FOA Standard For
Installing Fiber Optic Cable Plants

Guidelines For The Construction And Installation Of Fiber Optic Cable Plants

The Fiber Optic Association Inc.
The Professional Association Of Fiber Optics
www.foa.org

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About The FOA

The Fiber Optic Association, Inc. (FOA) was founded in 1995 to help develop the workforce to build the fiber optic networks to support a rapid expansion in communications and the Internet. The charter of the FOA was to promote professionalism in fiber optics through education, certification, and standards. Today the FOA is the international professional association for fiber optics and the most widely recognized certifying body for fiber optic technicians.

Today the FOA provides the world with sources of technically correct unbiased information on fiber optics in both print and online media. The FOA has published more than a dozen textbooks on fiber optics in multiple languages. The FOA Online Reference Guide is the largest and most used reference site on fiber optics on the Internet. FOA also offers Fiber U, a free online leaning site with dozens of self-study programs.

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1. Introduction

1.1. Foreword

Every fiber optic cable installation project is unique. The cable plant, routing, environment, components, communications systems and installation processes are all unique. This uniqueness makes creating a universal installation standard challenging. This document is intended to focus on the processes involved in a fiber optic project and to provide guidance on the design and installation of the project. The personnel involved in the project should be trained and experienced and able to use their judgement to properly complete the project.

This standard can be used as a reference for the installation of the cable plant. The following language is recommended for use in project documents: *Fiber optic cables shall be installed in accordance with the FOA Standard for Installing Fiber Optic Cable Plants*.

1.2. Open Source

This is an "open source" document. It was created by a team of FOA technical advisors and instructors based on their extensive knowledge and experience in fiber optics. It is made publicly available for anyone's use, including reading it, sharing it and modifying it to fit their project needs. Use of this standard is voluntary; users may edit it to use sections and modify those sections appropriately for their project.

Like many standards, FOA's Standards are only guidelines for project management, design, installation and testing of fiber optic networks. The network owner, project manager, contractor, designer or installer are always responsible for the work involved. The Fiber Optic Association does not assume any obligation or liability to users of this publication. Existence of a standard shall not preclude anyone from specifying or using alternate construction methods permitted by applicable regulations or provided by component or equipment suppliers.

While the document is copyrighted by the FOA, users are only expected to give credit to FOA for their use of it. Do not post this document on your own website without FOA permission, but you are free to link to this page.

Suggestions for revisions and improvements to this standard are welcome. They should be addressed to the FOA.

1.3. Scope

This standard describes procedures for installing and testing cabling networks that use fiber optic cables and related components to carry signals for communications, security, control and similar purposes. This standard covers fiber optic cabling installed for communications networks, both indoor (premises installation) and outdoor (outside plant - OSP installation) applications.

1.4. Workforce

The quality of a fiber optic project depends on the workforce involved in planning, designing, installing, and operating it. Proper planning and design of a fiber optic network is essential to the success of any project; if the project is not planned and designed properly from the beginning it will not meet communications needs today or in the future. The competence of installers is obvious as poor workmanship in installation will result in poor cable plant performance and reliability.

Everyone working on a fiber optic project should have the knowledge, skills, and abilities (KSAs) appropriate for their participation in the project. How do you evaluate the workforce? Training, certification, and field experience are the indications of competence.

Many regulating agencies for fiber optic projects require the workforce have an industry recognized certification like those offered by the Fiber Optic Association, trade schools and/or manufacturers of products being used in the project.

Every project should have workforce requirements included in the Scope of Work (SOW), Requests for Proposals (RFP), Requests for Bids (RFB) and contracts. Requirements should not just apply to contractors, but also to anyone working for their subcontractors or sub-subcontractors.

Only qualified persons familiar with the design, installation and testing of fiber optic cabling should perform the work described in this publication. Installation technicians should be trained and certified by recognized certifying bodies like the Fiber Optic Association.

Project documentation should state:
All personnel involved in planning, designing, installing, testing, operating, or managing the project should have appropriate:

- *Training*
- *Certifications, e.g. FOA CFOT*
- *Experience*
- *References*

1.5. Regulatory and Other Requirements

This publication is intended to comply with relevant international standards. It is the responsibility of users of this publication to comply with state and local codes, occupational safety regulations (OSHA or equivalent) as well as follow manufacturer's installation instructions when installing components and systems.

Since codes and standards are continually being revised, one should refer to the latest *version of any relevant standard. Codes are generally created and enforced by local governments.*

1.6. About The FOA

The FOA is an international non-profit educational association chartered to promote professionalism in fiber optics through education, certification and standards. FOA is the most widely recognized certifying body for fiber optic technicians worldwide and has certified over 100,000 fiber optic technicians. FOA has more than a quarter-century of experience in developing the fiber optic workforce around the world.

The FOA was founded in 1995 by a dozen prominent fiber optics trainers and leaders from the fiber optic industry, education and government as a professional organization for fiber optics with the goal to build a competent workforce needed by the fiber optic industry. The FOA was also created as a source of independent certification to be used by the industry. The FOA has grown to now being involved in numerous activities to educate the world about fiber optics and certify the workers who design, build and operate the world's fiber optic networks.

The FOA maintains an extensive technical reference web site on fiber optics relevant to the processes covered in this standard. This website covers topics related to fiber optic technology, components, installation, testing, troubleshooting and standards in depth. Visit http://foa.org/guide for more complete information.

2. Definitions, Abbreviations, and Acronyms

Attenuation Coefficient The *optical* loss of fiber per unit length, expressed in db/km at a specific wavelength.

Backscattering The scattering of light in a fiber back toward the source, used to make OTDR (Optical Time Domain Reflectometer) measurements.

Bandwidth The range of signal frequencies or bit rates within which a fiber optic component, link or network will operate.

Bend Radius or Diameter The minimum radius or diameter a fiber optic cable should be bent to prevent damage.

Bending or Microbending Loss Loss in fiber caused by stress on the fiber bent around a restrictive radius.

Bend-Insensitive fiber Fiber designed and manufactured to withstand a much smaller bend radius or diameter than regular fiber without excess loss or damage. Practically all multimode fiber is bend insensitive. Much of singlemode fiber is now bend insensitive to allow more rugged cables and smaller cables with high fiber density – microcables or high fiber count cables.

Blowing Cable A technique for installing fiber optic cables using high pressure air or gas to reduce friction and allow the cable to be pushed into the duct. Jetting cable is a similar process using a device attached to the cable to assist in pulling.

Buffer A protective plastic coating applied directly to the optical fiber during manufacture. Also called *primary coating or primary buffer coating.*

Cable One or more fibers enclosed in protective coverings and strength members.

Cable Plant The combination of fiber optic cable sections, splices, connections and hardware forming the optical path between two terminal devices.

Cladding The lower refractive index optical coating over the core of the fiber that confines light in the core.

Cleave To precisely scribe and break an optical fiber to prepare it for splicing or termination.

Connector A device that provides a demountable connection between two fibers or a fiber and an active device.

Core The center of the optical fiber through which light is transmitted.

Decibel (dB) A unit of measurement of optical power that indicates relative power on a logarithmic scale. dB = 10 log (power ratio).

Dispersion The spreading of a pulse in an optical waveguide that affects bandwidth. May be caused by modal, chromatic or polarization effects.

End Finish The quality of the end surface of a fiber prepared for splicing or terminated in a connector, tested by visual inspection in a microscope.

Ferrule A precision part, generally a cylinder, which holds a fiber in alignment for connection or termination. A ferrule may be part of a connector or mechanical splice.

Fiber Optics Light transmission through flexible transmissive fibers for communications.

Fiber To The Home (FTTH) Connecting subscribers to the network for phone, video and Internet or over fiber optics.

Fresnel Reflection Light reflected from the cleaved or polished end of a fiber caused by the difference of refractive indices of air and glass. Also called *Reflectance or Optical Return Loss*.

Fusion Splice A permanent joint between two fibers created by heating the fibers and fusing the joint.

Fusion Splicer A precision instrument that joins two fibers together by melting and fusing them.

Graded Index Fiber A type of multimode fiber, which uses a graded profile of refractive index in the core material to minimize modal dispersion.

High Fiber Count Cable A cable with a large number of fibers densely packed into a relatively small cable, generally 864 fibers to 6912 fibers.

Hybrid Cable An optical cable containing both singlemode and multimode fibers or fibers and electrical conductors.

Index Matching Fluid or Gel A fluid or gel with a refractive index similar to that of the fibers to reduce loss and reflectance at a joint.

Insertion Loss The loss caused by the insertion of a joint such as a splice or connector in an optical fiber. Also refers to the measurement of the loss of a cable or cable plant when tested with an optical loss test set.

Jacket The protective outer layers of the cable.

