REVISION OF SECTION 614
TELEMETRY (FIELD)

Section 614 of the Standard Specifications is hereby revised for this project as follows.

Subsection 614.01 shall include the following:

This work consists of fan-out and termination of fiber optic (interconnect) cable at each controller cabinet locations as identified in the plans. This work also includes providing and installing all necessary telemetry equipment including but not limited to optical splice closures, field patch panels, splice organizers, cables, pigtails/jumpers and labels.

Color-coded fibers and buffer tubes shall be used throughout the entire project. At the terminal points the jackets shall be stripped and the ends taped. Gel filled compound shall be removed using filled cable cleaner.

At every cabinet or optical closure, only the fibers identified in the plans to be spliced and/or connected to a patch panel or other internal device are required to be landed. All cut and unconnected fibers shall be sealed in a manner recommended by the fiber optic cable manufacturer and coiled neatly in a splice organizer.

The same color-coded pairs of fibers and/or wires shall be used throughout the entire project unless shown as otherwise in the plans. Gel filling compound shall be removed using filled cable cleaner.

Subsection 614.08 shall include the following:

Fiber Optic Patch Pigtail:

The fiber optic pigtail cables shall consist of MM fibers housed individually in protective jackets. Both ends of the cable shall be connected. Fiber optic patch cord cable shall be suitable for operation over a temperature range of -30 degrees to +60 degrees Celsius. Fiber optic patch cord cables shall be of length suitably long to be connected between
the interconnect panel and the communications equipment (i.e. fiber optic transceivers). Patch cord couplings shall be compatible with termination points. Appropriate strain relief in the cabinet (through cable ties) shall be installed at a minimum of three locations. Sufficient slack shall be left to allow relocation of the equipment anywhere in the cabinet. The attenuation of a fiber optic patch cord cable after installation, not including the connector loss, shall not exceed 0.1 dB measured at 850 nm and 1300 nm.

Connectors:

The connector shall have a ceramic ferrule with a nickel-plated nut and body. The connector shall be an AT&T ST style compatible field mounted connector. The connector shall be compatible with a physical contact (PC) finish. All connectors shall be polished to a PC finish such that the return loss per mated pair of connectors is less than -25 dB. The return loss when the connector is mated with previously installed connectors shall be less than -18 dB.

The connector insertion loss shall not be greater than 0.20 dB (typical). The connector loss shall not vary more than 0.20 dB after 1000 repeated matings. Tensile strength shall withstand an axial load of 20 lb. with less than 0.20 dB change.

Index matching fluids or gels shall not be used. The connectors shall be compatible with the optical fiber surrounding jacket and shall be installed on one end of the optical fiber in accordance with the manufacturer's recommended materials, equipment and practices. The connector shall be suitable for the intended environment and shall meet the following environmental conditions:

Operating Temperature:	-40° to +80º C
Storage Temperature:	-40° to +85° C

The connector loss shall not vary more than 0.20 dB over the operating temperature range. Connectors shall be protected by a suitably installed waterproof protection cap.

***Miscellaneous Cabling*:**

Fiber optic patch cords shall be fiber optic jumper cable, duplex, ceramic ferrule, MM 62.5 nm, adaptable to AT&T ST style connectors, 2 meters in length, ITT Canon Model 161001-4020 or approved equal. Cable from fiber optic modem to Port 3 controller harness shall be 25-pin cable Model 44982G4 or approved equal. The Contractor shall deliver transceivers to the City's Traffic Signal Shop. Contact Joe Strauss (720) 865-4062 for coordination.

***Optical Splice Closures*:**

Coyote Runt or Coyote Pup Type closures shall be provided for splicing lateral fiber optic cables to the main (backbone) fiber cable in all pull box locations that
are identified in the plans. All closures shall include 1-Inch future port kit (part no. 8003408, Pre-Formed Line Products). The Coyote Runt Closure shall be used at locations with 3 fiber optic cables. In locations requiring more than 3 cables, a Coyote Pup Closure shall be installed.

Subsection 614.13 shall include the following:

Telemetry (Field) shall be measured by the total number of cabinets at which the interconnect cable is fanned out, terminated, connected, patch panels and fiber-optic interfaces installed. All labor and materials required to perform panel installations including but not limited to fiber optic cables, provide in-cabinet strain relief, fan-out, cable termination and connection to the controller is considered included in the unit price for this item.

REVISION OF SECTION 614
TELEMETRY (FIELD)

This item, therefore, includes the following:

1. All required in-cabinet cable ties and strain relief (including ancillary hardware and labor to complete);
2. All required fan-out kits, kit tools, ancillary hardware and labor to accomplish the fan-out at the cabinet;
3. All required pigtails and harness cables;
4. All required interconnect centers and fiber optic interface panels in individual controller cabinets as shown in the plans;
    - All required termination enclosures (including specified features), connectors, adapters,jumpers, pigtails, patch cord cables, ancillary hardware and labor required to accomplish the cabinet termination;
    - All required optical splice closures;
    - All other labor and material necessary to complete the item

All labor and materials necessary to complete this item shall be considered included in the unit price and will not be paid separately.

Subsection 614.14 shall include the following:

Payment will be made under:

Pay Item	**Pay Unit**
Telemetry (Field)	Each

REVISION OF SECTION 614
ETHERNET MANAGED SWITCH

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

Subsection 614.01 shall include the following:

This work consists of furnishing and installing an Ethernet Managed Field Switch for the City and County of Denver's traffic controller cabinets. The switch shall be compatible with the existing system.

