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CFX ITS Inspection Reference & Training Manual

Chapter 5
Fiber Optic Cable

5.0 INTRODUCTION TO FIBER OPTIC CABLE (FOC)

Fiber optic cable (FOC) is a cable assembly that utilizes optical fibers, which are transparent strands of glass only slightly thicker than a human hair, to transmit communications signals in the form of light. FOC is utilized in CFX's ITS infrastructure to provide a means of transmitting data to and from the numerous ITS and tolling devices deployed throughout CFX's system, ultimately forming CFX's fiber optic network (FON) which will be discussed in greater detail in Chapter 6. This Chapter will introduce the basic terminology needed to understand the theory behind FOC communications, how FOCs are constructed, types of FOC utilized in CFX's ITS infrastructure, and requirements for FOC being installed and terminated on CFX projects.

5.1 FIBER OPTIC COMMUNICATION THEORY AND TERMINOLOGY

Before we cover the details of types of FOC and installation requirements, we will start with a brief introduction to the theory and terminology behind fiber optic communications in order to become comfortable with this technology.

5.1.1 Fiber Optics Theory – Figure 5.1 below is a diagram showing the various portions of the electromagnetic spectrum. The electromagnetic spectrum defines the range of wavelengths for the various types of electromagnetic radiation (e.g. visible light, radio waves, microwaves, etc.) all of which are forms of "light" which is the medium fiber optic technologies use to transmit data from one point to another. Fiber optic technologies utilize infrared light, which is invisible to the naked eye, to transmit communications signals with wavelengths ranging from 850 nm to 1550 nm. Specifically, fiber technologies typically utilize wavelengths within the infrared spectrum of 850 nm, 1300 nm, and 1550 nm. We will now move into defining some common terminology used in fiber optics which will provide some insight into why these wavelengths are most commonly used.

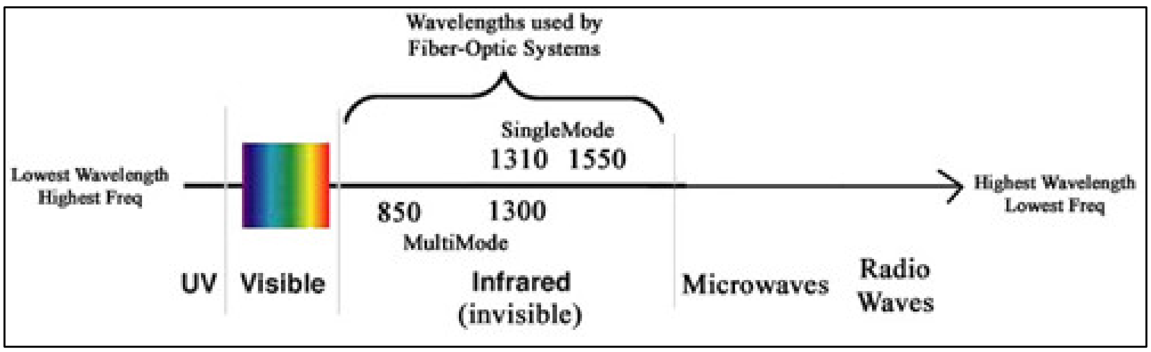

Figure 5.1: Fiber Optic Communication Wavelengths

5.1.2 Attenuation – Attenuation, also known as transmission loss or just simply loss, refers to the reduction in intensity of a signal (or light) lost in an optical fiber. Attenuation is measured in decibels (dB) which is a measure of signal strength. All optical fibers have an inherent loss typically measured in dB per kilometer (dB/km) generally due to absorption and scattering which we will define next. Other sources of loss in an optical fiber are bends (most notably macro bends), splices, and terminations all of which will be discussed in this Chapter.

5.1.2-1 Absorption – Absorption is a phenomenon that causes signal loss in optical fiber when the light interacts with molecules in the glass causing the light to be converted to heat. Absorption commonly occurs at specific wavelengths which are determined by the molecules the light interacts within the fiber.

5.1.2-2 Scattering – Scattering is a phenomenon that causes signal loss in optical fibers when the light transmission interacts with microscopic impurities present in the optical fiber from the manufacturing process causing the light to scatter. Scattering is the largest inherent cause of attenuation in an optical fiber. Scattering occurs less at longer wavelength transmission, so a 1550 nm transmission will experience less signal loss due to scattering than an 850 nm transmission.

Figure 5.2 below displays graphically why the 850 nm, 1310 nm, and 1550 nm wavelengths are the most widely used in fiber optic systems. Put simply, these wavelengths are long enough to where signal loss is relatively low due to scattering and they are outside of the bands where signal loss due to absorption is a known issue.

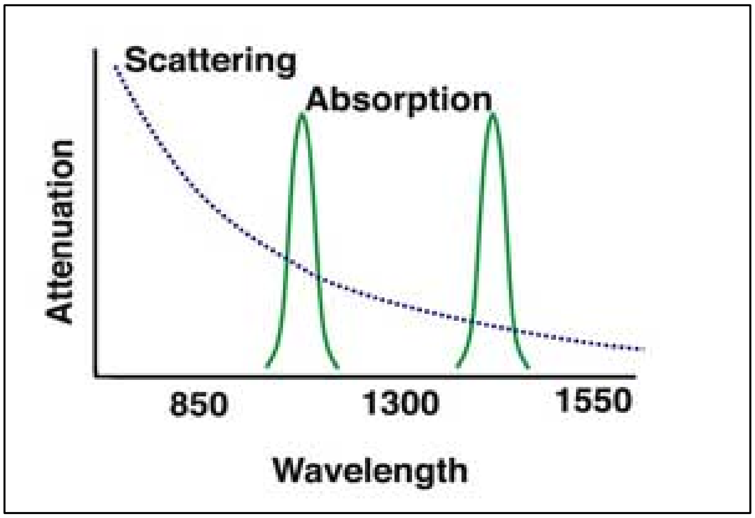

Figure 5.2: Attenuation Due to Scattering and Absorption

5.2 OPTICAL FIBERS

All types of FOC will include optical fibers. These optical fibers are the medium that allows the transmission of information as light pulses. The components which make up a single optical fiber are the core, cladding, and buffer coating as shown in Figure 5.3 below. We will now briefly discuss each of these components and how the propagation of a light signal occurs through an optical fiber.

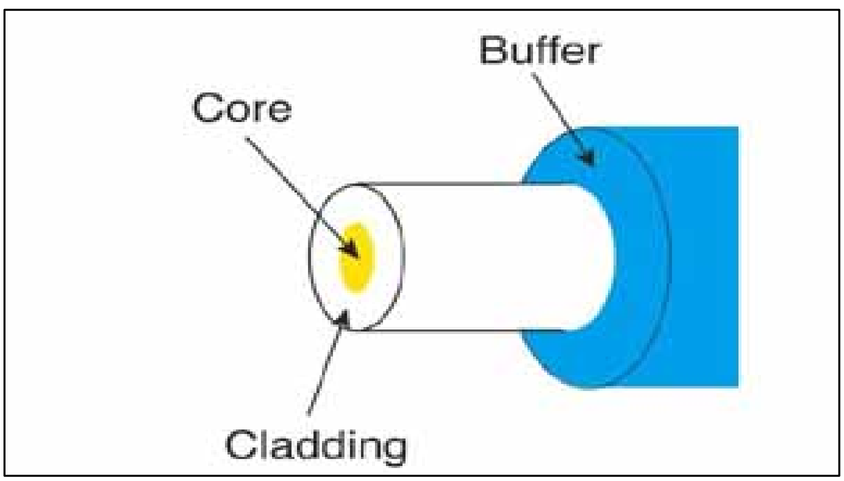

Figure 5.3: Components of an Optical Fiber

5.2.1 Core – The core is a cylindrical piece of glass at the center of an optical fiber that spans its entire length. Light, carrying communication signals, is transmitted within the core of an optical fiber. The diameter of the core ranges from 9 microns to 62.5 microns depending on the type of FOC. (NOTE: A micron is equal to one-millionth of a meter.)