Launch Cable A high quality fiber optic reference jumper cable used for testing loss with an optical loss test set or OTDR. See also Reference Test Cable

Link, **Fiber Optic** A combination of transmitter, receiver and fiber optic cable capable of transmitting data. Also referred to as a datalink

Local Area Network A premises network use to connect computers and wireless access points into an organizations server(s).

Loss Budget The estimated amount of power lost in the link calculated from the cable plant design.

Loss Margin The additional amount of loss that can be tolerated in a link. The difference between the loss acceptable to the networking equipment and the actual loss of the link.

Mechanical Splice A joint between two fibers made with a mechanical alignment device that contains index matching gel or adhesive.

Microscope, Fiber Optic Inspection A microscope used to inspect the end surface of a connector for flaws or contamination or the end of a fiber for cleave quality.

Microcable A small fiber cable designed to be installed by blowing into small plastic ducts (microducts).

Microduct Small fiber optic ducts designed to fit into small spaces for the installation of microcables by blowing in the cable.

Multimode Fiber A fiber with core diameter much larger than the wavelength of light transmitted. It allows many modes (rays) of light to propagate.

Optical Fiber An optical waveguide comprised of a light carrying core, surrounding cladding that traps light in the core and the primary coating.

Optical LAN (OLAN) LAN architecture based on FTTH passive optical network (PON) systems.

Optical Loss The amount of optical power lost as light is transmitted through fiber, splices, couplers, etc.

Optical Loss Test Set (OLTS) Tester comprised of fiber optic power meter and test source used to test the loss of components or cable plants. It may be two instruments or a combination of the two in one package. It is also called a LSPM for light source and power meter.

Optical Power The amount of radiant energy per unit time, expressed in linear units or watts or on a logarithmic scale in dBm (where dB=10 log (power/1 mW), 0 dB = 1 mw).

Optical Time Domain Reflectometer (OTDR) An instrument that uses backscattered light to find faults in optical fiber and to infer loss for link testing and troubleshooting.

Passive Optical Network A network used for Fiber to the Home (FTTH) or Passive Optical LAN using optical splitters to allow bidirectional communications over a single fiber shared by multiple users.

Passive Optical LAN (POL) A LAN based on FTTH passive optical network (PON) systems

Pigtail A length of fiber with a fiber optic component such as a connector, laser or coupler on one end and a bare fiber on the other end. Pigtails with connectors can be spliced onto cables as an alternative to direct termination.

Power Budget For network equipment, the difference (in dB) between the transmitted optical power (in dBm) and the receiver sensitivity (in dBm), used to determine the amount of cable plant loss that can be tolerated by the equipment.

Power Meter, Fiber Optic An instrument that measures optical power emitted from the end of a fiber, calibrated in dB at wavelengths typically used in fiber optics, 850nm, 1300nm and 1550nm..

Receive Cable A short single fiber jumper cable with connectors on both ends used for testing. See also Reference Test Cable.

Reference Test Cable A short single fiber jumper cable used for testing. The fiber type and connectors must match the cables to be tested.

Singlemode Fiber A fiber with a small core that only allows one mode of light to propagate.

Splice A joint or permanent connection between two fibers. See Fusion Splice and Mechanical Splice.

Splice-On Connector (SOC) A factory made fiber optic connector with a short fiber stub made to splice onto a fiber for termination.

Step Index Fiber A multimode fiber where the core is composed of a material with a constant index of refraction. Step index fiber is generally plastic optical fiber (POF) or plastic-coated silica fiber (PCS.)

Termination Preparation of the end of a fiber to allow non-permanent joining to another fiber or an active device, sometimes called connectorization.

Test Source A laser diode or LED used to inject an optical signal into fiber for testing loss of the fiber or other components.

Visual Fault Locator A device that couples high power visible red light from a laser into the fiber to allow tracing fibers or testing continuity and finding breaks or stress loss.

Wavelength A measure of the color of light, usually expressed in nanometers (nm) or microns (µm).

Wavelength Division Multiplexing (WDM) **T**ransmitting signals of different wavelengths of light through a fiber simultaneously.

Working Margin The difference (in dB) between the power budget and the loss budget Also called excess power margin.

Abbreviations And Acronyms

ADSS – all-dielectric self-supporting aerial cable

dBm optical power in decibels referenced to 1 milliwatt

dB optical power in decibels referenced to an arbitrary reference, used for testing loss.

OLTS optical loss test set

OTDR optical time domain reflectometer

PON passive optical network

POL passive optical LAN

SOC splice-on connector

3. Fiber Optic Installation Safety

3.1. General

Safety is most important in fiber optic installation. All employees must be trained in safety procedures, not only those unique to fiber optics, but general safety issues common to all construction. Safety rules should be given to all workers and posted on work sites.

Safety in fiber optic installation involves many of the same issues as installing any other cable, whether the cable plant is installed outdoors underground or aerial or indoors. This includes safety climbing ladders or poles, working with the equipment and processes used in outside plant installations which involve underground and aerial cables and working in areas with hazards typical of construction sites. Outdoor installations require control of traffic in the vicinity of the construction or installation.

Underground construction requires careful attention to other buried utilities that may be harmed by trenching or directional boring. Preparation for all underground projects should include checking with the local authorities or through services such as "Call

Before You Dig - Call 811" or the local authority.

Aerial construction should follow good practices for safety with respect to traffic, areas below the cable installation and worker safety.

Safety issues unique to fiber optic installations specifically includes avoiding exposure of the eyes to light radiation carried in the fiber; proper disposal of fiber scraps produced in cable handling and termination; and safe handling of hazardous chemicals used in termination, splicing or cleaning.

While fiber optic cables generally are all dielectric and carry no electrical power, it may be necessary to work in areas that have installed electrical power cables and hardware. Care should be taken to avoid these cables or have the power disconnected for the duration of the installation.

The following are examples of safety precautions that should be followed during fiber optic cable installations. This is not a comprehensive list of OSHA regulations governing fiber optic installations.

3.2. Eye Protection

a. Always wear safety glasses with side shields. Always ensure that safety eyewear complies with relevant requirements including OSHA.
b. After handling fiber, wash hands thoroughly before engaging in any other activities, especially touching eyes or contact lenses.
c. Never look directly into the end of any optical fiber unless you are certain that no light is present in the fiber. The light used for signal transmission in fiber optics is generally invisible to the human eye but may operate at power levels that can be harmful to the eye. Inspection microscopes can concentrate the light in the fiber and increase the danger. Use an optical power meter to verify that no light is present in the fiber. Some mobile phone cameras are sensitive in the infrared and may be used to detect light in optical fibers.
d. When using an optical tracer or continuity checker, look at the fiber from an angle at least 300 mm (12 in.) away from the eye to determine if the visible light is present.

3.3. Protection from Fiber Scraps

a. Fiber splicing and termination processes produce small scraps of glass fibers, also called fiber shards, that can be hazardous and must be disposed of properly.
b. A black mat on the work area makes seeing the fibers and the fiber scraps easier.
c. Do not allow eating, drinking or smoking near the working area. Fiber particles can be harmful if ingested.
d. Small scraps of bare fiber produced as part of the termination and splicing process must be disposed of properly in a safe container marked for fiber scraps. Some technicians prefer to stick fiber scraps to double-sided adhesive tape on the work surface, but that is not recommended since requires additional caution to avoid on the work area.
e. According to local regulations, fiber scraps or the disposal containers may be considered hazardous waste and must be disposed of properly.
f. Do not drop fiber scraps on the floor where they will stick in carpets or shoes and be carried elsewhere.
g. Thoroughly clean the work area when finished. Do not use compressed air to clean off the work area. Sweep all scraps into a disposal container.
h. Wash hands well after working with fibers.
i. Carefully inspect clothing for fiber scraps when finished working with fiber.

Protection from fluids

a. Avoid skin contact with any fluids, for cleaning fiber or cables.
b. Do not inhale the vapors from fluids, if you can smell it you are inhaling it.

3.4. Underground Utility Location During Construction

It is the responsibility of the contractor/installer to confirm the location of all

underground utilities before beginning digging. Digging, microtrenching or directional boring can be dangerous to the workers, the neighborhood, and the local infrastructure. Underground utilities include electrical and gas lines that can be extremely dangerous if damaged. Water mains can flood neighborhoods.
Call before you dig: Even if the contractor has received information from the local authorities, it is their responsibility to confirm that information and, since that data may be incomplete or out of date, confirm the location of utilities using proper location instruments.

3.5. Other Safety Issues

a. Work only in well-ventilated areas. Confined spaces, such as equipment vaults, manholes can contain toxic or explosive gases or insufficient air to sustain life.
b. Materials and chemicals used in installation processes may be hazardous. Request Material safety Data Sheets (MSDS) on all chemicals used.
c. Fusion splicers create an electric arc. Ensure that no flammable vapors and/or liquids are present. Do not use in confined spaces.

4. Cleanliness

The small size of optical fibers makes them very sensitive to dust and dirt. Maintain the highest standards of cleanliness when working with fiber to optimize its performance.