Subsection 614.08 shall include the following:

An Ethernet Managed Field Switch is hereby added to the Standard Specifications and shall comply with the following specifications:

General System Requirements: The Ethernet Managed Field Switch, or equivalent with the Industrial Ethernet Managed Field Switch, shall be a Garrettcom Magnum Ethernet Managed Field Switch comprising of the following four (4) parts:

(1) 6KQ-24VDC base unit with four 10/100 copper ports in slot A (without 24VDC power supply).
(2) 6KQ-RJ45 module with four 10/100 copper ports in slot B.
(3) 6KQ4-MLC module with four 100Mb 2km multi-mode LC fiber ports in slot C.
(4) 6KQ-BLNK blank cover for 1 unused module in slot C.

The field switch must also meet the following requirements:

- May be configured with a variety of 10/100/1000 Mb fiber and copper port connector types - 16 total ports maximum.
- Heavy duty and environmentally hardened fully enclosed metal case with advanced thermal design used as a heat sink (no fan).
- Dual LEDs for all-around status viewing.
- Wire speed filtering and forwarding across all ports - 802.3x flow control, 802.1p priority packet processing, self learning 4K-node address table, large 240KB packet buffers for 10/100 and 120KB for 1000Mb.

The unit shall be configured as a minimum:

Filtering/Forwarding Rate Performance:

- Ethernet (10Mb):14,880 pps
- Fast Ethernet (100Mb): 148,800 pps
- Gigabit Ethernet (1000Mb): 1, 488,000 pps
- Switching Processing Type: Store and Forward with IEEE 802.3x full duplex flow control, non-blocking
- Data Rate: 10Mbps, 100Mbps and 1000Mbps
- Address Table Capacity: 4K node, self-learning with address aging
- Packet buffer size: 240KB for 10/100 and 120KB for 1000Mb
- Latency: 5 μs + packet time (100 to 100Mbps); 15 μs + packet time (10 to 10 Mbps, and 10 to 100Mbps)

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ETHERNET MANAGED SWITCH

- Throughput with 12 10/100 and 2Glink max.- 4.76M pps (Transmit)
- Back plane- 2.66 GB/s per slot LEDs:
- Per Port (one set at the port, one set on swivel top on right side)
- LK: Steady ON when media link is operational
- ACT: ON with receiver port activity
- FDX/HDX: ON = Full-Duplex Mode; OFF = Half-Duplex Mode
- 100/10: ON = 100Mbps speed; OFF = 10 Mbps

Network cable connectors:

- 1000Mb fiber ports: all standard Gb SFP Transceiver types supported
- 1000Mb copper ports: 10/100/1000Mb auto-negotiating, Cat5e & 6 UTP/STP
- 100Mb Copper and PoE: Category 5 UTP/STP; 10 Mb: Cat. 3, 4, 5 UTP/STP
- 100 Mb Fiber ports connector options: multi-mode FX-MTRJ, LC, ST, SC; Single-mode 15Km LC, 20Km SC and ST, and 40 Km "long reach" single-modes SC.

Operating Environment:

- Ambient Temperature: -40° to 140° F (-40° to 60°C)

Alarm Relay Contacts:

- One NC indicating internal power, one NC software controllable

DC Power Supply:

- 24VDC Power Input nominal (range 18 to 36VDC)
- Power Consumption: 35 watts worst case (for a fully loaded fiber model); 12 watts typical (for a small 4 port copper-only model)

Vertical mounting normal:

- Suitable for wall or DIN-Rail mounting

Testing Requirements: The Contractor shall supply one unit of Ethernet Managed Switch to the Engineer for specification compliance testing and approval. If the product passes the specification compliance testing and approval evaluation, the Contractor will be notified to complete the order. If the product does not pass the specification compliance testing and approval evaluation by CCD-TES, the test unit will be returned back to the Contractor. The Contractor shall supply other units until satisfactory test results are achieved

Subsection 614.13 shall include the following:

The Ethernet Managed Switch will be measured by the number of units fully operational and tested in accordance with this specification or as directed by the Engineer. All work and installation shall include all wiring for hook-up and related labor and material required for the completion of the installation. All necessary documentation and testing shall also be included in the contract bid price.

REVISION OF SECTION 614
ETHERNET MANAGED SWITCH

Subsection 614.14 shall include the following:

Each package shall contain one Ethernet Managed Field Switch, set of mounting bracket, Installation and User guides, and Product Registration Card

Pay Item	**Pay Unit**
Ethernet Managed Field Switch package	Each

REVISION OF SECTION 614
FIBER OPTIC CABLE - GENERAL

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

Subsection 614.01 shall include the following:

This work provides for the installation of fiber optic communications cable to be installed in conduit or duct as specified in the plans. All labor and materials required to fan-out, terminate, splice or otherwise connect fiber optic cables at individual controller cabinets, will be paid separately under the Telemetry (Field) pay item. The contractor shall be required to demonstrate successful signal system communications to the Engineer as a requirement of acceptance of this item.

Subsection 614.10 shall include the following:

All fiber-optic interconnect cable shall be furnished by the Contractor, and installed, spliced (if required and only as approved by the Engineer), terminated, connected and tested by the Contractor. The number denoted prior to the "MM" designator identifies the number of multi-mode fibers (Strands) in the cable. The number denoted prior to the "SM" designator identifies the number of single-mode fibers (Strands) in the cable.