5.2.2 Cladding – The cladding is the piece of glass immediately surrounding the core and is responsible for confining the light signal to the core. The material which makes up the cladding has a lower index of refraction than the material that makes up the core, and this results in the light signal being reflected when it hits the core-cladding boundary and therefore remaining confined to the core, as shown in the Figure 5.4 below. We will not go into additional details on the subject except to say that if a light signal exceeds a specific angle it can be absorbed into the cladding leading to attenuation which is the case with the loss due to scattering that we previously discussed.

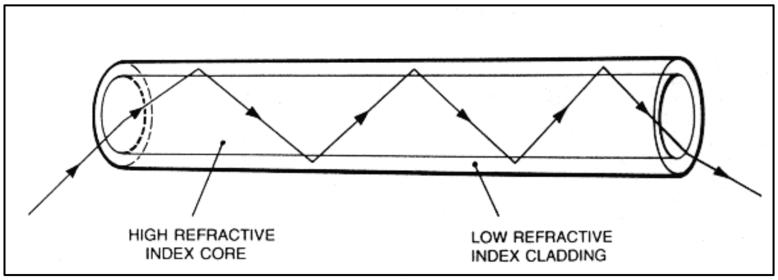

Figure 5.4: Light Propagation in Optical Fibers

5.2.3 Buffer Coating – The buffer coating, not to be confused with buffer tube which will be discussed in the next Section, is a plastic layer surrounding the cladding that protects the glass from physical damage and moisture but does not contribute to the light signal transmission.

5.3 FOC CONSTRUCTION

FOCs come in a wide variety of cable types, as shown in Figure 5.5 below, which are used in different applications. FOC refers to the complete cable assembly of optical fibers, and other components such as the jacket, buffer tubes, strength members, ripcords, and stiffeners. The cable assembly provides protection for the optical fibers it houses and the cable construction should be appropriate for the environment in which it will be utilized. FOC types are typically separated into indoor (premise) and outdoor (outside plant) installations. For the purposes of the training, we will focus only on loose tube FOC construction as this is the type that will be required for installations in CFX's ITS infrastructure.

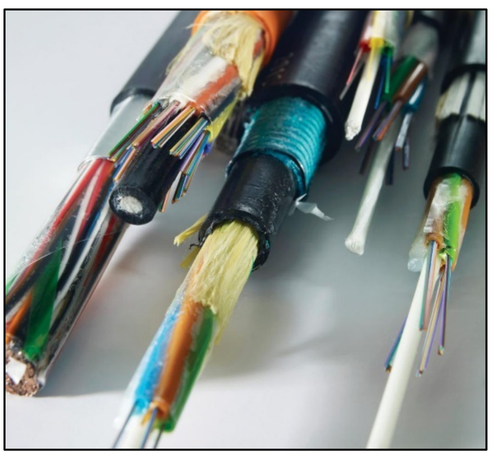

Figure 5.5: Types of FOC

5.3.1 Loose Tube Cable – Loose tube FOC is a particular type of cable construction that is specifically designed for use in harsh outdoor environments. Loose tube cables will have an outer jacket that houses inner buffer tubes, optical fibers, and a central strength member. All loose tube cables will utilize some form of water blocking technology to prevent moisture intrusion.

5.3.1-1 Jacket – The jacket (or sheath) is the outermost protective layer typically made of black polyethylene that protects the inner components from physical damage, moisture, and sunlight exposure. The sheath will be marked with sequential measurement markings at 2-foot increments allowing for easy measurements of installed cable lengths.

5.3.1-2 Buffer Tube – Buffer tubes are small plastic colored tubes housed within the outermost jacket. Groupings of twelve optical fibers will be housed within each individual buffer tube.

5.3.2 Fiber Counts – One of the key characteristics of a FOC is the fiber count; that is how many optical fibers the cable contains. The fiber count will be determined in design, based on multiple factors including, number of fibers needed for data transmission, level of redundancy needed, and future network demands. FOCs can come with fiber counts ranging from just two up to hundreds of optical fibers in a single cable. For CFX's ITS infrastructure the most common fiber counts required will be 12, 24, 72, and 144 count FOC.

5.3.3 Color Code – Both the buffer tubes and buffer coatings for individual optical fibers in a FOC assembly will follow a specific color code. The twelve optical fibers within each buffer tube and the buffer tubes themselves will be color coded as shown in Figure 5.6 below.

Fiber or Buffer Tube Number	Color	
1	Blue	
2	Orange	
3	Green	
4	Brown	
5	Slate	
6	White	
7	Red	
8	Black	
9	Yellow	
10	Violet	
11	Rose	
12	Aqua	

Figure 5.6: Fiber Color Code

Figure 5.7 on the following page shows the cross section of a typical 72 FOC that is commonly installed in CFX's ITS infrastructure. Notice that the cross section shows six buffer tubes (matching buffer tube colors 1 thru 6 from Figure 5.6) and each buffer tube contains twelve optical fibers (matching fiber colors 1 thru 12 from Figure 5.6) for a total of 72 fibers.

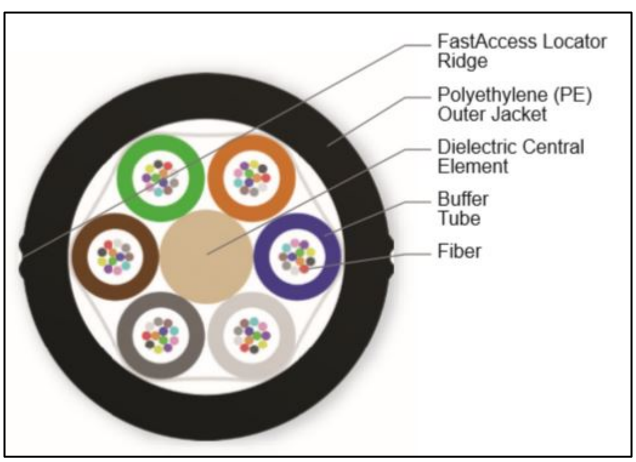

Figure 5.7: 72 FOC Cross Section

5.4 TYPES OF FOC

Despite the large amount of available cable construction types, there are only two main types of optical fibers, multi-mode and single-mode. Multi-mode and single-mode fibers are defined by their core and cladding diameters and how light signals travel through them.