4.1. Work Rules For Cleanliness

a) Work in clean areas. If the area is dusty, working in a splicing trailer or tent with filtered air may be necessary.
b) Always keep protective caps on connectors, mating adapters, patch panels, test equipment and network equipment. These caps are often called "dust caps," but they often contain dust or fluids which can contaminate connectors. After removal of the protective cap, a connector should inspected and cleaned before connecting to another connector or equipment port.
c) Do not touch the ends of the connectors.
d) Use special cleaning tools and liquids made for cleaning optical fiber connectors. Other solvents can attack adhesives or leave a residue. Cotton swabs or pads may leave threads on surfaces and are not recommended.
e) Use dry-cleaning swabs designed for mating adapters or equipment ports. Compressed air often contains oils and “canned air” contains propellants that can contaminate the parts.
f) Test equipment fiber inputs/outputs and test cables should be cleaned periodically.
g) Test cable connectors should be inspected and cleaned along with the connectors they are testing, preferably every time they are connected.

5. Fiber Optic Cable Plant Topologies

Fiber optic cabling is being used for virtually every communications network. It is used indoors for computer networks (LANs), data centers, closed circuit TV (video), voice links (telephone, intercom, audio) including wireless and first responder networks, building management, security or fire alarm systems, or any other communications link. Outdoors, fiber is used for telecommunications and the Internet, wireless networks (cellular and WiFi), CATV, utility grid management, security systems, intelligent traffic control systems and many, many more applications.

5.1. Outside Plant

Outside plant (OSP) fiber optic cable installations are typically point-to-point links with two fibers used for full duplex communications. Cables are spliced where needed for long continuous links and terminated inside buildings or other structures housing the communications equipment, repeaters and intermediate connections. Fiber to the home (FTTH) networks use passive optical splitters to connect multiple users over a single fiber with signals transmitted bidirectionally over the one fiber.

OSP cables may be installed by direct burial underground, pulled or blown into underground ducts or conduit or mounted on poles in aerial installations. In some instances, fiber optic cable may even be laid underwater to cross rivers, lakes or oceans.

Outside plant cables often span distances longer than the limits of manufactured cables (5-15 km typically), Deploying cables of lengths >5km can be difficult, so cables may need to be spliced to produce a continuous fiber cable for longer distances. Cables are also spliced to split a cable into two or more cables to provide intermediate drops or splits. Splicing is generally done with fusion splicing, a highly automated process. Splice closures may be mounted on the messenger wire or poles for aerial cables and in pedestals, manholes or handholes for underground cables.

5.2. Premises Cabling

In premises applications, fiber optic cables can be used as the backbone cabling in a traditional structured cabling star network, connecting network hardware in the computer room/main cross connect to local network hardware in a telecom closet. Centralized fiber architecture bypasses the telecom closet and connects fiber straight to the desktop. Passive optical networks (PONs) based on fiber to the home (FTTH) networks may also be used for premises cabling.

In traditional structured cabling architecture, the connection from the computer room to telecom closet is made with optical fiber, replacing a UTP backbone and providing greater bandwidth and longer distances. Multimode fiber has been used in this architecture in the past, but singlemode fiber is becoming more widely used for its greater capacity for future upgrades.

In a centralized fiber optic network, cables go directly from the computer room to the work area with only passive optical connections in the links. Backbone cables typically contain larger numbers of fibers than horizontal fiber optic cables and may contain singlemode fibers as well as multimode fibers. Conversion from optical to electrical signals is done at the desktop to allow devices like computers or wireless access points to connect using UTP cables. Again multimode fiber is primarily used in this architecture.

Premises fiber optic networks may also use the same network architecture used for fiber to the home (FTTH) called a passive optical network (PON). These networks use an optical splitter instead of an electrical switch to share a single fiber with 32 or more users. These networks are called passive OLANs (optical LANs) or POLs (passive optical LANs.) Each user is connected by one singlemode fiber that transmits signals bi-directionally. The architecture of an OLAN is similar to centralized fiber, but the fiber used is all singlemode and splitters are strategically placed in the building.

Premises fiber optic cables are generally short enough to run continuous lengths from point to point and are terminated at the ends. Splicing is not generally required unless it is used for termination with splice-on connectors. Cables may be placed in splice trays, conduits or other appropriate hangers. Termination is typically in patch panels, rack or wall mounted, and equipment connected with patchcords.

6. Fiber Optic Cable Plant Components

6.1. Fiber Optic Cables

The type of fiber optic cable and the fibers in the cable should be chosen appropriate for the type of communications system(s) being supported, the type of installation and the environment in which the cable is installed. The methods for installation may depend on the type of cable chosen.

6.2. Cable Types

Choose the proper type of fiber optic cable for the installation. An outside plant cable installation may require several different types of cables depending on the method of installation and the route of the cable plant, e.g. where some cables are installed underground, some aerial, and some underwater.

The role of the fiber optic cable is protection for the fibers during installation and during its lifetime in the environment where they are installed. Fiber optic cables are available in many types and styles depending on the installation method and the environmental exposure. Outdoor cables must be designed to be rugged and resist the environment. Indoor cables must be designed for flame retardance.

6.3. Cable Markings

For identification and installation, cables are marked by the manufacturer on the jacket with relevant information.
That information should include:

- manufacturer’s part number
- the number of fibers in the cable

- the type of fiber(s) (singlemode or multimode with core size
- measurement of the cable length, repeated periodically
- flammability rating for premises cables

In addition, the markings may include

- color coded jacket for premises cables
- cable diameter and/or minimum bend diameter (radius)
- maximum pulling tension

6.4. Cables by Fiber Types

Fiber optic cables may contain multimode optical fibers, singlemode fibers or a combination of the two, in which case it is generally referred to as a “hybrid” cable. Multimode fibers are generally used only for short premises cabling networks. Fibers are generally 50/125 laser-optimized (OM3. OM4 and OM5) fiber but may be 50/125 (OM2) fiber or 62.5/125 micron (OM1) fiber which is considered obsolete but still used in legacy networks.

Singlemode fibers are used for all outside plant networks and many premises networks. Most networks use G.652 type fiber. G.657 fiber is a type which is bend-insensitive, but much of regular G.652 fiber is now similar to G.657.A1 fiber in bend insensitivity. Specialty singlemode fibers can be uses in some long links or those using wavelength division multiplexing and fiber amplifiers as repeaters. Premises networks standards call for OS1 and OS2 (low water peak) singlemode fiber, designations for G.652 fiber types.

Fibers with different core diameters are not compatible and must not be mixed. Connecting 62.5/125 fiber to 50/125 multimode fiber can lead to excess loss of 1-4 dB at connections. Connecting multimode fiber to singlemode fiber may lead to losses of nearly 20 dB at connections. Cable markings, color codes and/or connector types should be chosen to ensure that cable plants including more than one type of fiber are not connected improperly.

The type of fiber optic cable is required to be positively identified by jacket markings and, if hybrid, the type of each fiber, since multimode and singlemode fiber are also terminated in a different manner.

Many fibers used in patchcords, microcables and high fiber count cables are designed to be “bend insensitive” to allow being installed around tight bends or packed more densely into smaller cables without causing stress loss in the fiber. Bend-insensitive fibers are generally compatible with regular fibers. The manufacturer of the fiber or cable should be consulted to determine if there are issues with compatibility with other fibers.

6.5. Fiber Optic Cables by Construction Type

6.6. Premises Cables

Tight Buffered Cables

Tight buffered cables are widely used for patch cords and premises installations in environments considered benign and protected. These cables incorporate fibers coated with a 900-micron buffer coating layer, providing protection for the fiber and color-coding for identification. Tight-buffered cables are designed with strength members, such as aramid fiber yarn, surrounding the fibers inside thick jackets in simplex, zip cord and multifiber configurations.

Simplex Cable and Zipcord: Simplex cable and zipcord are used for patchcords and short links. They have a single fiber surrounded by strength members and a jacket. Simplex cables are generally installed to connect other cables in a patch panel or connect a patch panel to communications equipment.

Distribution Cable: Distribution cable includes multiple tight buffered fibers protected by aramid fiber yarn strength members and optionally a central glass fiber stiffener within the cable jacket. Distribution cable is used for premises backbones, horizontal runs or general building cabling. It may be installed in cable trays, under floors, on J-hooks or pulled into conduit. Pulling distribution cable should be done carefully as it is designed for lower pulling tension than more rugged outside plant cables.

Breakout Cable: Breakout cable bundles multiple simplex cables inside a cable jacket. Breakout cables are more rugged cables than distribution cables and can be installed in difficult environments. The simplex cables can be terminated individually and routed directly to equipment. It may be installed in cable trays, under floors, on J-hooks or pulled into conduit.