Cable ends shall be stored in pull boxes or splice closures at locations indicated in the plans or as directed by the Engineer. Fibers to be spliced and/or connected in any manner shall be limited to those identified in the plans, and only in designated controller cabinets or splice closures. All other fibers shall be left uncut or sealed as appropriate in a manner recommended by the cable manufacturer.

Fiber optic cable shall be installed in a continuous run between all controller cabinets and splice closures as shown in the plans. Lateral cables shall be spliced only in splice closures and routed to the controllers as shown in the plans. **Under no conditions shall the fiber cable be cut out or spliced at intermediate points without the express written direction of the Engineer.**

Cable shall be installed in new conduit or existing conduit as specified in the plans. The Contractor shall be required to leave a minimum of 10 feet of cable slack in the equipment controller cabinet. The Contractor shall leave a minimum of 50 feet of cable slack in the pull box adjacent to the controller and shall leave a minimum of 50 feet of slack in all other communication pull boxes.

Cable Tags and Labels:

Fiber optic cable shall be neatly coiled and clearly tagged and labeled at each communication pull box and at all locations where the fiber is exposed. Cable tags and Labels shall be as follows:

Materials: Metal or heavy plastic identification tags with cable type and number, copper pair or optic number assignments, and destination shall be provided on both ends of all cables (except station cables) and all splice cases. All cables shall be clearly labeled with cable number (City to determine scheme) and size at each end of the cable, when it enters or leaves a conduit and at 30-foot intervals when run in accessible areas such as tunnels, manholes, ceilings, etc.

Manufacturer: Tags shall be 3M, Panduit or an approved equivalent.

REVISION OF SECTION 614
FIBER OPTIC CABLE - GENERAL

***General Requirements*:** The Contractor shall provide the Engineer with two copies of the cable manufacturer's cable specifications and installation instructions for fiber optic cable in conduit. 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 Contractor's responsibility. The main cable shall be installed in continuous runs except where cable type changes or where maximum pull lengths govern. The manufacturer's recommended limits for cable pull tensions shall not be exceeded. Cable ends shall be stored in controller cabinets or pull boxes immediately adjacent to cabinets or as directed by the City.

Lateral and Branch cables shall be installed using appropriate strain relief in the cabinet (through cable ties) at a minimum of three locations.

All fiber optic cables to be installed shall be checked with an OTDR before and after installation. Documentation of fiber performance shall be provided to the City within 30 days of test. All optical fibers shall be within the manufacturer's recommended tolerances. In addition, any other acceptance testing recommended by the manufacturer shall be provided. Data shall be supplied to the City prior to completion of the project.

Fiber optic cable shall be transported to site using cable reel trailers. Care shall be taken at all times to avoid scraping, denting, twisting, or otherwise damaging the cable before, during and after installation. Damaged cable shall be replaced by the Contractor without additional compensation.

Cable shall be installed in conduit or duct in the field in accordance with the contract drawings. The conduit and duct ends shall have all rough edges smoothed to prevent scraping the cable. All existing or suspected dirt and debris within the conduit shall be cleaned with compressed air before installing cable. A manufacturer recommended lubricant shall be applied to the cable to reduce friction between the cable and duct or conduit. Where fiber optic cables are to be installed in inner duct, the Contractor shall secure each section of the conduit to prevent it from being pulled without the cables.

A cable grip shall be attached to the cables so that no direct force is applied to the optical fiber. 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 cable or ropes shall be used as required. **The maximum pulling tension as defined by the cable manufacturer shall not be exceeded.** 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. Personnel equipped with two-way radios shall be stationed at each maintenance hole, cabinet, pedestal, communications box, and junction box through which the cable is to be pulled to observe and lubricate the cable. Intermediate splices between pull boxes shall not be allowed. The cable shall be securely fastened in place within pull boxes, pedestals, manholes and cabinets.

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FIBER OPTIC CABLE - GENERAL

The contractor shall ensure cable length is sufficient to allow for connection between the communications equipment and the splice equipment and the splice enclosures 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.

***Lateral and Branch Fiber Optic Cable*:** Lateral/Branch fiber optic cable shall consist of 6 multi-mode fibers and 6 single-mode fibers. Lateral/Branch fiber optic cable shall be installed in new or existing conduit, or along existing span wire, as depicted in the plans. Cables shall be provided with appropriate strain relief in the cabinet, consisting of cable ties in at least three interior cabinet locations. Lateral and Branch fiber optic cable shall be clearly tagged and labeled as such at pull boxes and all other locations where it is exposed. At any location where the cable is brought into or out of a span wire pole, the Contractor shall install a new weather-head to accommodate the bending radius of the cable.

Subsection 614.13 shall include the following:

Fiber Optic Cable for the main (backbone), lateral and branch cables will not be measured separately, but shall be included in the item Telemetry (Field), and shall include all labor and materials required to install the main, lateral, branch, and start cables through conduits to all pull boxes, cabinets and closures specified in the plans. Installation of all internal field cabinet telemetry, splicing, fan-out and termination of the cable at individual controller cabinets is described and paid for under Telemetry (Field).

Subsection 614.14 shall include the following:

No separate measurement or payment will be made for fiber optic cable. All fiber optic cable shall be considered incidental to the Telemetry (Field) pay item.

REVISION OF SECTION 614
LOOSE TUBE FIBER OPTIC CABLE

Section 614 of the Standard Specifications is hereby revised for this project as follows.