5.4.1 Multi-mode – Multi-mode fiber has a core and cladding diameter of either 50 and 125 microns or 62.5 and 125 microns, receptively. Multimode fiber is generally used with laser sources at wavelengths of 850 and 1300 nanometers. Multimode fiber allows multiple modes of light to propagate within a single strand, hence the name 'multi'-mode. The inherent loss due to absorption and scattering for multi-mode fibers are as follows:

- 3.0 dB/km for 850 nm sources
- 1.0 dB/km for 1300 nm sources

Multi-mode fiber is only found in CFX's ITS infrastructure, between the DMS cabinet and the DMS housing. The DMS manufacturers use multi-mode fiber to communicate from the cabinet to the sign due to the short distance, thus making multi-mode fiber suitable for this application.

5.4.2 Single-mode – Single-mode fiber has a core and cladding diameter of approximately 9 and 125 microns, respectively. This means that the core in a single-mode fiber is approximately 6x smaller than a multi-mode fiber as shown in Figure 5.8. Light travels in a single-mode fiber in only one ray (mode), which is why it is called single-mode. Single-mode fibers use laser sources at wavelengths of 1310 nm and 1550 nm. Due to the longer optical wavelengths and one mode of light propagation, single-mode fiber experiences lower loss than multi-mode fiber and is therefore ideal for longer distances and higher bandwidth installations. The inherent loss due to absorption and scattering for a single-mode fiber is as follows:

- 0.5 dB/km for 1310 nm sources
- 0.4 dB/km for 1550 nm sources

Single-mode fiber is the standard for installations in CFX's ITS infrastructure due to its effectiveness at transmitting large amounts of data over long distances with limited signal loss. Single-Mode fiber is the only permitted fiber type for use on CFX's networks, with the exception of DMS communications as described above.

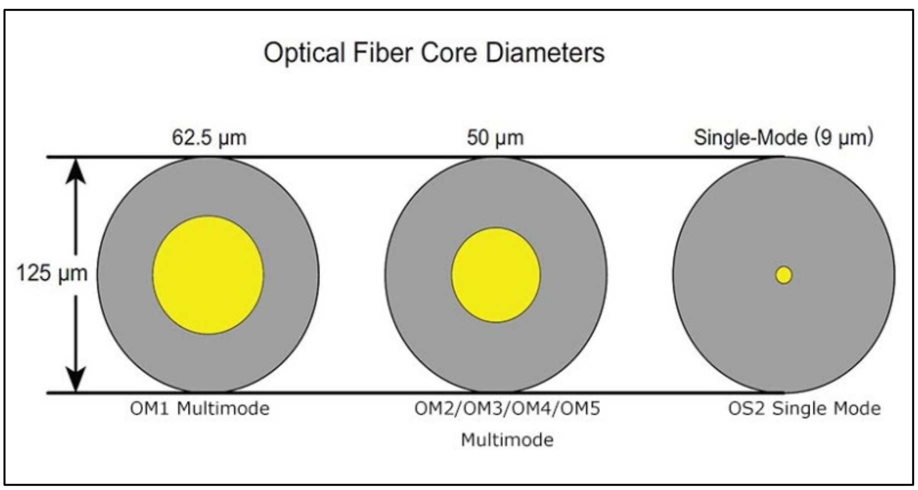

Figure 5.8: Multi-mode vs. Single-mode Optical Fiber Diameters

5.4.3 CFX FOC Requirements – CFX Technical Specification 633-1 requires Corning® Single-Mode Altos® stranded loose tube FOC as shown in Figure 5.9 below with a fiber count of 12, 24, 72, or 144 (Part Nos. 012ZU4-T4F22D20, 024ZU4-T4F22D20, 072ZU4-T4F22D20 and 144ZU4-T4F22D20 respectively) or as specified in the plans. The FOC jacket shall be labeled with the manufacturer's name, the words "CFX 12 SM", "CFX 24 SM", "CFX 72 SM", or "144 SM" accordingly, date of manufacture, type of cable, fiber and sequential measurement markings every 2 feet. It is important for the CEI inspector to verify that FOC specifically manufactured for use on CFX's system, as shown in Figure 5.10, is being installed.

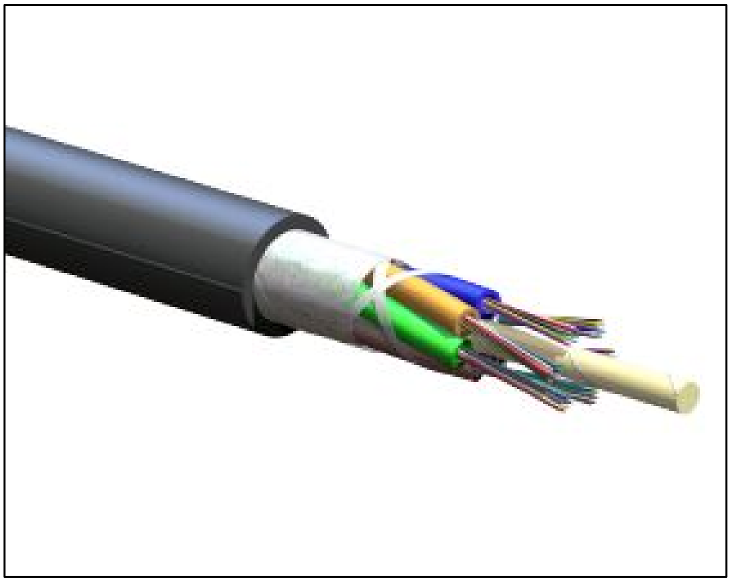

Figure 5.9: Corning® Single-Mode Altos® FOC

Figure 5.10: FOC Sheath 'CFX 72 SM' Markings

5.5 FOC INSTALLATION REQUIREMENTS

Now that we have covered the basic theory behind fiber technologies, FOC construction, and the type of FOC commonly used in CFX's ITS infrastructure, we are ready to move to FOC installation topics. In this Section, we will review the requirements for properly installing, splicing, and terminating FOC installed on CFX's system. Specifically, we will cover the following topics:

- FOC installation
- Fusion splicing

- Patch panels
- Terminations
- Splice trays
- Splice closures
- Jumper cables

5.5.1 FOC Installation – FOC comes from the manufacturer on reels as shown in Figure 5.11 on the following page. If FOC needs to be unreeled or backfed in preparation for long cable installations, it is recommended that the cable be laid out on the ground in a figure-eight configuration, as shown in Figure 5.12, to prevent twisting or kinking of the cable during installation. The area in which the figure-eight configuration is laid out should be a safe/protected area where no vehicles will run over it and the area should be roped or coned off while the fiber is on the ground. FOC is installed by one of two methods: pulling or blowing. Each of these methods can have advantages in certain situations, but the length of the run is typically what will dictate which method the contractor elects to use. Regardless of which installation method is used, an appropriate pulling or blowing lubricant shall be used to reduce friction and make the cable installation easier. The CEI and the fiber installation crews need to ensure proper techniques are employed and the cable is handled with care at all times during installation to avoid damaging the FOC.

Figure 5.11: Fiber Reel

Figure 5.12: FOC Laid Out in Figure-Eight Configuration

When installing fiber optic cable, it is crucial to avoid damaging the optical fibers. Never directly pull on the fiber itself. Fiber optic cables have Kevlar aramid yarn or a fiberglass rod as their strength member, as shown in Figure 5.13. When installing fiber, you must pull on the fiber cable strength members only.