High Fiber Count Cables: High fiber count cables are flexible ribbon cables which generally have 864 fibers, 1728 fibers, 3456 fibers or up to 6912 fibers. These cables are not designed for pulling but are installed by blowing into ducts or laying into cable trays. These cables are large diameter, stiff and have large minimum bend diameters. They are limited in applications because of the need to accommodate both their large bend diameter for service loops and the large size of the splice closures. These cables are primarily used in high density premises cabling installations like data centers.

Simplex, zipcord and breakout cables can have connectors terminated directly on the cable and with the jacket protecting each individual fiber are rugged enough for making most connections. The 900 micron buffered fibers in distribution cables may be terminated directly, but the lack of protection for the individual fibers from the strength members and cable jacket requires they be placed inside patch panels or wall-mounted boxes.

6.7. Outside Plant Cables

Outside plant cables are rugged cables designed to withstand installation stress and harsh environments. Cables may be installed underground, aerial or underwater using many different methods. Different cable types are available depending on the installation, application environment, number of fibers and types, and other factors.

Loose Tube Cable: Loose tube (also called loose buffer) fiber optic cable is used in outside plant applications where the cable is expected to protect the fibers from the stress of installation and the long-term environment. It is generally pulled or blown into conduit or fiber optic ducts buried underground.

A loose tube cable consists of one or more protective tubes, each containing multiple fibers with only a 200 or 250 micron primary coating over the fiber. Many fibers can be incorporated into the same tube, providing a small size, high fiber density construction. The tubes are usually filled with a dry water-blocking compound or gel that prevents water from entering the cable. Strength members generally include aramid fiber yarn and may also include a central glass fiber strength member to add stiffness.

Fibers in loose tube cables are spliced and placed in splice trays in protective closures. Fibers in loose tube cables which have only the 200 or 250 micron primary coating are normally terminated by fusion splicing pigtails or splice-on connectors to the fiber in a splice tray inside a patch panel or wall-mounted box. If exposed outside a protective enclosure, the fiber should be sleeved with a breakout kit for protection.

Fibers with smaller diameter primary coatings in the range of 180-200 microns are used in high density cables like microcables or cables with high fiber counts, generally 864 to 6912 fibers.

Central Tube Cable: Cable with a single central tube to accommodate fibers, generally ribbons. The jacket is thick and has strength members imbedded in the jacket on opposite sides.

Ribbon Cable : Ribbon cables offer high fiber density in installations where many fibers are required and the cable must be as small as possible. See high fiber count cables below. Ribbon cable has fibers in flat groups of fibers called ribbons of 12, 24 or 36 fibers. Ribbons may be rigid with all the fibers held together tightly or ribbons may be flexible with the fibers loosely held together.

Ribbons of fibers can be spliced to other ribbons at one time with special fusion splicers which reduces the time required to splice cables, especially important when splicing cables with large numbers of fibers. Tools allow loose tube fibers to be "ribbonized," made into 12 fiber ribbons to allow fusion splicing as a ribbon to save time in splicing high fiber count cables.

Armored Cables: Most of the cables above are available with armor. These cables have metallic armor under a secondary jacket to protect the cable from penetration by rodents or high crush loads. Armored cables are generally direct buried in trenches or by plowing in areas with soft dirt. Armored cable is sometimes used for aerial installations where rodents are known to chew through cable jackets. Armored cable is sometimes also used in data centers when cables are installed underfloor and there is concern about the fiber cable being crushed.

Armored cable is conductive, so it must be grounded properly.

Microcables And High Fiber Count Cables
These two categories of cables are high density cables made possible by using bend-insensitive fibers which can be packed more densely in the cable and reducing the size of strength members and jacket thickness. The reduction in strength members and cable jacket thickness makes these cables unsuitable for pulling, so they are installed by blowing into ducts.

Microcables: Microcables are very small cables with up to 432 fibers that are installed by blowing the cables into microducts. Microducts may be added to existing ducts or installed by microtrenching. Microcables may have individual fibers or flexible ribbons.

High Fiber Count Cables: High fiber count cables generally have 864 fibers, 1728 fibers, 3456 fibers or up to 6912 fibers, in flexible ribbons. These cables are not designed for pulling but are installed by blowing into ducts. Due to the large minimum bend diameter of these cables, OSP installations are difficult for cables above 1728 fibers because of the difficulty of blowing cables and size of vaults needed to accommodate their bend radius for service loops and the size of the splice closures. These cables are also used in high density premises cabling installations like data centers.

Aerial Cables

Aerial cables used in outside plant installation can be of several types which require different installation techniques.

Lashed To Messenger (Sometimes called Strand and Lash): Regular loose tube cables can be installed by lashing them to a messenger wire installed between poles. Cables may be lashed to a messenger alone or overlashed to existing bundles of cables. In some areas, armored cables may be used for aerial installations to prevent damage by rodents or birds.

Figure 8 Cable: Figure 8 cable is a loose tube cable with messenger wire molded into the cable creating a figure 8 cross section which is installed like a messenger wire alone. Installation is similar to installing a messenger wire except it also includes a fiber optic cable that requires careful handling like any other fiber optic cable.

All-dielectric self-supporting cable (ADSS cable): ADSS is designed to withstand the tension loads of aerial installation and may be installed without a separate messenger wire. Special installation hardware is required, and installation requires careful tensioning of the cable. Manufacturers' recommendations on installation should be followed for these cables.

Cables For Underwater Installation

Installation in a location that will be underwater requires cables designed to withstand long term submersion. Consult with cable and hardware manufacturers regarding such cables and recommendations for installation directly or protected in ducts. Unless the underwater link is too long, cables should be installed in one continuous run to prevent having splice closures in an underwater location.

6.8. Prefabricated Cable Assemblies

Prefabricated cable assemblies are cables that have been terminated in a factory to specific specifications and shipped to the work area for installation. Sometimes called “plug and play” cable systems, they require no field splicing or termination.

Tight buffer premises cables are made to specific lengths according to the building design factory terminated and ready to install and connect. Some may have fibers terminated in single fiber connectors while others use multifiber connectors like the MPO connector with modules in patch panels to break out multifiber cables to single fiber or duplex connectors. Alternatively, breakout cables with MPO type multifiber connectors on one end and single fiber or duplex connectors are used.

Prefabricated cable assemblies for outside plant installations are generally used for fiber to the home drop cables. Special weatherproof connectors are used for these cables. The distribution cable has a weatherproof termination box near the home and the prefabricated drop cable plugs into that box on one end and on another panel at the home, so no termination is required. These cables are generally ordered in an assortment of lengths to meet the needs of the specific drop.

Connectors on prefabricated cables are generally protected by boots which may also have pulling eyes to facilitate installation.

6.9. Flammability - Cable Ratings and Markings (Premises)

For indoor applications, use only premises cables that have flammability ratings to meet relevant fire and building codes. Cables without markings should never be installed inside buildings. Outside plant cables entering a building may be limited to a specific distance by codes unless they are installed in rated conduit or are indoor/outdoor cables with propre ratings.

Optical cable flammability markings in the US are as follows:

OFN	optical fiber nonconductive
OFC	optical fiber conductive
OFNG or OFCG	general purpose
OFNP or OFCP	plenum rated cables for use in air handling plenums
OFNLS	low smoke density

In the European Union, indoor cables must meet requirements of the EU Construction Products Regulations (CPR). EU CPR designations A to F cover flammability, smoke production, flaming droplets and acidity.

Consult local authorities for regulations applicable to the project.

6.10. Fiber Optic Cable Color Codes (Premises)

Cable Jacket Color Codes

Table below details color codes for premises fiber optic cables as specified in TIA-598. Some indoor cables may be different colors than these, depending on the manufacturer or user. Outdoor cables are generally black to prevent UV damage from the sun and the installer should rely on the identification printed on the cable jacket.

Fiber Type	**Color Code**		
	Commercial	**Military**	**Printed Nomenclature**
Multimode (50/125) OM2	Orange	Orange	50/125
Multimode (50/125) (850 nm Laser-optimized) - OM3, OM4	Aqua (EU OM4 – Erica Violet)	Undefined	850 LO 50/125
Multimode (50/125) (850 nm Laser-optimized, wideband, OM5)	Lime Green	Undefined	OM5
Multimode (62.5/125) (OM1)	Orange (EU – slate)	Slate	62.5/125 OM1
Multimode (100/140)	Orange	Green	100/140
Singlemode (OS1, OS2)	Yellow	Yellow	SM/NZDS SM
Polarization Maintaining Singlemode	Blue	Undefined	Undefined

Fiber Color Codes

Inside the cable or inside each tube in a loose tube cable, individual fibers will be color coded for identification. Fibers follow the convention created for telephone wires except fibers are identified individually, not in pairs.