Notice:
Every effort has been made to ensure that the information contained in this specification is complete and accurate at the time of publication; however, information contained herein is subject to change.

Trademarks:
ANSI® is a registered trademark of the American National Standards Institute, Inc.
KELLEMS® is a registered trademark of Harvey Hubbell, Inc.

Scope:

This specification covers the general design requirements and performance standards for fiber optic cables intended primarily for use in the outside plant environment. The purpose of this document is to provide the essential requirements for All-Dielectric Single Jacket, Single Jacket / Single Armor, and Double Jacket / Single Armor Loose Tube Fiber Optic cable to be used in the City of Denver networks.

The product requirements and features described in this specification are those considered useful for ensuring proper selection and manufacturing of fiber optic outside plant cables.

In this specification, all observed or calculated values are rounded off "to the nearest unit" in the last right hand place of figures used in expressing the limiting value. The round-off method of ASTM E 29 is used.

These cables should comply with industry standards such as Telcordia Technologies GR-20 (formerly Bellcore), Electronic Industries Association (EIA), Telecommunications Industry Association (TIA), International Telecommunications Union (ITU), International Electrotechnical Commission (IEC), and American Society for Testing and Materials (ASTM).

Optical Fiber Characteristics

High quality optical fibers should be made with pure silica-based glass to have very low loss for infrared wavelengths and to be used to carry large amounts of information for very long distances in optical communication systems.

Details of the optical fibers are not covered in this specification, but the proposed cable should contain AllWave® or TrueWave® fibers for Single-Mode applications, or Multimode fibers that comply with the specific fiber requirements supplied by the City of Denver.

Cable Core Characteristic:

1. Color Code:
The individual colors for fibers and buffer tubes in loose tube cable cores should comply with EIA/TIA-598 as given in the following table.

REVISION OF SECTION 614
LOOSE TUBE FIBER OPTIC CABLE

Table 1 – Fiber and Tube Color Code

Fiber or Tube No.	**Color**
1	Blue (BL)
2	Orange (OR)
3	Green (GR)
4	Brown (BR)
5	Slate (SL)
6	White (WH)
7	Red (RD)
8	Black (BK)
9	Yellow (YL)
10	Violet (VI)
11	Rose (RS)
12	Aqua (AQ)

2. Central Strength Member

The central member functions as an anti-buckling element, and should be a glass/epoxy composite dielectric rod. A polyethylene overcoat may be applied to the central member to provide the proper spacing between buffer tubes during stranding.

3. Loose Tube Cable Buffer Tubes

Optical fibers are enclosed within buffer tubes that have a diameter several times larger than the diameter of the fibers. The optical fibers are loose within the buffer tubes allowing the fibers to move freely. The loose buffer tubes should have a 2.5 mm diameter, with a nominal wall thickness of 0.4 mm. For composite cable designs when both and multi-mode fibers are contained within the same cable, the single-mode fibers will be contained in the first buffer tubes. The multi-mode fibers will be contained in the sequenced buffer tubes following the multi-mode buffer tubes.

Table 2 – Buffer Tubes

Fiber Count	**Buffer Tube OD (mm)**	**Fibers per Tube**
1-288	2.5	12

The buffer tubes (and filler rods, if necessary) must be stranded in a reverse oscillation lay (ROL) technique around the central member to allow for easy mid-span access. The core of buffer tubes should be wrapped with two counter helically applied threads to bind together the cable core.

4. Filler Rods

In order to create a round cable, filler rods of the same diameter as the buffer tubes may be used to fill empty positions. Filler rods are made out of HDPE and are natural in color.

5. Water Blocking System

Water blocking of the core outside and around the buffer tubes must be accomplished via “dry” elements. **In addition, water-blocking <u>inside</u> the buffer tubes must be accomplished via “dry” elements as well.**

These "dry" water blocking elements form a gel compound when in contact with water. The gel should effectively fill the interstices of the core and the inside of the tubes to prevent water penetration along the length of the cable. This dry water blocking significantly reduces cable core access time by eliminating the step of cleaning the buffer tubes and fibers upon entry. Additionally, this technology reduces the cable weight.

Dry water blocking elements should be in the form of binders, tapes, or yarns depending on where they are being applied.

Cable Sheath Characteristic:

The sheaths described in this section are:

- All-Dielectric Single Jacket: One polyethylene jacket, no metallic elements (SJ)
- Strength Elements: Sheath strength elements are applied over the cable core to provide the cable with the required tensile strength. These elements are made of fiberglass (Aramid yarns may be used as well).
- Inner Jacket (NOT APPLICABLE TO THIS PROJECT)
- Steel Armor (NOT APPLICABLE TO THIS PROJECT)
- Outer Jacket: An outer polyethylene jacket is applied over the cable to provide overall mechanical protection. This jacket is made of MDPE (or HDPE upon request) and is usually black. If required, the jacket could have two co-extruded colored tracer stripes located 180 degrees apart to aid in cable identification. The jacket will be continuous, free from pinholes, splits, blisters, or other imperfections.
- Ripcords: For ease of jacket removal, one clearly identifiable polyester ripcord is provided under the outer jacket for SJ designs. SJ/SA designs shall have two under armor ripcords placed 180 degrees apart. DJ/SA designs shall have one ripcord under both the inner jacket and steel armor.