- Cables should be pulled with swivel pulling eyes to prevent twisting the cable.
- Always roll the cable off the spool instead of spinning it off the spool end, this will put a twist in the cable for every turn on the reel. Never twist the fiber cable. Putting a twist in the cable can stress the fibers.
- Use fiber optic cable lubricant. Lubricate the cable when installing in conduits. Lubrication reduces the pulling load and the chance of breakage. Make sure the lubricant is compatible with the cable jacket material.

Figure 5.13: Cable pulling Members

- Blown cable installation refers to a method of installing cables in ducts using compressed air and a machine that pushes the cable into the duct. The cables are not blown into the duct, but the blowing air floats the cable in the duct and reduces friction so the machine can push the cable into the duct.
- Cable bend radius: During pulling operations, care should be taken to not pull cable around corners too tightly. Fiber optic cables are to be installed with a minimum bend radius of 20 times the cable diameter under tension and a bend radius of 10 times the cable diameter under no tension after installation.

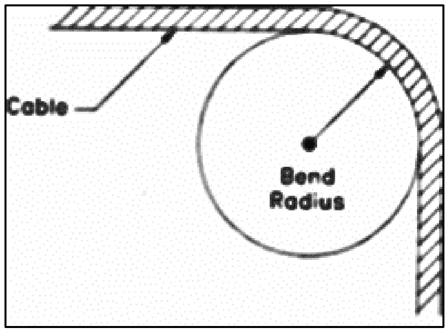

Figure 5.14: Cable bend Radius

5.5.1-1 Pre-Installation – Prior to installing the FOC, the duct shall be proofed to ensure the pathway is clear and free from obstructions. A projectile will be blown through the conduit using an appropriately sized air compressor. CFX requires the use of an Innerduct Cup Projectile for 1” nominal tube size, such as Part Number 2120-010 manufactured by Cal Am as shown in Figure 5.15. CFX also allows the use of a 1” wooden dowel in lieu of the proofing dart as they have found that wooden dowels are better at identifying any deformations in the conduit.

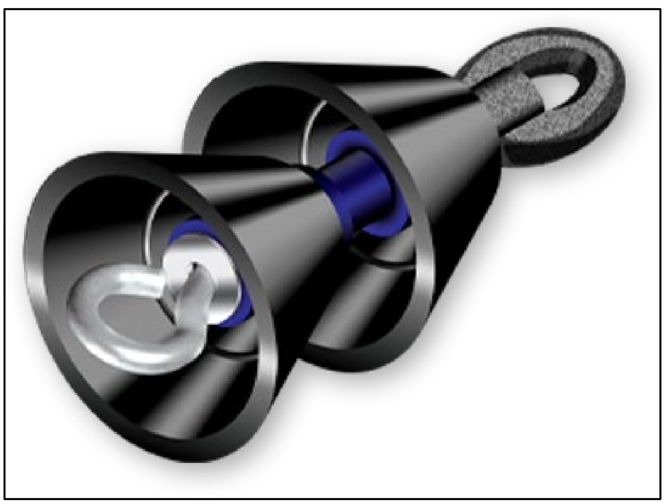

Figure 5.15: Cal Am Proofing Dart (PN: 2120-010)

It is important that when proofing, the contractor does not blow air or shoot projectiles into the ITS cabinet or directly into a pull box or FOMH which house expensive equipment or FOC. Figure 5.16 below shows an example of a damaged FOC from a conduit proofing operation where a proofing dart was blown directly into a FOMH which is extremely undesirable. In these situations, an extension should be added onto the duct entering the FOMH such that the projectile is routed outside and not blown directly into the FOMH, thereby avoiding any damage the projectile could cause to the existing FOC.

Figure 5.16: FOC Damage from Proofing Dart

If obstructions are identified in the duct during proofing, a duct rodder, as shown in Figure 5.17, can be used to attempt to clear the duct passage. Duct rodders can also be used to install a pulling rope for FOC pulling operations which we will discuss in the next Section.

Figure 5.17: Duct Rodder

5.5.1-2 Pulling – CFX Technical Specification 633-3.1.2 outlines the requirements for installing FOC by pulling. Fiber can be pulled into a duct by hand or by using a mechanical pulling machine similar to the fiber pulling trailer shown in Figure 5.18 below. FOC installation by pulling is typically advantageous for short runs.

Figure 5.18: Fiber Pulling Trailer

FOC shall be pulled by the central strength member or the jacket if the cable design allows. Pulling attachments such as a swivel pulling eye or a Kellems grip, as shown in Figure 5.19, shall be used to attach to the pulling rope and prevent cable twisting during the pulling operation which can stress and cause damage to the optical fibers. A tension meter should be used during pulling operations to ensure that the manufacturer's recommended maximum pulling tension (typically 600 lbs. for stranded loose tube FOC) is not being exceeded.

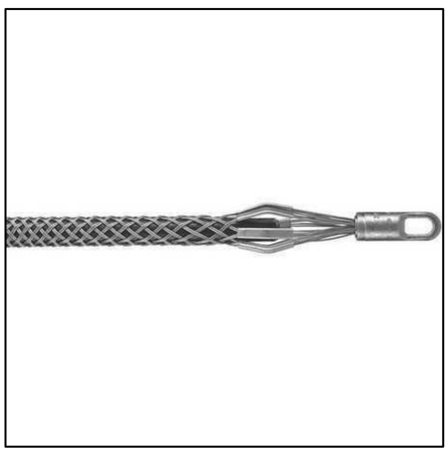

Figure 5.19: Kellems Grip

5.5.1-3 Blowing – CFX Technical Specification 633-3.1.3 outlines the requirements for installing FOC by blowing. Blowing is an air-assisted FOC installation technique where compressed air causes the cable to float within the duct, reducing friction, and a mechanical pushing device pushes the FOC into the duct. Figure 5.20 below shows a FOC blower which is used for FOC blowing operations. Blowing techniques provide an efficient, stress-free installation and are capable of far greater installation distances than are possible with pulling. There are two common methods of blowing FOC: the high airspeed blowing (HASB) method and the piston method.

Figure 5.20: FOC Blower

The HASB method is shown in Figure 5.21 below. The HASB method uses relatively high air volumes of between 300-600 cubic feet per minute. The air flow is distributed along the cable length creating a pulling force on the cable. The mechanical pusher then pushes the cable into the duct.

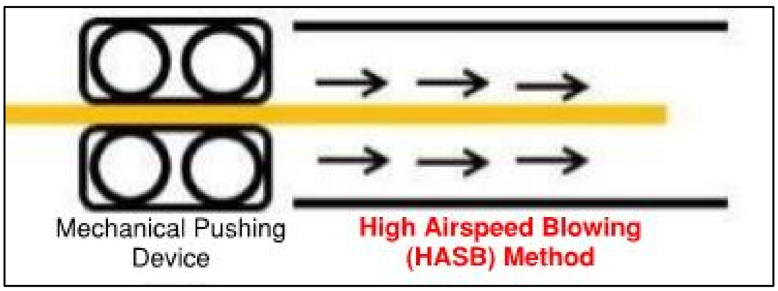

Figure 5.21: High Airspeed Blowing (HASB) Method for FOC Installation

The Piston method is shown in Figure 5.22 below. In this method, a missile (or piston) is attached to the front end of the FOC within the duct, blocking the duct. Air volumes of between 200-300 cubic feet per minute are applied to the duct building up air pressure behind the missile which pulls the cable into the duct.