The color codes are standardized by numerous standards including EN 50174-1, ISO/IEC 14763-2, IEC TR 63194 and TIA-598. Color codes may differ in some countries or may be unique to a cable manufacturer. IEC TR 63194 lists the various color codes that are used in different countries. The color code might also be specified by company standards of telecommunication companies. Although the sequence of the colors might be different, the colors themselves are the same.

For the design and documentation of the cable plant, the color code should be agreed upon with the manufacturer of the cable when specifying and ordering cable.

In loose tube cables, buffer tubes follow the same color sequence up to 12 tubes, then, for example, tubes 13-24 will repeat the colors with a black stripe (black will have a yellow stripe), tubes 25-36 will follow the same color with an orange stripe, 37-48 use a green stripe, following the same color code sequence for the stripe. Tubes containing more than 12 fibers will use binder tape to separate fibers into groups of 12 fibers.

In ribbon cables, the ribbons follow the same color code sequence. 24 or 36 fiber ribbons will have some visible identification of the individual groups of 12 fibers.

Premises cables like distribution cables will have each 900 micron fiber color coded in sequence with binder tapes identifying separate groups of 12 fibers.

For splicing two cables, like color fibers are spliced to ensure continuity of color codes throughout a cable run. Cables where some fibers are split out to smaller cables or PON splitters are used need documentation in the design.

For termination, the fiber color code may be hidden so it may require adding a marker near the connector or marking the connector with an identification tag.
In addition to color codes, all cables must be marked on the outside with fiber type and size, applicable approvals for the cable and cable length marking.

Fiber optic cable color codes for fibers as specified in TIA598C.

Fiber No.	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

For 16 fiber array connectors, 4 additional fiber colors are specified.

13 Olive
14 Magenta
15 Tan
16 Lime

Connector color codes are covered in Termination Section

7. Construction Guidelines

Before the fiber optic cable plant can be installed, construction may be needed to provide the infrastructure in which the fiber optic cables will be installed. The needs for outside plant and premises installations are different. Regulations, codes and standards vary according to countries or locality, so always check for local requirements.

7.1. Outside Plant Construction

Outside plant (OSP) cables can be installed overhead (aerial), underground or in special circumstances even underwater.

Underground Construction

Construction: Underground cables may be installed by trenching and installing ducts for pulling or blowing cables in ducts or direct burial of armored cable in trenches. If the ground is soft and free of obstacles, armored cable may also be installed by plowing the cable into the ground. Ducts can also be installed by directional boring or drilling. Locations of intermediate splice points must be determined before construction begins and manholes, handholes, vaults, pedestals, huts or other locations must be built during the construction phase.

Call Before You Dig: Most areas where cables are being installed will already have underground utilities such as water, sewer, gas communications and electrical. Digging or boring in the vicinity of underground cables can be disruptive and dangerous, especially near gas pipes and electrical power. lines There are agencies that should be called to check the location of current buried utilities and notify the owner of the utility who may wish to be present when construction is being done.

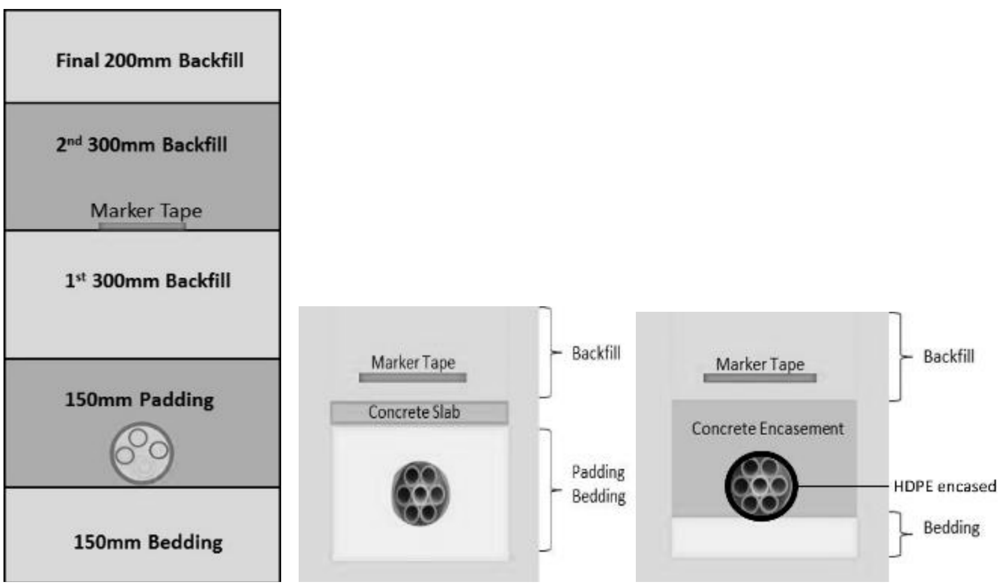
Underground Utility Location: It is the responsibility of the contractor to confirm the location of all underground utilities before beginning digging. Even if the contractor has received information from the local authorities, it is their responsibility to confirm that information and confirm the actual location of utilities using location instruments, since that data may be incomplete or out of date,.

Dig Once: If a trench is being opened for installation of fiber ducts, it is policy in many areas that the contractor will install additional ducts for future cable installation, avoiding the need for additional construction. Check with the local authority when obtaining permits to get information on this policy.

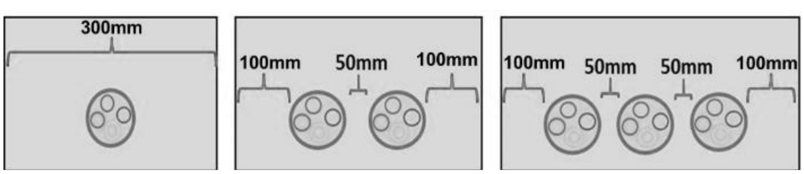
Duct Size And Fill Ratio

Duct size must be chosen appropriate for the cable size being installed. For optimum hauling performance, it is recommended that the cable-to-duct diameter fill ratio does not exceed 65% for pulling cable or 75% for blowing cable or as per the cable specification sheet. Fill ratios are calculated by comparing the area of an inside diameter of the duct to the outside diameter of the fiber optic cable.

Trenching Depth And Backfill: Trenching depth should be adequate to allow approximately 800mm (32 inches) of backfill as shown below. If the ground does not allow trenching to this depth, a shallow trench of a minimum of 300 mm (12 inches) can be used if the duct is covered with concrete slabs or poured concrete.



Trench width must be adequate to allow sufficient space for the ducts being buried as shown below.



Marker or locator tape or tracer wire should be installed in the trench above the fiber duct and identified at the termination points of the cable for use in future location of the duct.

Microtrenching: Microtrenching is a technique where a narrow groove is sawed in a roadway or sidewalk to allow the installation of small fiber optic cables or microducts. Local officials should be contacted before microtrenching to request the approval of local authorities and determine the location of sensors or cables, e.g. those for traffic control, imbedded in the roadway that may be cut by microtrenching. Microtrenching backfill should be properly added to ensure the integrity of the roadway.

Horizontal Directional Drilling: Horizontal directional drilling or boring is used to install ducts under roadways or streams where it is simpler and less disruptive than trenching. When horizontal directional drilling is used, it is important to know the exact location and depth of all buried utilities in the path precisely. Horizontal directional drilling can puncture sewers without visible damage that may not be known until sometime in the future. It can puncture water mains and flood areas quickly. Most dangerous is puncturing gas lines that may cause gas explosions and fires. Underground utility location is required before drilling begins and during the drilling process.

Aerial Construction

Construction: Aerial construction may include installation on current poles or towers, installation of messenger wires on existing poles before cable installation or the installation of poles when none currently exist. Existing poles require permission of the owner and may require the owner make the pole ready for the addition of cables. Local authorities may also require permits for cable installation.

Installation Of Poles: Installation of new poles includes several processes, beginning with a location survey to determine the location of the poles. The type of poles to be installed and height will depend on the route and the cables being supported. Areas subject to adverse weather conditions (weather including hurricanes or winter icing) or wildfires may require special pole types. Installation of the poles depends on the type and size of the poles and the ground conditions.

Lashing To Existing Cables: If permitted by the owner of the poles and local codes, cables may be lashed to existing cables, minimizing construction required. If there are several cables already in the bundle, the ability of the current messenger wire to support additional cables must be proven.

Installation Of Messenger Wire: Installation of messenger wires requires choosing the correct gage wire and installing the wire in the telecom space on the pole with proper hardware before lashing the fiber optic cable to the messenger wire. Messenger wire requires proper tensioning to control sag and support cables.

Additional Construction Methods: Fiber optic cables may require installation in many other conditions, for example, lashing cables or cables in conduit to current structures such as buildings, bridges, overpasses, or crossing streams or lakes under water. These special installations begin with determining local requirements that have been determined by authorities for these conditions and how they will determine the construction and installation of the cable plant. Special components or techniques may be required and should be determined well before the project begins.