Cable Cross-Sections: Single Jacket (SJ)

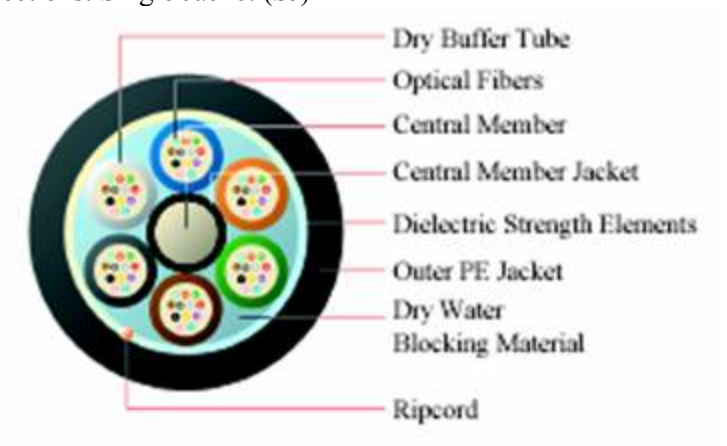

Figure 1 – Single Jacket

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LOOSE TUBE FIBER OPTIC CABLE

Table 3 – Target Cable Outer Diameters

NUMBER OF FIBERS								
	2 - 60 (5 Pos.)	**2 - 72 (6 Pos.)**	**73 - 96 (8 Pos.)**	**97 - 120 (10 Pos.)**	**121- 44 (12 Pos.)**	**145-216 (18 Pos.)**	**217-240 (20 Pos.)**	**241-288 (24 Pos.)**
SHEATH TYPE	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**	**Cable OD in. (mm)**
SJ	**0.42 (10.6)**	**0.43 (11.0)**	**0.50 (12.8)**	**0.57 (14.4)**	**0.64 (16.2)**	**0.66 (16.7)**	**0.69 (17.4)**	**0.76 (19.2)**

Mechanical, Environmental and Electrical Requirements:
These cables must meet the requirements of *Telcordia GR-20-CORE* with all testing performed based on *EIA/TIA-455* standards. The manufacturing company must provide proof of their quality control standards with *ISO 9001* and *TL9000* certifications. The cables should comply with the following temperature ranges:

Operation:	-40°C to 70°C (-40°F to 158°F)
Installation:	-30°C to 60°C (-22°F to 140°F)
Storage/Shipping:	-40°C to 75°C (-40°F to 167°F)

Single-Mode Fibers

Per *Telcordia GR-20*, the magnitude of the attenuation change shall be less than or equal to 0.05 dB for 90% of the test fibers and less than or equal to 0.15 dB for the remaining 10% of test fibers. Cable aging allows for 0.10 dB/km average attenuation change with a magnitude of the maximum attenuation change for each individual fiber to be less than 0.25dB/km. These attenuation values include a 0.05 dB allowance for measurement repeatability During mechanical and environmental testing evidence of cracking, splitting or other failure of the sheath components when examined under 5X magnification would result in failure of the proposed test requirements. In addition, no fiber shall lose optical continuity because of the test.

Table 4 – Testing for Single Mode Fibers

Cable Test	Test Method	Requirement
Tensile Loading and Bending	EIA/TIA-455-33 IEC 794-1-E1	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Cyclic Flexing	TIA/EIA-455-104 IEC 794-1-E6	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Cyclic Impact	EIA/TIA-455-25 IEC 794-1-E4	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Compressive Loading	TIA/EIA-455-41 IEC 794-1-E3	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Twist	TIA/EIA-455-85 IEC 794-1-E7	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
Low and High Temperature Bend	EIA/TIA-455-37 IEC 794-1-E11	90% < 0.05 dB Max. Added Loss 100% < 0.15 dB Max. Added Loss
External Freezing	EIA/TIA-455-98 IEC 794-1-F6	< 0.05 dB Mean Added Loss < 0.15 dB Max. Added Loss
Temperature Cycling	EIA/TIA-455-3 IEC 794-1-F1	□ 0.05 dB/km Mean Added Loss □ 0.15 dB/km Max Added Loss
Cable Aging	EIA/TIA-455-3 IEC 794-1-F1	□ 0.10 dB/km Mean Added Loss □ 0.25 dB/km Max Added Loss
Water Penetration	EIA/TIA-455-82 IEC 794-1-F5	No flow after 24 hours from one meter length of cable

Multimode Fibers

Per *Telcordia GR-20*, the allowable attenuation increase during the mechanical and environmental testing is 0.20 dB. Cable aging allows for the maximum attenuation change for each individual fiber to be less than 0.40dB/km.

During mechanical and environmental testing evidence of cracking, splitting or other failure of the sheath components when examined under 5X magnification would result in failure of the proposed test requirements. In addition, no fiber shall lose optical continuity because of the test.