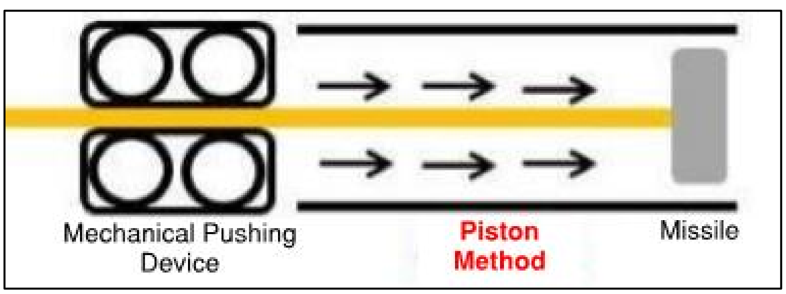

Figure 5.22: Piston Method for FOC Installation

There is also a device available called a Y-Block, as shown in Figure 5.23 below, which allows for FOC to be installed in a duct that is already occupied with an existing FOC. Use of a Y-Block can be very beneficial when there are limited conduits available for a proposed FOC installation or when trying to avoid device downtime when replacing an existing FOC.

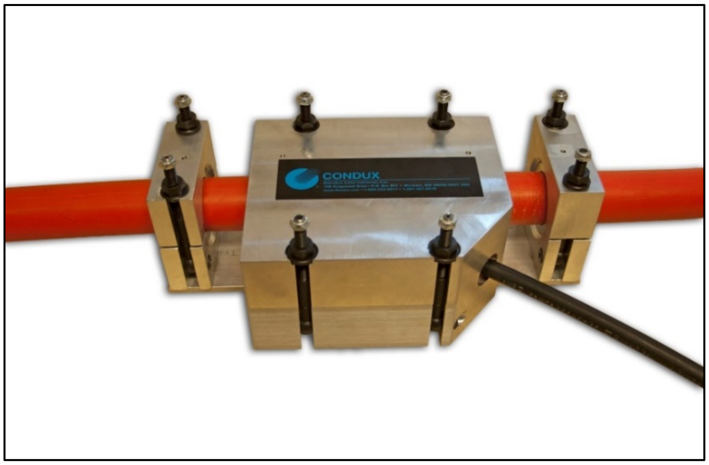

Figure 5.23: Y-Block FOC Blowing Accessory

It is important that during all FOC blowing operations, regardless of the particular method used, that the CEI and fiber installation crew are mindful of how much air pressure is applied to the conduit. Typical 1" HDPE SDR 11, like the type CFX requires for their fiber duct bank, has a pressure rating of 200 pounds per square inch. Blowing operations should remain well under this pressure rating to ensure the integrity of the duct is not compromised during cable installation operations.

5.5.1-4 Slack Requirements – CFX Specification 633-3.1.5 states that Slack Cable Storage shall be as noted in the plans. Slack cable is required for future maintenance or construction needs. If a splice is required to be installed in the existing fiber optic cable path, the slack from upstream and downstream pull boxes can be used to provide the additional fiber optic cable needed to perform the splice. Accurate slack loop lengths can be obtained by using the sequential markings on the FOC sheath, as shown in Figure 5.24 on the following page.

Figure 5.24: FOC Sheath Sequential Markings

5.5.1-5 Cable Identification – Cable tags, as shown in Figure 5.25, are required in accordance with CFX Technical Specification 633-3.1.1. Cable tags shall be within 1 foot of each splice and/or termination point indicating the cable type, fiber count, and each fiber optic cable origination and termination points. The cable tags shall be permanent labels suitable for outdoor applications and shall have lettering in permanent ink and display the phrase "CFX FIBER OPTIC CABLE." The cable tag shall also indicate the cable type, fiber count and each fiber optic cable origination and termination points.

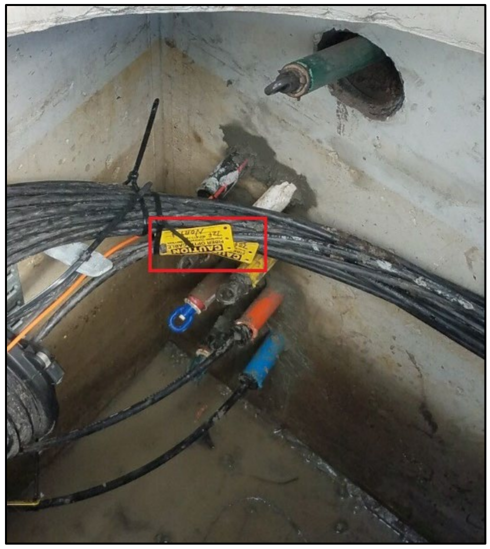

Figure 5.25: FOC Identification Tags

5.5.2 Fusion Splicing – Fusion splicing is the act of joining two optical fibers end-to-end. The goal is to fuse the two fibers in such a way that light passing through the fibers is not scattered or reflected back by the splice, and so that the splice and the region surrounding it are almost as strong as the intact fiber. Fusion splicing is done using a fusion splicer, similar to the one shown in Figure 5.26 below. The basic process for fusion splicing fiber strands is shown in Figure 5.27. When fiber optic cable is spliced or terminated, the buffer is stripped away from that portion of the fiber optic cable, leaving only the core and the cladding.

Figure 5.26: Fiber Optic Fusion Splicer

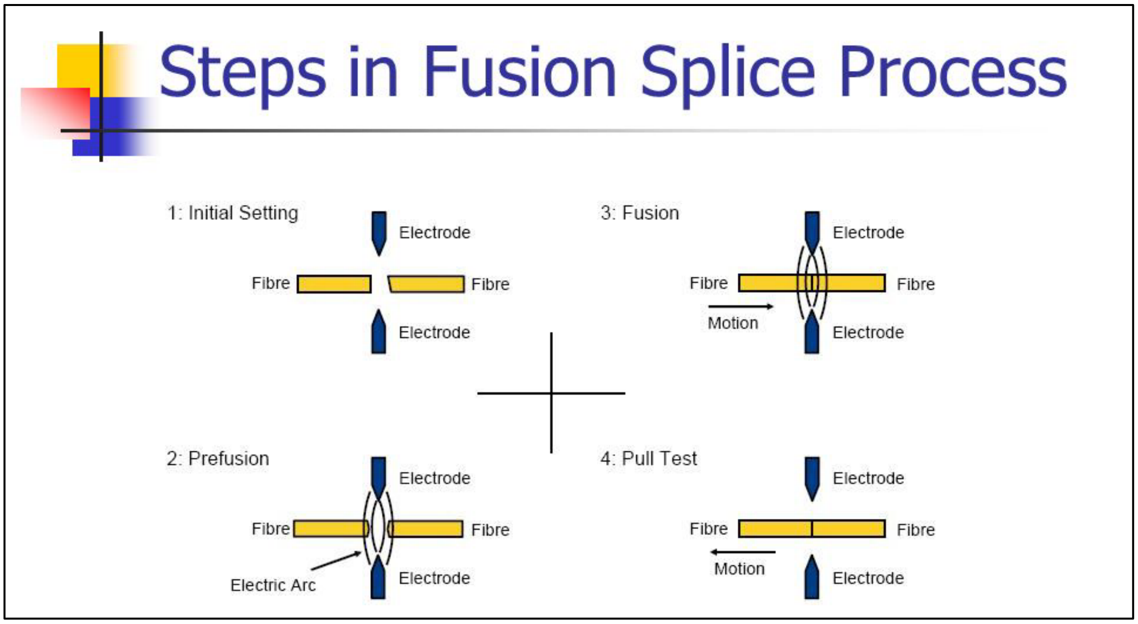

Figure 5.27: Fusion Splice Process

5.5.3 Fiber Optic Patch Panels - Within all local hubs, data centers, and toll plazas, the fiber optic cable is terminated into a fiber optic patch panel. These fiber optic patch panels provide quick and secure access to connect network equipment into the fiber optic network. Patch panels shall be rack-mountable and shall be equipped with the correct size and number of pre-terminated ports, as shown in the project plans. A typical design will provide spare ports or Bulkheads to allow for easy expansion on future projects.