7.2. Premises Construction

Fiber optic cables are generally terminated in structures where communications equipment reside such as central offices, head ends, repeater enclosures or pedestals. These structures may also include fiber optic cables entirely inside the building to connect other communications equipment. Premises cabling networks used for computer local area networks (LANs), cellular distributed antenna systems (DAS), building security or management systems or similar systems are contained entirely within a building or a campus.

Cables entering buildings from outside require entrance facilities to accommodate all cables entering or leaving the building. The entrance facility requires entrances for cables that meet building codes and provide environmental protection.

Building codes generally limit the distance OSP cables may be run inside a building because they are not generally rated for flame retardance, although some cables used in campuses are rated for indoor/outdoor use. For non-rated OSP cables, the entrance facility should provide termination facilities for the OSP cable to connect to properly rated premises cables or transition to rated conduit to allow OSP cables to continue into the building.

Within the building, infrastructure to support cables should be designed to support all cables used in the building. This may involve conduits, cable trays, underfloor trays, or J-hooks. Since building systems may require many types of cables, both fiber and copper, these cables should be separated to protect the fiber cables from damage and all cables marked properly. Termination points, including patch panels, should be placed where necessary.

Premises cabling standards include design requirements for cabling infrastructure which should be used as a reference. Premises structures should follow all relevant building codes and the guidelines in standards such as TIA569 and ISO/IEC 14763-2.

8. Installation

8.1. Receiving Fiber Optic Cabling and Equipment on Site

a) Fiber optic equipment and components are subject to damage by improper handling and must be handled accordingly.
b) Ensure that all components and parts which have been ordered are received. Verify products received match what has been ordered, e.g. fiber optic cable contains the number and type of fibers ordered and is the length ordered. Any

discrepancies or damaged goods should be noted and replaced as required.

c) When initially received on the job site, visually inspect all fiber optic components for visible damage. Test cables on the reel, sampling fibers with a visual fault locator VFL for continuity or if damage is suspected, test loss with an OTDR.
d) Store all equipment and cabling in a clean and dry location, protected from harsh environments and extremes of cold and heat.
e) Cables and other components are valuable and may be targets for theft. Thieves often do not know the difference between copper cables which are valuable when sold for scrap and fiber optic cables which are not, so cables and other components should not be left unprotected on the worksite.

8.2. Handling Fiber Optic Cables

a. Handle reels of fiber optic cable with care. All reels, regardless of size or length, must have both ends of the cable available for the testing. A visual fault locator and bare fiber adapters can be used for continuity testing of a sample of fibers. Cables suspected of having been damaged in handling require OTDR testing to verify the condition of the cable.
b. Damaged cables should not be installed, even if only a few fibers show damage. The cable may have long term reliability problems. Reels of cable that have been damaged should be returned to the manufacturer for replacement.
c. Move small, lightweight spools of fiber optic cable by hand. Move larger reels with appropriate lifting equipment or using two or more installers skilled in the moving operation.
d. Move large reels with a matched set of slings or chokers, attached to an appropriately sized piece of pipe inserted into the hole in the center of the reel. Do not use lifting equipment to pick up cable from the floor, by the reels or supported on the cable itself.
e. Do not attach slings and chokers around the spooled cable area of the reel. Move cable reels carefully to avoid damage to the cable.

8.3. Support Infrastructure

Support structures for fiber optic cable installations should be completed before the installation of the fiber optic cable itself. Outside plant structures should be installed in conformance with all permits and relevant building codes and “Dig Once” guidelines. Premises structures must follow all relevant building codes and the guidelines in relevant standards such as TIA569 and ISO/IEC 14763-2.

Allow for future growth in the quantity and size of cables when determining the number and size of ducts or the pathway requirements.

Do not install a fiber optic cable in a conduit or duct that already contains cabling, regardless of the cable type. Existing or new empty ductwork can be modified to accept several different installations by the placement of innerduct or microduct within it. Procedures may be used to remove current ducts and replace with fabric ducts or microducts to gain additional space in the duct.

8.4. Removal of Abandoned Cables

Unless directed by the owner or other agency that unused cables are reserved for future use, remove abandoned copper or optical fiber cables. Removal of abandoned premises cabling is required by the National Electrical Code in the US. Outside plant cables that are abandoned should be removed if they can be removed without damaging other cables.

Cables which are removed should be recycled if possible.

8.5. Fire Stopping (Premises)

a. All telecommunications fire stopping shall comply with applicable codes and standards.
b. All penetrations shall be protected by approved firestops. Fire stopping compounds and devices shall be used whenever a fire separation has been breached by an installation.
c. In most geographical locales the breaching of a fire separation will require physical monitoring until it has been repaired.
d. Check with the “Authority Having Jurisdiction” for specific requirements on the project before commencing work.

8.6. Grounding and Bonding

a. Ground systems shall be designed as specified by the NEC, CEC and other applicable codes and standards (e.g. IEEE 1100, TIA607, or local requirements).
b. Although most fiber optic cables are not conductive, any metallic hardware used in fiber optic cabling systems (such as splice closures, pedestals, messenger wire, wall-mounted termination boxes, racks, and patch panels) must be grounded.
c. Conductive cables such as metallic-armored cable or hybrid cables with both conductors and fibers require proper grounding and bonding for the applicable conductors.

9. Installing Fiber Optic Cable

9.1. General

Fiber optic cable may be installed indoors or outdoors using several different installation processes and as appropriate for the cable type being installed. Outdoor cable may be direct buried, installed underground by being pulled or blown into conduit or innerduct, or installed aerially between poles. Indoor cables can be installed in raceways, cable trays, placed in hangers, pulled into conduit or innerduct or blown though special ducts with compressed gas. The installation process will depend on the nature of the installation and the type of cable being used.
Installation methods for both wire and optical fiber communications cables are similar. Fiber cable is designed to be pulled with much greater force than copper cable if

pulled correctly, but excess stress may harm the fibers, potentially causing immediate or long term failure.

9.2. Installation Guidelines

a. Follow the cable manufacturer's recommendations for installation. Fiber optic cable is often custom designed for the installation and the manufacturer may have specific instructions on its installation.
b. Check the cable length to make sure the cable being pulled is long enough for the run to prevent having to splice fibers other than at locations where splicing is required or planned.
c. Try to complete the installation in one section to prevent unnecessary splicing and accommodation of splicing closures, service loops or other hardware. Prior to any installation, assess the route carefully to determine the methods of installation and obstacles likely to be encountered.
d. Do not mix fiber optic cables and copper cables in one conduit or cable tray. Copper cables can be much heavier and damage the fiber cables by crushing. In premises installations, if needed attach fiber optic cables or fiber ducts to the side of copper cable trays and pull the fiber optic cable into the duct.

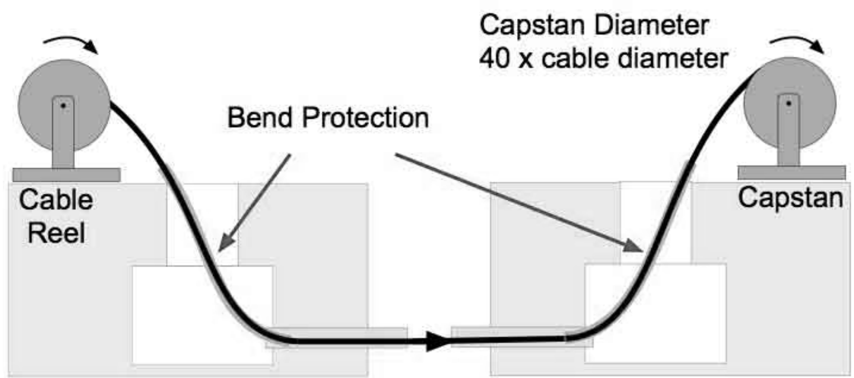
9.3. Pulling Tension

a. Most cables have strength members, usually aramid yarn, designed for pulling the cable. Fiber optic cable should only be pulled by these strength members. Any other method may put stress on the fibers and harm them.
b. Swivel pulling eyes should be used to attach the pulling rope or tape to the cable to prevent cable twisting during the pull. Breakaway swivels will prevent using excessive pulling tension.
c. Cables should not be pulled by the jacket unless it is specifically approved by the cable manufacturers and an approved cable grip is used.
d. Tight buffer cable can be pulled over short distances by the jacket in premises applications if a large (~40 cm, 8 in.) spool is used as a pulling mandrel. Wrap the cable around the spool 5 times and hold gently when pulling.
e. Do not exceed the maximum pulling tension rating. Consult the cable manufacturer and suppliers of conduit, innerduct, and cable lubricants for guidelines on tension ratings and lubricant use.
f. On long runs pulled in conduit, it may be necessary to use proper lubricants and make sure they are compatible with the cable jacket. If possible, use an automated puller with tension control and/or a breakaway pulling eye. On very long runs (farther than approximately 4 kilometers [2.5 miles]), pull from the middle out to both ends or use an automated fiber puller at intermediate point(s) for a continuous pull.
g. When laying loops of fiber on a surface during a pull, use “figure 8” loops to prevent twisting the cable *(see Figure 3, page 14)*.