Table 5 – Testing for Multi-Mode Fibers

Cable Test	Test Method	Requirement
Tensile Loading and Bending	EIA/TIA-455-33 IEC 794-1-E1	0.20 dB Max. Mean Added Loss
Cyclic Flexing	TIA/EIA-455-104 IEC 794-1-E6	0.20 dB Max. Mean Added Loss
Cyclic Impact	EIA/TIA-455-25 IEC 794-1-E4	0.40 dB Max. Mean Added Loss
Compressive Loading	TIA/EIA-455-41 IEC 794-1-E3	0.20 dB Max. Mean Added Loss
Twist	TIA/EIA-455-85 IEC 794-1-E7	0.20 dB Max. Mean Added Loss
Low and High Temperature Bend	EIA/TIA-455-37 IEC 794-1-E11	0.40 dB Max. Mean Added Loss

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LOOSE TUBE FIBER OPTIC CABLE

Table 5 (continue) – Testing for Multi-Mode Fibers

Cable Test	Test Method	Requirement
External Freezing	EIA/TIA-455-98 IEC 794-1-F6	0.20 dB Max. Mean Added Loss
Temperature Cycling	EIA/TIA-455-3 IEC 794-1-F1	□ 0.5 dB/km Max Added Loss 80 % □ 0.25 dB/km Added Loss
Cable Aging	EIA/TIA-455-3 IEC 794-1-F1	□ 1.0 dB/km Max Added Loss 80 % □ 0.5 dB/km Added Loss
Water Penetration	EIA/TIA-455-82 IEC 794-1-F5	No flow after one hour from one meter length of cable

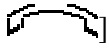
Note:

The tensile rating for all of the cables described should be 2.7 kN (600 lbf), with a compression rating of at least 220 N/cm under GR-20 requirements.

Cable Marking

Printed Characters
For standard outer jackets, printed characters shall be indent printed with white characters for black jackets, black characters for non-black jackets, or as otherwise specified.
For standard striped outer jackets, printed characters shall be indent printed with white characters for red, green, orange, yellow, blue striped cables, light-blue characters for white striped cables, or as otherwise specified by the customer.
The characters shall be of proper height and space to produce good legibility. Character heights of 2 mm should facilitate adequate readability. An occasional illegible marking is permitted if there is a legible marking on either side.

Markings
The cable shall be sequentially marked at one meter, or two-foot intervals depending on specific requirements issued by the City of Denver. The length marks shall not be reset to zero on any length of the cable. The actual length of cable shall be within +1, -0% of the marked length.

Each length of cable shall be marked with the following legend:
"(Manufacturer Name) OPTICAL CABLE, (Product Part Number), (Month and Year of Manufacture, [MM-YY]), (Telephone Symbol []), (Fiber Count [XXX F], where XXX is the number of optical fibers in the cable), and (Manufacturers' Serial Number) "

Re-Markings
Only one remarking is permitted. If required, either of the following methods for remarking shall be used:

Method A: Completely remove the defective marking and remark the characters with the original color.

Method B: Leave the defective marking on the jacket and remark on a different portion of the cable jacket with yellow character print. The new number sequence shall differ from any other existing marking by at least 5000.

REVISION OF SECTION 614
LOOSE TUBE FIBER OPTIC CABLE

Any cable that contains two sets of markings shall be labeled to indicate the color and sequential numbers to be used. The labeling shall also be applied to the reel tag.

Cable Packaging

Reels
The manufacturer shall supply the product using their standard reel sizes, methods, apparatus, and reel wood lagging, but stenciled according to these specifications. The specifications outlined here are guidelines on what is expected with respect to packaging.

Reels are assumed to be in good working condition, firm, and be able to support the product through shipping and final installation. Reels shall be clean, dry and free of excessive dirt. All reels shall be checked for high nails, stave fit and proper stenciling.

Reel Labels

Each wooden reel shall be permanently marked with the following information:

- "(Manufacturer's name)" (red paint)
- "OPTICAL CABLE" (black paint)
- An arrow and the wording "cable end" to indicate the position of the outside cable end. (red paint)
- An arrow and the wording "ROLL THIS WAY" to indicate the direction the reel should be rolled to prevent loosening of the cable. (black paint)
- Reel Number (red paint)

Cable handling stickers/cards must be attached to both flanges of every reel. Each sticker must be stapled to the flange. See Figure 4 for illustrations of the stickers to be used.

Reel Lagging

Thermal Protection
Outer layers of the reel shall be covered with a protective wrap to limit the solar heating of the cable. This helps limit the cable surface temperature so that it will not exceed 10 C (18 F) above ambient temperature under maximum solar radiation according to Telcordia GR-20 requirements. All foil wrap shall be securely fastened to the cable by at least 2 pieces of strapping tape.

Composite & Wood Lagging
Reels shipping domestically shall be lagged with a suitable protective wrap (can be the same thermal protection wrap) and banded with steel straps. This wrap shall cover the cable from flange to flange and provided some mechanical protection to the outer layers of cable as well as weather resistance. Reels shipping for export shall be lagged with wooden boards nailed to each flange and banded with steel straps in addition to the protective wrap around the outer layers of cable.