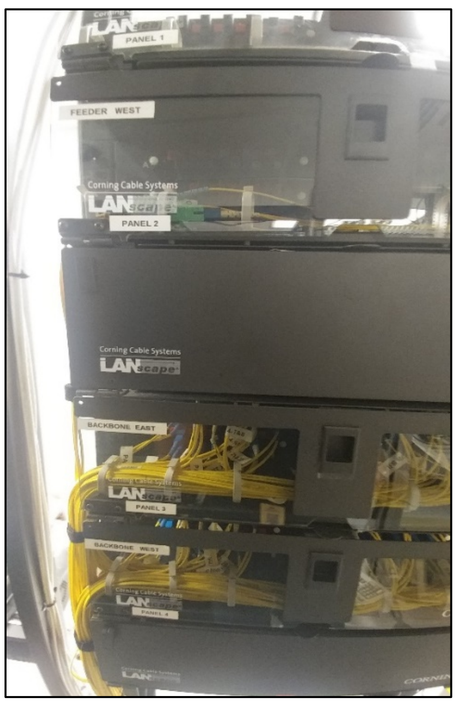

Figure 5.28: Corning Patch Panels

5.5.4 Terminations – FOC terminations occur within a fiber patch panel. Figure 5.29 below shows a typical Corning CCH-01U fiber panel patch panel and associated connector panels. The end of the fiber optic cable being installed will be spliced to pre-terminated pigtails within the patch panel assembly. As an example, If a 12 single-mode fiber optic drop cable is being terminated, fibers 1 thru 12 would be spliced to the connector panel by fiber color in the order shown in Figure 5.30.

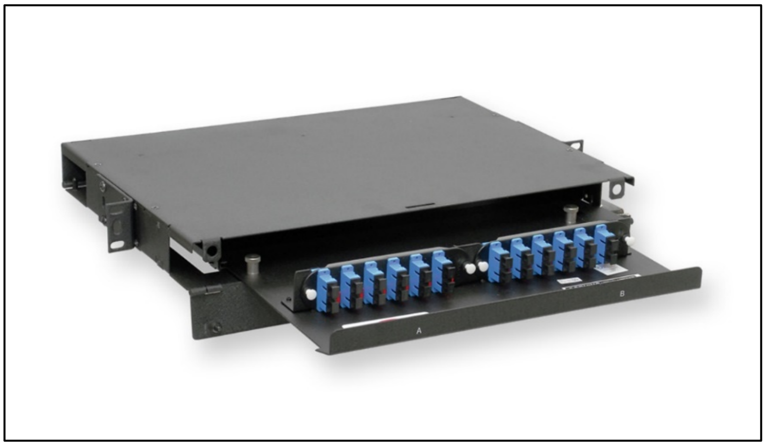

Figure 5.29: Corning CCH-01U Rack Mountable Fiber Patch Panel

Figure 5.30: Fiber 1 thru 12 Termination Order by Color Code

5.5.5 Splice Trays - Splice trays are designed to hold individual or mass fusion spliced fibers. These trays are typically installed within fiber optic enclosures and patch panels. Notice in Figures 5.31 and 5.32, the pictures to the right, how the individual fibers are neatly placed within the splice tray and patch panel with sufficient bend radius as to not excessively bend or break the fibers. Whenever fibers are broken out individually, it is important to dress the cables neatly, to avoid any damage to the fiber, but also so that future maintenance and troubleshooting is easier.

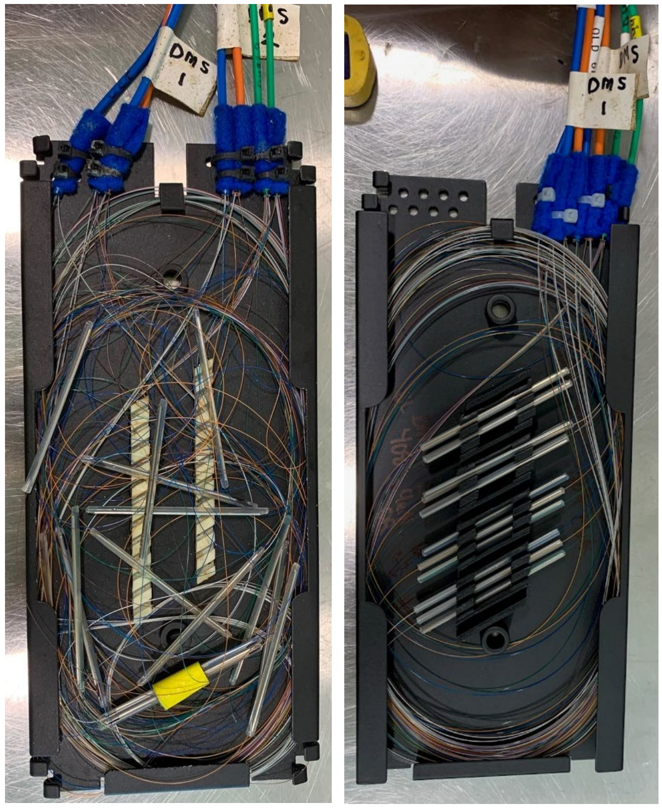

Figure 5.31: Fusion Splice Tray (unacceptable vs acceptable)

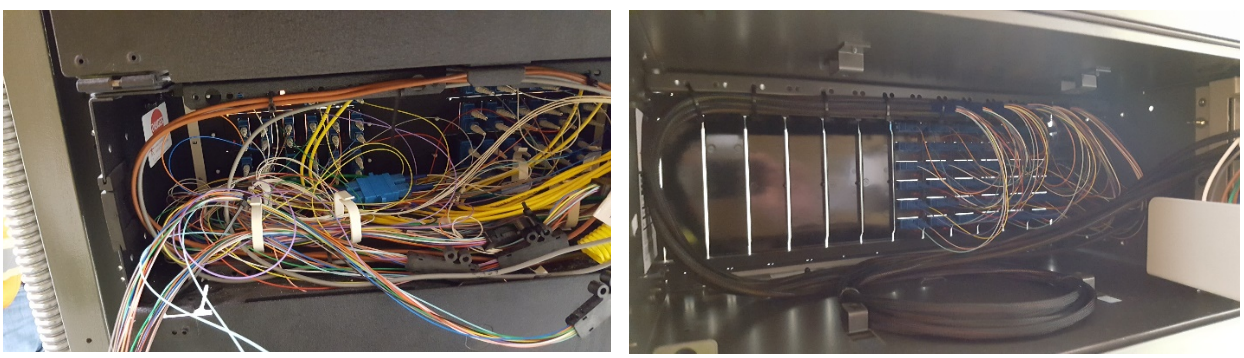

Figure 5.32: Fiber patch panel (unacceptable vs acceptable)

5.5.6 Fiber Optic Splice Enclosures - Wherever a butt-splice (full end-to-end splice of fiber optic cables) is required or where a fiber optic drop cable is spliced into the feeder cable (mid-span splice), a fiber optic splice enclosure is used to house the fusion splices. These enclosures are stored within manholes, or fiber optic pull boxes throughout the system and are watertight.