9.4. Minimum Bend Radius Or Diameter

Fiber optic cables are designed to withstand bending both during installation where tension is applied to the cable and after installation. Do not exceed the cable minimum

bend radius or diameter specification. Fibers in fiber optic cable can be broken when the cable is kinked or bent too tightly, especially during pulling.
For underground installation, guidelines for minimum bend diameter or radius should be followed for pulling capstans, pulleys and sheaves or quadrant blocks used for bend protection when pulling cables into underground ducts. After completion of the pull, service loops of the cable should also be no smaller than the specification for the cable when not under pulling tension.



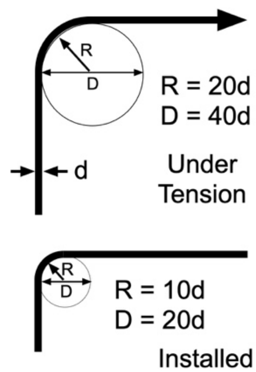
For aerial installation, guidelines should be followed whether the installation is lashed, ADSS or figure 8 cable and the installation is done with the moving reel or stationery reel method. The size of pulleys, cable in storage loops, points of transition up or down the pole, etc. can involve bends in the cable that require careful monitoring.

Cable Bend Specifications: Traditionally, the minimum bend radius has been specified for cables, but most fiber optic cable manufacturers are now specifying minimum bend diameter. The diameter is twice the radius and diameter is used because it specifies directly the diameter of pulleys and capstans used in pulling cables.

A different minimum bend diameter applies to bends used in the installation of the cable while under tension and the diameter of service loops of cable stored after installation. Generally the permissible diameter for storage loops is half the specification for cables under tension

There are general guidelines for most optical fiber cables using shown below. Unless one knows that the cable has a different specification, use the following guidelines.

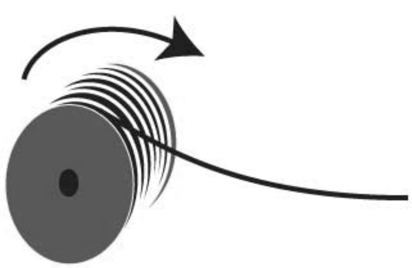
d = diameter of cable
D = minimum bend diameter
R = minimum bend radius



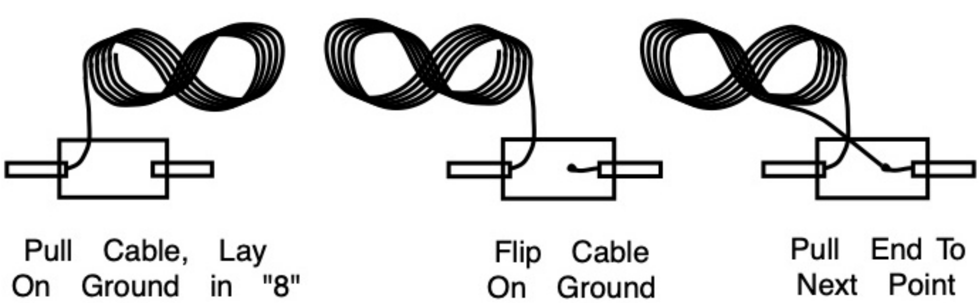
Calculation for cable bend radius R or bend diameter D

9.5. Twisting cable

a. Do not twist the cable. Twisting the cable can stress the fibers. Tension on the cable and pulling ropes can cause twisting.
b. Use a swivel pulling eye to connect the pull rope to the cable to prevent pulling tension causing twisting forces on the cable.
c. Roll the cable off the cable spool instead of spinning it off the side of spool to prevent putting a twist in the cable for every turn on the spool.
d. When laying cable out for a long pull or aerial installation requiring a intermediate pull, use a "figure 8" on the ground to prevent twisting. The figure 8 puts a half twist in on one side of the 8 and takes it out on the other, preventing twists.



Roll cable off the spool to prevent twisting.



Use "figure 8" loops to protect the cable when pulling.

Vertical Cables (Premises)

a. It is preferable to drop vertical cables in a building down rather than pulling them up whenever possible. Care must be taken to drop the cable in a slow, controlled manner. Care should be taken to follow minimum bend diameter for the cable being installed.
b. Support cables at frequent intervals to prevent excess stress on the jacket. Support should include a service loops of proper diameter held by cable ties, lightened snugly, not tightly enough to deform the cable jacket, or other suitable strain relief grip device.
c. Use service loops to assist in gripping the cable for support and to provide cable for future repairs or rerouting.

9.6. Installation Guidelines

9.7. Guidelines For Underground Installations

Pulling Cables

a. Cables should be attached to pulling ropes or tapes using the cable strength members or if specified by the manufacturer, appropriate grips on the cable jacket.
b. Cables should be pulled with swivel pulling eyes to prevent twisting and if high pulling tension is anticipated, a breakaway swivel should be used.
c. Special fiber optic pulling tapes should be used if available. Ropes manufactured from nylon are not suitable as their stretch factor is too high and they can potentially cut into ducts. Steel hauling rope or galvanized wire must never be used as they can damage ducts and/or cables.
d. Controlled tension pulling machines using capstans larger than the minimum bend diameter of the cable being pulled should be used on long pulls.
e. Proper attention should be paid to all bends in the cable to not violate the cable's minimum bend diameter.
f. Long cable runs may require lubrication and/or midspan pulls to limit pulling tension. Lubricants used should be appropriate for fiber optic cables of the types being installed.
g. Midspan pulls can be done in two ways: 1) pull from one end to the center where the cable is laid in a figure 8 coil, then flipped over and the end pulled in the other direction or 2) place the cable reel in the center and pull to one end, then remove cable from the reel in a figure 8 then pull to the other end.
h. During midspan pulls the fiber optic cable should be coiled in a figure 8 coil in preparation for the next pull to prevent twisting. Coils of cable should be laid on a protective tarp to prevent the cable from getting dirty between pulls.
i. Following installation, any fiber ducts should be capped to keep out dust or other contaminants.
j. Following installation, cables should be sealed properly until they are spliced or terminated.

Blowing or Jetting Cables

a. Cables may be blown into ducts using special machines that float the cable on high pressure air or gas to reduce friction and push the cable through the duct. Jetting adds a device attached to the end of the cable to use the air pressure to help pull the cable through the duct which adds stress to the cable.
b. Before blowing cables, the ducts must be tested for sealing and cleaned to ensure they are clear and ready for blowing the cable.
c. Follow the directions of the manufacturer of the blowing machine for setup including adjustments for the size and weight of the cable.
d. Smaller diameter and lower weight cables make possible larger blowing distances, up to ~4 km..
e. The maximum cable push force will decrease as the duct inside diameter increases, reducing the achievable blowing distances.
f. Blowing distance is directly related to the weight of cable, the pressure used, air flow and friction from the inside of the microduct.
g. Adding a small amount of lubricant to a tight-fitting foam carrier (sponge) before blowing it through the duct, will provide an open and lubricated pathway.
h. Following installation, any fiber ducts should be capped to keep out dust or other contaminants.
i. Following installation, cables should be sealed properly until they are spliced or terminated.

9.8. Guidelines For Aerial Installations

These guidelines refer primarily to “strand and lash” installations, cables lashed to a wire messenger. Some exceptions exist for ADSS (all-dielectric self-supporting) cables which may be installed in the power space or telecom space.

a. Installers must follow local ordinances and customer requirements for the aerial cable plant.
b. Cables on poles sharing electrical and telecom/CATV cables must be installed in the telecom space with proper clearance from both electrical cables and other low voltage cables. This includes separation mid-span where both electrical cables and the messenger/fiber cables both sag from their weight. The exception is ADSS cables which are approved for installation in the power space by qualified personnel.
c. All aerial cables should be installed clear of any obstructions including buildings, trees and other cables. Weather conditions, e.g. storms, icing or potential wildfires, at the location may justify greater separation from trees.
d. The span must be analyzed for the size of messenger, the tension required for the span length and cable weight to meet sag requirements. Sag is

generally limited to <2% of span length and maximum tension <30% of cable minimum breaking strength. Recommended reference: ANSI/ICEA P-79-561-2020 Guide for Selecting Aerial Cable Messengers and Lashing Wires.

e. Cables must be sufficiently high above the ground to clear all obstacles including traffic that may pass underneath it.
f. All cables must be securely lashed to the messenger and/or cable(s) with no loose hanging cables anywhere along the span. Messenger wire must be neatly terminated at the ends.
g. Splice closures should be attached to poles with necessary service loops using appropriate hardware. Closures attached to the messenger and their cable(s) must be securely attached and service loops secured along the current cables with snowshoe turnarounds or a cable loop that respect the cable's minimum bend diameter.
h. No service loops or cables awaiting further installation may be left hanging from the span. All loops of cable must be secured to a pole at the end of the span. Excess cable awaiting installation may be secured at poles for short periods of time only.
i. The steel messenger wire and lashing wire are electrical conductors and should be properly grounded.
j. Overlashing must consider the current cable loading, the weight of the cable intended to be added and the effects on span tension and sag.
k. Any damage done to current cables during OMTR (one touch make ready) or overlashing must be reported to the permitting authority and the owners of the other cables on the span.