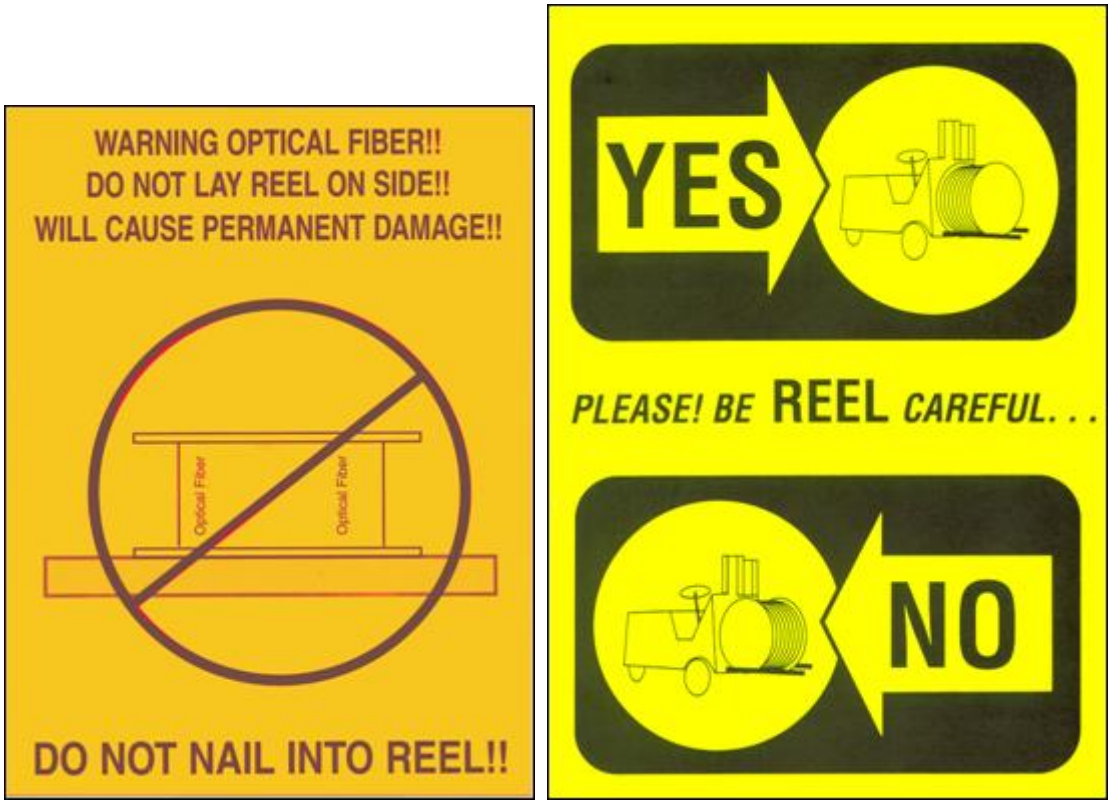


Figure 4 – Reel Stickers

Other

Cable Ends

Each end of the cable shall have end seals, either end caps or KELLEMS® pulling grips, in order to prevent moisture ingress into the cable during shipping, storage, or installation.

The top end of the cable shall be securely fastened to the inside of the reel flange to prevent the cable from becoming loose in transit or during handling. The bottom end, "test tail", shall be approximately three meters in length and easily accessible. The end shall be protected within a cable slot and be securely fastened to the outside of the reel flange with wire ties or walkout straps. Staples, nails or yarn attached to the reel during manufacturing shall be removed.

The cable slot can be partially protected to prevent the cable tail from moving outside this, however for export orders the cable slot must be completely sealed by either metallic protection rings, plywood covers, or other.

Cable Length Tolerance

Cables ordered to standard factory lengths shall have an actual length within –0% and +5% of the length ordered unless otherwise specified by the customer.

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LOOSE TUBE FIBER OPTIC CABLE

Certified Test Data

Each cable shall have certified test data securely fastened to the reel in a waterproof wrapping. The certified test data sheet shall include the following information:

- Cable Number
- Date
- Customer Name
- Ordered Length
- Customer Order Number
- Ship Length
- Customer Cable Code
- Customer Reel Number
- Customer's Attenuation Specification(s)
- Number of Fibers
- Cable Construction
- Fiber Transmission Data
- Bandwidth Data – only applies to Multi-Mode Fibers
- Authorized Signature

Reel Tag

Each cable shall have a reel tag securely fastened to the reel in a waterproof wrapping. The Reel Tag (Cut Length Data Sheet) shall include the following information:

- Cable Number
- Date
- Customer Name
- Ordered Length
- Customer Order Number
- Ship Length
- Customer Cable Code
- Customer Reel Number
- Customer's Attenuation Specification(s)
- Number of Fibers
- Beginning and Ending Sequential Length Markings
- Gross Weight
- Net Weight
- Inspected By Signature

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(p), Test Fiber Optic Cable, is hereby added to the Standard Specifications and shall include the following:

This work consists of testing fiber optic cable. Testing shall include both new cable and existing cable. The test procedures involve an OTDR test and an Optical Power Meter Test.

The guidelines for fiber optic cable testing include:

Test jumpers and patch cords must be of the same fiber core size and connector type as the cable system.

The light source and OTDR must operate with the range of 1310±10 nm or 1550±20 nm for testing in accordance with ANSI/EIA/TIA-526-7.

The power meter and the light source must be set to the same wavelength during testing.

The power meter must be calibrated and traceable to the National Institute of Standards and Technology (NIST).

All system connectors, adapters and jumpers must be cleaned as per manufacturer's instructions before measurements are taken.

Materials

The following items are required to perform fiber optic cable tests:

- an OTDR;
- a test reel, if necessary;
- a light source at the appropriate wavelength;
- Optical Power Measurement Equipment; and
- Test Jumpers as specified below.

    (a) 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.

