans require installation of a fiber optic patch panel, the Contractor shall supply patch cords to patch all terminated fibers through the panel for all fiber testing. If patch cords are specified in the Plans for final equipment installation, these patch cords shall be connected using a test coupling for the end-to-end test.



OTDR readings will be used to ensure proper installation and to troubleshoot faults. OTDR signature traces will be used for documentation and maintenance. An OTDR provides an indirect estimate of the loss of the cable plant, generally, more accurate or reliable values will be obtained by using an Optical Power Meter. For fibers that are identified in the Plans to be left unterminated, an OTDR shall be used to test end-to-end attenuation.

Loss numbers for the installed link shall be calculated by taking the sum of the bi-directional measurements and dividing that sum by two.

The Contractor shall use an OTDR that is capable of storing traces electronically and shall save each final trace.

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**REVISION OF SECTION 614**

**TEST FIBER OPTIC CABLE**

To ensure the traces identify the end points of the fiber under test and the fiber designation, the Contractor shall use a test reel, if required, to eliminate the “dead zone” at the start of the trace so that the start of the fiber under test can be identified on the trace. Indicate the length of the test reel for all test results.

If the fiber designation is not indicated on the trace itself, the Contractor shall provide a cross-reference table between the stored trace file name and the fiber designation.

In compliance with EIA/TIA-455-61 “Measurement of Fiber or Cable Attenuation Using an OTDR” the Contractor shall record the following information during the test procedure:

1. Names of personnel conducting the test.
2. Type of test equipment used (manufacturer, model, serial number, calibration date).
3. Date test is being performed.
4. Optical source wavelength and spectral width.
5. Fiber identification including tube color and fiber color
6. End point locations
7. Launch conditions
8. Method of calculation for the attenuation or attenuation coefficient.
9. Acceptable link attenuation
10. Identify loss event
11. Test direction

C) Optic Fiber Cable Testing with Optical Power Meter. The Contractor shall conduct an Optical Power Meter Test for each fiber installed.

Single Mode segments shall be tested in one direction at both the 1310 nm and 1550 nm wavelength.

Fiber Cable Plant” and TIA/EIA-526-7 “Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant,” the following information shall be recorded during the test procedure:

1. Names of personnel conducting the test.
2. Type of test equipment used (manufacturer, model, serial number, calibration date).
3. Date test is being performed.
4. Optical source wavelength, spectral width, and for multimode, the coupled power ratio (CPR).
5. Fiber Identification including tube color and fiber color.
6. Identify loss event
7. End point locations.
8. Test direction.
9. Reference power measurement (when not using a power meter with a Relative Power Measurement Mode).
10. Method of calculation for the attenuation or attenuation coefficient.
11. Measured attenuation of the link segment.
12. Acceptable link attenuation.

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**REVISION OF SECTION 614**

**TEST FIBER OPTIC CABLE**

The minor attenuation differences due to test direction are on par with the accuracy and repeatability of the test method. Lateral segments within a building are limited to 90 meters. Therefore, attenuation differences caused by wavelength are insignificant, and as a result, single wavelength testing is sufficient.

D) Acceptable Attenuation Values. Acceptable attenuation values shall be calculated for each fiber tested. These values represent the maximum acceptable test values.

A connection is defined as the joint made by mating two fibers terminated with re-mateable connectors (e.g. ST, SC, LC).

1. Singlemode Fiber.The general attenuation equation for any Single Mode link segment is as follows:

Acceptable Link Attn. = Cable Attn. + Connector Attn. + Splice Attn.

*8.3 μm Single-mode Attenuation Coefficients:*

* 1. Cable Attn.=Cable Length (km) x (0.34 dB/km@1310 nm or 0.25 dB/km@1550 nm)
	2. Connection Attn. (ST or SC connectors) = (# Connections x 0.39dB) No more than 0.75dB per connector
	3. Splice Attn. (Mechanical or Fusion) = Splices x 0.10dB

E) Test Procedures. All fiber testing shall be performed on all fibers in the completed end-to-end system.

1. Single Mode Fiber.The Single Mode Optical Power Meter fiber test shall be conducted as follows:

	1. Clean the test jumper connectors and the test coupling per manufacturer’s instructions.
	2. Follow the test equipment manufacturer’s initial adjustment instructions.
	3. Connect Test Jumper-1 between the light source and the power meter. Avoid placing bends in the jumper that are less than 100 mm (4 inches) in diameter.



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**REVISION OF SECTION 614**

**TEST FIBER OPTIC CABLE**

* 1. If the power meter has a Relative Power Measurement Mode, select it. If it does not, reduce the Reference Power Measurement (Pref). If the meter can display power levels in dBm, select this unit of measurement to simplify subsequent calculations.
	2. Disconnect Test Jumper-1 from the power meter. Do NOT disconnect the test jumper from the light source.
	3. Attach Test Jumper-1 to one end of the cable plant to be measured and Test Jumper-2 to the other end.



* 1. Record the Power Measurement (Psum). If the power meter is in Relative Power Measurement Mode, the meter reading represents the true value. If the meter does not have a Relative Power Measurement Mode, perform the following calculation:

		1. If Psum and Pref are in the same logarithmic units (dBm, dBu, etc.):
		CPR (dB) = Psum - Pref
		2. If Psum and Pref are in watts:
		3. CPR (dB)= 10 x log10 [Osum/Pref]

 F) 7 Test Acceptance. The Contractor shall demonstrate that each Optical Power Test results in acceptable attenuation values.

The Contractor, solely at the Contractor’s cost, shall remake any fusion splices and/or connectors that have test results exceeding acceptable attenuation values.

The Contractor, solely at the Contractor’s cost, shall retest any fiber links that have been re-spliced.

The Contractor, solely at the Contractor’s cost, shall bring any link not meeting the requirements of this specification into compliance.

G) Submittals.The Contractor shall submit test results documentation as both a hard copy and electronic copy.

After each reel test, the Contractor shall submit one (1) hard copy of the OTDR trace for every fiber on the reel. After installation, the Contractor shall submit one (1) hard copies of the OTDR trace for every spliced fiber. Hard copy traces shall be organized and bound in

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**REVISION OF SECTION 614**

**TEST FIBER OPTIC CABLE**

logical order in an 8 ½” x 11” 3 ring hard cover binder in addition to other documentation listed in this Special Provision and other splicing documentation listed in the project Special Provision package.

The Contractor shall submit, after approval of the hard copy traces, electronic copies of all traces and appropriate software to allow reading the traces.

The Contractor shall submit one (1) copy of all Optical Power Test results.

The Contractor shall submit one (1) copy of the complete contract Plans, including additional drawings issued as part of any change orders, with any deviations clearly marked in color. Deviations to be noted and shall include but not be limited to the following:

Fiber Splice location

(1) Fiber Splice configuration

(2) Termination layout

Subsection 614.13 shall include the following:

The complete end-to-end OTDR test on one fiber, including document submission, represents one OTDR test.

The complete end-to-end optical power meter test on one fiber, including document submission, represents one optical power meter test.

The accepted quantities will be paid for at the contract price per pay unit of measurement for the work completed.

Subsection 614.14 shall include the following:

Pay Item Pay Unit

Test Fiber Optic Cable Lump Sum