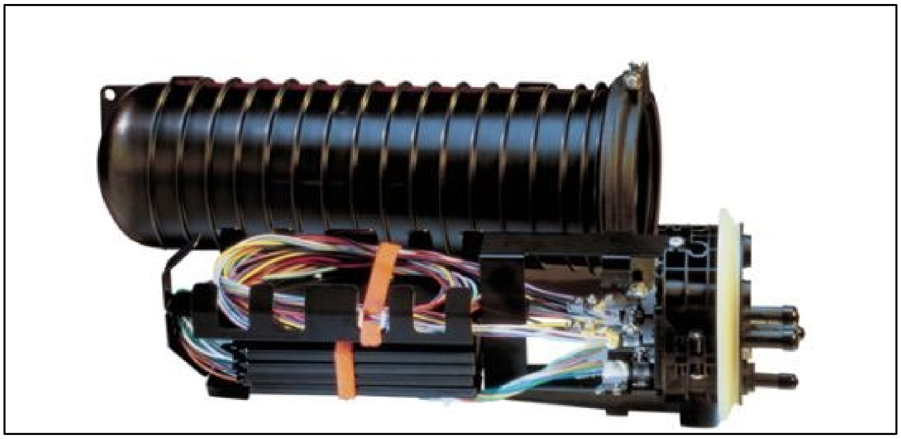

Figure 5.33: Corning Splice Enclosure

5.5.7 Fiber Optic Jumper Cables - Within all of the fiber optic patch panels, there will be fiber optic patch cables, often referred to as jumpers. Fiber optic patch cords are used to connect multiple patch panel ports for passing through, or "jumpering", the fiber optic signal directly through the patch panel or as connections to and from network switches or optical devices.

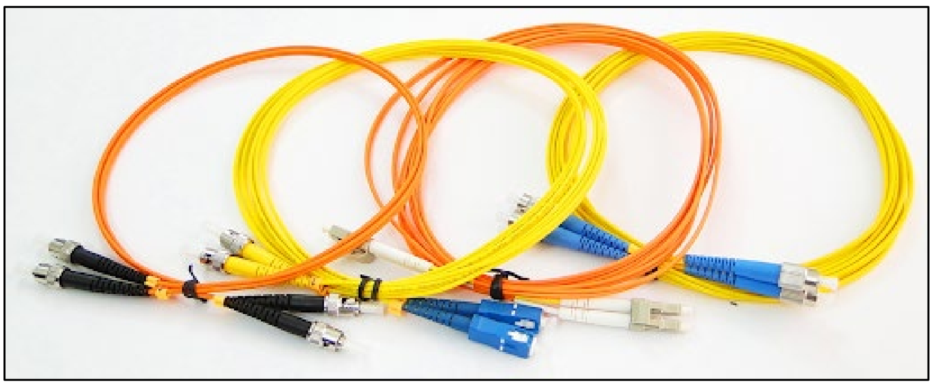

Figure 5.34: Corning Patch Cords

5.6 Fiber Optic Backbone, Feeder and Translateral Cables

CFX utilizes several different types of large-scale fiber optic cables for transmitting data between toll plazas, ITS devices, and data centers. These cables provide a high-level of redundancy throughout CFX's system and are installed beneath the ground and or asphalt paved surfaces – which offers an additional layer of protection to potential cable damage.

5.6.1 Fiber Optic Backbone Cable - The fiber optic backbone cable is a 72sm count cable and is installed within the Orange 1" conduit throughout the entire CFX system as well as both sides of the roadway. This cable is stored in intermediate manholes strategically spaced throughout the system and is used for transmitting data from the toll plazas back to the data centers as well as for creating a network ring between core network switches on the network to provide an additional layer of redundancy for data.

5.6.2 Fiber Optic Feeder Cable - The fiber optic feeder cable is a 72sm count cable installed within the Blue 1" conduit throughout the entire CFX system as well as both sides of the roadway. This cable is stored in intermediate manholes strategically spaced throughout the system and is used for transmitting data from the ITS devices back to the data centers.

5.6.3 Translateral Fiber Optic Cable - The fiber optic translateral cable is a 144sm count cable and is installed within the Orange 1” conduit at major crossings throughout the CFX system. This cable is stored in intermediate manholes strategically spaced throughout the system and is used to create a network ring between core switches for fiber optic cables on both sides of the roadway.

5.6.4 Fiber Optic Drop Cables - Fiber optic drop cables are used to connect the device locations to the fiber optic backbone. These drop cables typically consist of 12sm fiber optic strands and allow device connectivity back to the Backbone fiber. Fiber optic drop cables are typically installed by hand. Care should be taken to ensure that the drop cables are not damaged during installation. Sharp bends that exceed the cable bending radius can damage the buffer tubes and fiber optic strands within.

5.7 Optical Time-Domain Reflectometer (OTDR)

The (OTDR) is an important instrument used to certify the performance of fiber-optic links and detect problems with existing fiber links from end to end. The OTDR trace is a graphical signature of a fiber's attenuation along its length. The trace provides insight into the performance of the link and its components (cable, connectors and splices) while examining non-uniformities and characterizing individual events that can often be invisible when conducting only loss/length (tier 1) testing. An OTDR is shown in Figure 5.35. Fiber optic testing requirements are detailed within CFX Specification 633-3. Please note that tests need to be conducted at both 1310nm and 1550nm wavelengths.

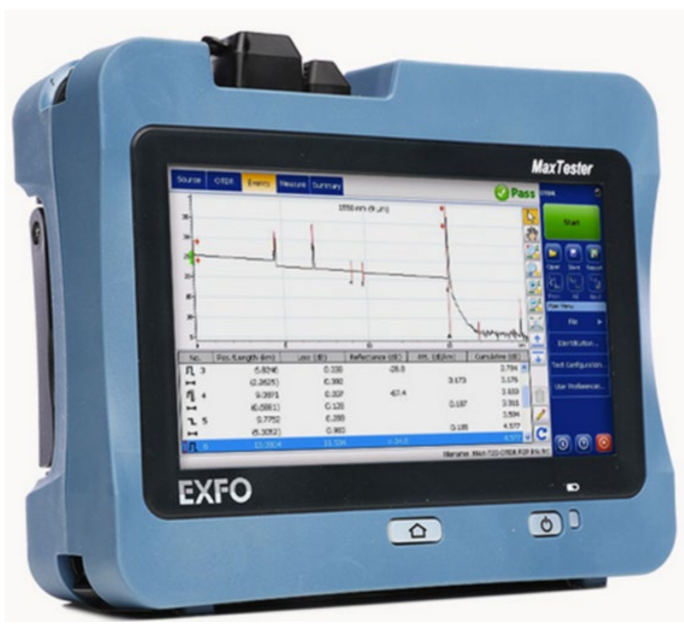

Figure 5.35: EXFO Brand OTDR with OTDR trace shown

5.8 Pre-Installation Testing

The contractor is to provide factory OTDR reel testing on all new cables, verifying that the cable meets project specifications. The contractor is also required to provide an OTDR reel test, which is performed again in the field prior to installation. These two tests are to be compared for variances caused by damage in shipping or transport to the field. A separate report is to be provided per cable size and for each reel. This report certifies that the fiber optic cable is in good working condition before installation.