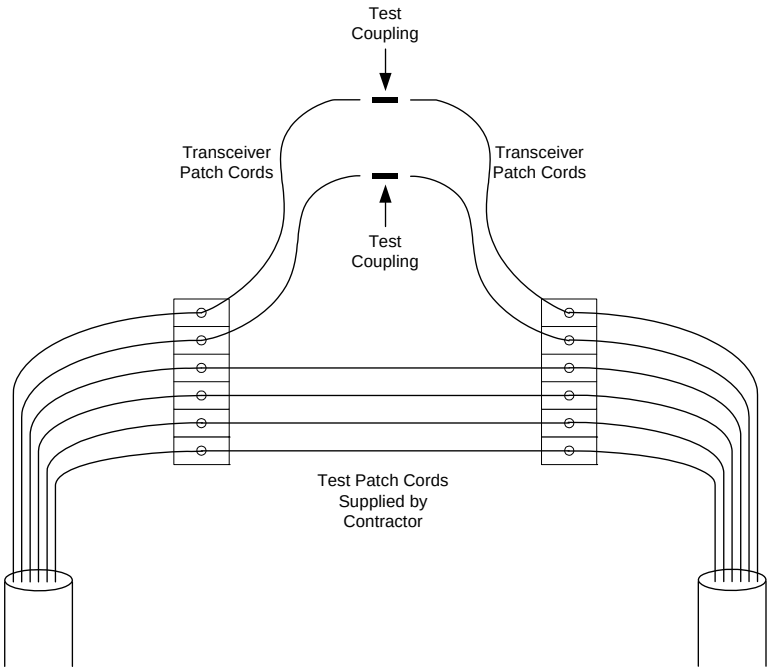
Optical Fiber Cable Testing with O.T.D.R.

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.

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 and 1550nm. 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 non-terminated, 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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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:

- Names of personnel conducting the test.
- Type of test equipment used (manufacturer, model, serial number, calibration date).
- Date test is being performed.
- Optical source wavelength and spectral width.
- Fiber identification.
- End point locations.
- Launch conditions
- Method of calculation for the attenuation or attenuation coefficient.
- Acceptable link attenuation.

Optic fiber Cable Testing with Optical Power

The Contractor shall conduct an Optical Power Meter Test for each fiber installed.

Fiber optic cable segments shall be tested in one direction at both the 1310 nm and 1550 nm wavelength.

In compliance with 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:

- Names of personnel conducting the test.
- Type of test equipment used (manufacturer, model, serial number, calibration date).
- Date test is being performed.
- Optical source wavelength and spectral width.
- Fiber identification.
- End point locations.
- Test direction.
- Reference power measurement (when not using a power meter with a Relative Power Measurement Mode).
- Measured attenuation of the link segment.
- Acceptable link attenuation.

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.

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TEST FIBER OPTIC CABLE

Acceptable Attenuation Values

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

SM Fiber: The general attenuation equation for any SM link segment is as follows:

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

8.3 μm Single-mode Attenuation Coefficients:

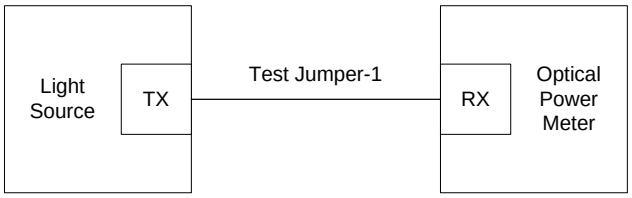
Cable Attn.=Cable Length (km) x (0.34 dB/km@1310 nm or 0.25 dB/km@1550 nm)
Connection Attn. (ST or SC connectors)=(No. of Connections x 0.39 dB)+0.42 dB.
Connection Attn. (LC connectors)=(No. of Connections x 0.14 dB)+0.24 dB.
Splice Attn. (Mechanical or Fusion)=Splices x 0.30 dB.

Test Procedures

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

The Optical Power Meter fiber test shall be conducted as follows:

Clean the test jumper connectors and the test coupling per manufacturer's instructions.
Follow the test equipment manufacturer's initial adjustment instructions.
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.



If the power meter has a Relative Power Measurement Mode, select it. If it does not, reduce the Reference Power Measurement (P_{ref}). If the meter can display power levels in dBm, select this unit of measurement to simplify subsequent calculations.

Disconnect Test Jumper-1 from the power meter. Do NOT disconnect the test jumper from the light source.

Attach Test Jumper-1 to one end of the cable plant to be measured and Test Jumper-2 to the other end.

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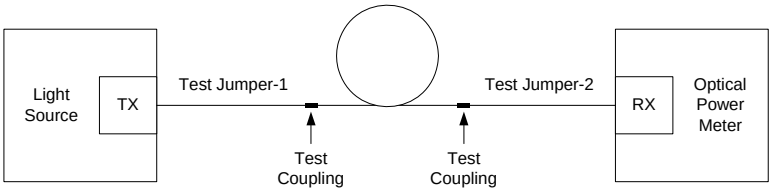
TEST FIBER OPTIC CABLE



Record the Power Measurement (P_{sum}). 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:

If P_{sum} and P_{ref} are in the same logarithmic units (dBm, dBu, etc.):
CPR (dB) = P_{sum} - P_{ref}
If P_{sum} and P_{ref} are in watts:
CPR (dB)= 10 x $\log_{10}$ [O_{sum}/P_{ref}]

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 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.

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 hard copy of the OTDR trace for every fiber on the reel. After installation, the Contractor shall submit one hard copy of the OTDR trace for every spliced fiber. Hard copy traces shall be organized and bound in logical order in an 8 ½" x 11" hard cover binder.

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 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;
- Fiber Splice configuration; and
- Termination layout.

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TEST FIBER OPTIC CABLE

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.

Subsection 614.14 shall include the following:

No separate measurement or payment will be made for fiber optic cable testing. All cable (system) testing shall be considered incidental to the Telemetry (Field) pay item.