5.9 Post-Installation Testing

Perform bi-directional testing of all fiber optic cables post-installation; this is to ensure that the cable has not been damaged during installation and that all fusion splices and terminations meet the required specifications. Launch and tail cords are to be used with OTDRs when the attenuation of the “Cabling under Test,” connector “A,” and connector “B” must be measured. A proper bi-directional test requires that only the OTDR be moved to the far end of the tail cord. The launch cord and tail cord should never be removed from the cabling under test. Only the OTDR is moved during bi-directional testing, as shown in Figure 5.36 below.

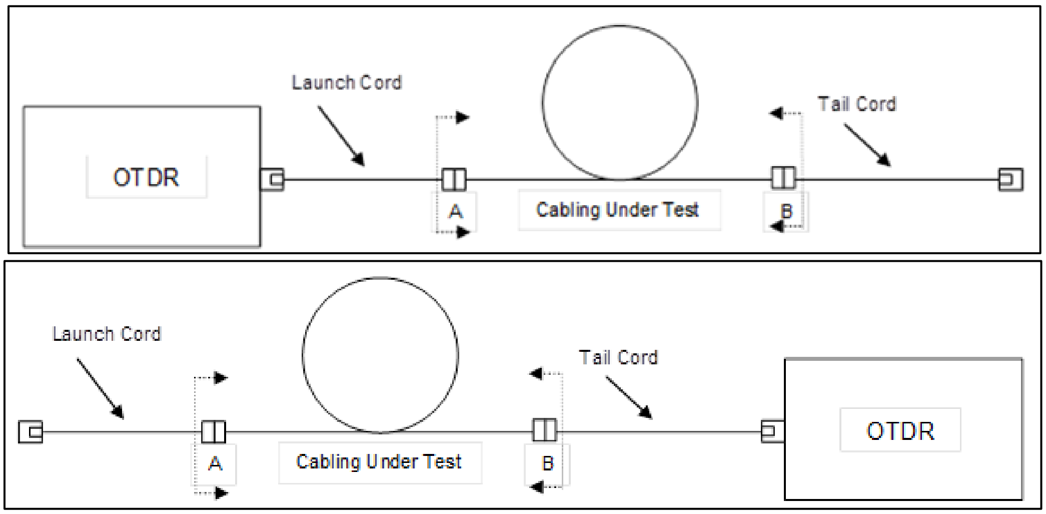

Figure 5.36: Measurement for a bi-directional OTDR test

5.10 Pre-Activity Considerations

Below are items that need to be considered and discussed with the Contractor, as applicable, before the Contractor performs the installation of Fiber-optic cable on CFX’s system.

1) **Conduit path -** Review the conduit path shown in the approved construction plans, ensure conduit and inner-duct is clean, and free from damage prior to installing fiber optic cable. The CEI shall coordinate the review of CFX's FON GIS database to verify there are no discrepancies between the approved construction plans and existing conditions reviewed in the field. Review the route with the Contractor to ensure you are both on the same page.

2) **Reel test** - Prior to the installation, the Contractor shall first perform on-site on-the-reel OTDR testing at 1310nm and 1550nm to demonstrate continuity and measure the attenuation. The Contractor shall test all fibers on each reel of cable. On-the-reel testing shall be done in one direction only. The resultant OTDR trace(s) shall reflect the overall length and attenuation expressed in dB/km. The results of the on-site tests and the manufacturers on the reel tests that were performed at the factory shall be compared. If the on-site test results are not within ±3.0% of factory data, then the reel shall be rejected. The Contractor shall supply hard copy and disk-based (with applicable software) OTDR traces of the testing to CFX for approval prior to the installation of cables.

3) **Blowing -** Review CFX standard 633-3.1.3 Blowing: with the Contractor. Blowing uses either the high airspeed blowing (HASB) method or the piston method. When using either method, ensure that the volume of air passing through the conduit does not exceed the conduit manufacturer’s recommended air volume.

4) **Pulling** -Review CFX standard 633-3.1.2 Pulling: with the Contractor. If a mechanical pulling machine is used, verify the machine is equipped with a monitored or recording tension meter. Ensure that at no time, the

manufacturer's recommended maximum pulling tension is exceeded. Ensure that the central strength member and aramid yarn are attached directly to the pulling eye during cable pulling. Ensure that the optical and mechanical characteristics are not degraded during the fiber optic cable installation. Ensure that excess cable is coiled in a figure eight and fed manually when pulling through pull boxes and splice boxes by hand. If pulleys and sheaves will be used to mechanically pull through pull boxes and splice boxes, submit a drawing of the proposed layout showing that the cable will never be pulled through a radius less than the manufacturer's minimum bend radius.

5) **Withdrawing -** Review CFX 633-3.1.4 Withdrawing: with the Contractor. The Contractor shall withdraw the fiber optic cable by hand. A pull box or manhole may not be skipped as a pulling point. The Contractor shall lay the cable in a figure-eight formation at each manhole or pull box. The contractor shall not leave the coiled cable outside of the conduit system overnight.

Prior to withdrawing existing cable for re-installation, the Contractor shall first coordinate a scheduled downtime with CFX to perform withdrawing and re-installation of any FOC. Prior to withdrawing existing cable for re-installation, the Contractor shall first perform OTDR testing at 1310nm and 1550nm to demonstrate continuity and measure the attenuation. After re-installation of the cable, the contractor shall perform the same OTDR tests on the cable and provide the results to CFX in a hard copy and disk-based format. CFX representatives will then compare the test results, and if the test results are not within ±3.0% of the original tests, then the cable shall be deemed damaged and shall be replaced at the contractor's expense.

6) **Footage Documentation -** The Contractor shall document the sequential cable length markings at each splice box and pull box wall that the cable passes through and include the information with the as-built documentation.

7) **Cable Identification** - Develop a nomenclature plan for the identification of fiber optic cable. Submit the nomenclature plan to the Engineer for approval. Use approved cable nomenclature to create cable tags for the identification of fiber optic cable. Provide cable tag identification on all test results or fiber-related documents submitted to the Engineer. Install cable tags within 1 foot of each splice and termination point, indicating the cable type, fiber count, and each fiber optic cable origination and termination points. Ensure that the cable tags are permanent labels suitable for outside plant applications and are affixed to all fiber optic cables. Ensure that lettering is in permanent ink and displays the phrase "CFX FIBER OPTIC CABLE."

8) **Testing -** Review CFX-633-3 Testing Requirements with the Contractor Prior to beginning any formal testing or using an Optical Time Domain Reflectometer (OTDR). The Contractor shall certify that each tester has received complete training in the proper use of the OTDR by a factory representative from the OTDR manufacturer.

9) **Testing Equipment Certification Requirements -** All Optical Time Domain Reflectometers (OTDR) shall have a current notarized certificate of accuracy and calibration, including the model type and serial number of the device stated on the certification. Current is defined as not exceeding one (1) year since calibration.