9.9. Cable Plant Hardware

Outside plant cables may use many types of hardware depending on whether they are installed underground in conduit or conduit, direct buried or installed aerially on utility poles. Outside plant cables may be spliced or terminated in handholes, manholes or buildings along the cable route. Outside plant hardware should be chosen to be appropriate to the cable type installed, splicing and termination methods used and the environment of the installation.

All premises hardware and support structures should follow the recommendations of TIA569 and ISO/IEC 14763-2.

Cable Racks, Trays, Conduit and Innerduct

a. Outside plant cables can be installed in conduit or innerduct or direct-buried, depending on the cable type. Conduit may be large plastic pipe with fiber optic innerduct installed in the conduit. Ducts or microducts may also be buried directly, often in bundles to allow installation of additional cables in the future without construction (Dig Once).
b. Premises cabling can be installed in cable trays, ladder racks, J-hooks, or other appropriate support structures.
c. Premises cables may be installed directly or pulled inside premises-rated

innerduct to provide protection for the fiber cable. Innerduct is usually bright orange and will provide identification of fiber optic cable and protect it from damage.

Fiber Optic Splicing and Termination Hardware

a. *Breakout kits*: The fibers in loose tube cables have only the 250 micron primary buffer coating. Breakout kits are designed to isolate and protect each individual fiber and to prepare it for termination.
b. *Splice enclosures*: For long cable runs outside, splices are necessary to connect lengths of cable. Fusion splicing is preferred for low loss and reliability. Splices require protection that is provided by a sealed splice closure with trays for splices. Choose closures with adequate space for the number of fibers in the cables and port locations appropriate for the final mounting. Splice closures can be sealed and buried in the ground, placed in a vault or suspended aerially. Outdoor closures should be sealed and pressure tested.
c. *Splice panels and patch panels*: Terminate or splice distribution cables inside panels or boxes to protect the fibers from damage. Boxes or panels may be rack-mounted or wall-mounted. All should have locks to prevent unauthorized entry.
d. *Racks and cabinets*: Enclosures for patch panels and splice panels are used to terminate and organize cables. Use appropriate cable management hardware on the racks to route and separate cables to minimize potential for damage and facilitate moves, additions and changes.
e. All splicing and termination hardware must be of large enough to maintain cable bend radius or diameter limits, prevent pinching or kinking of fibers and separate fibers to allow for future restoration, moves or other work.

Use Of Cable Ties

Fiber optic cables, like all communications cables, are sensitive to compressive or crushing loads. Cable ties used with many cables, especially when tightened with an installation tool, may be harmful to fiber optic cables, causing attenuation and potential fiber breakage.

When used, cable ties should be hand tightened to be snug but loose enough to be moved along the cable by hand. Then the excess length of the tie should be cut off to prevent future tightening. Hook-and-loop fastener ties are preferred for fiber optic cables, as they cannot apply crush loads sufficient to harm the cable.

9.10. Service Loops

Installations will generally include the storage of lengths of cables needed for splicing cables during installation or included for future changes or repair to the network. These are generally referred to as service loops. Service loops should be securely mounted as part of the cable installation.

OSP cables that are spliced will have service loops long enough to allow splicing to be done some distance from where the splice closure is mounted, leaving excess cable that must be stored. Manholes or handholes must be large enough to accommodate the excess cable coiled with a diameter greater than the specified bend radius or diameter of the cable and provide for the securing of the cable coils.

Aerial cable service loops should generally be lashed to the messenger wire supporting the cable in one loop along the messenger with each end of the loop carefully lashed with a radius greater than the bend radius of the cable. Plastic supports called "snowshoes" can be used to support the loop. Large coils of cables should not be lashed to the messenger or pole for permanent storage of the cable.

In premises applications, service loops should be coiled on walls near the termination points of the cable in wall mounted boxes or racks.

10. Fiber Optic Splicing

10.1. Types of splices

Splices are used as a permanent joint or connection between two fibers, for example when two or more OSP cables are joined in a cable plant. Splices are also used to terminate fibers by splicing pigtails or splice-on connectors (SOC) to the fiber.

There are two basic types of splices, fusion and mechanical. Fusion splicing should be used for concatenating two cables for long cable runs as it is the most reliable method of splicing. Fusion splicing can also be used to splice ribbon splices or individual fibers that are ribbonized, a time-saving method especially for fibers with large fiber counts.

Fusion Splices: Fusion Splices "weld" the two fibers together with heat, usually in an electric arc. Fusion splicers are generally automated and produce splices that have minimal loss and reflectance as well as high reliability. Fusion splicing is generally done in a clean environment such as a van or trailer. It should not be performed in a dusty or explosive atmosphere as the electric arc may cause an explosion or fire.

Mechanical Splices: Mechanical splices align two fibers in a ferrule or v-groove with index-matching gel or adhesive between the fibers to reduce loss and reflectance. Mechanical splices are generally used for temporary restoration but occasionally as permanent joints.

Splicing is generally done in a splice trailer or van or on a table on the ground near the splice location. Splicing in a trailer or van is preferred due to the isolation from weather, wind, dust, etc.

To reach the splicing machine and provide sufficient length for preparing the cable for splicing, approximately 10 meters (30 feet) of extra cable from both cables must be available for the splicing technician. Aerial cables may need longer lengths to allow splicing on the ground.

10.2. Splice Performance

Splice performance shall be within industry standard or customer specified limits. Industry standards have high loss limits so splice performance may be specified by end users at a different value, and if so, those values shall be used for acceptance.

Splice Performance Verification

Fusion splicers generally provide an estimate of splice loss for every splice made. Splice loss should be verified as splices are made by testing with an OTDR. Testing in real time ensures that all splices are properly made, reducing the need to troubleshoot problems after the cable installation is finished.

End-to-end tests of fiber optic cable loss include the losses caused by splices. If the cable loss exceeds the maximum value calculated in the loss budget (See Annex A), or if the customer requires splice loss verification, test the cable with an OTDR to measure the loss of individual components (fiber, connections, and splices) in the cable.

10.3. Splice Protection

a. Splices shall be placed in an protective closure appropriate for the environment. There are many types of splice closure so follow the manufacturer's instructions for the closures being used to ensure the cables and fibers are installed properly and the closure is sealed when splicing is complete.
b. Cables shall be secured at the entry to the closure. All fiber, tube and cable lengths shall be appropriate to the splice closure to prevent damage to the cable and fibers.
c. Closures for loose tube cable will have fiber tubes leading to a splice tray. Within the splice tray, individual fibers are spliced and carefully organized to avoid damage. This process ensures that, when the splice tray is closed and placed inside the closure, the fibers remain protected and secure.
d. Closures designed for ribbon cables often require specialized routing or the addition of protective sleeving for the ribbons. These measures are important to maintain the integrity of the ribbons and provide suitable protection inside the closure.
e. If cables have conductive elements, ensure the cable and closure are properly grounded and bonded,
f. Splice closures should be properly sealed and tested to prevent moisture ingress to ensure long term reliability.
g. Splice closures and their associated service loops of cables should be securely mounted to prevent damage.

11. Fiber Optic Termination

11.1. General

Fiber optic termination processes vary according to the types of fiber being terminated, the style of connectors or splices used and the termination process appropriate for that connector. Fiber optic cable can be terminated in two ways, using splices that create a permanent joint between two fibers or connections that use two connectors attached to the end of fibers that mate two fibers to create a temporary joint and/or connect the optical fiber to network equipment.

The decision whether to use connectors or splices depends on the application. Outside plant cables may have permanent joints made by splicing fibers as well as terminations for patch panels and connecting to communications equipment. Premises cabling generally uses connections to allow making moves, adds and changes.

All terminations and splices must be of the right style, installed in a manner that provides low light loss and reflectance at the fiber joint, and is protected against the expected environment, dirt or damage while in use.

11.2. Fiber Optic Connectors

Choice of Connector Style

Fiber optic connectors are manufactured in a variety of different styles, (e.g. SC, LC, MPO). Industry standards allow the use of any connector with a reference FOCIS document (Fiber Optic Connector Intermateability Standard), but during the design of the cable plant consideration should be given to compatibility with current cable plant hardware and system electronics.

Should the cable plant connectors be different from the communications electronics, hybrid patch cables will be required for connecting the cable plant to the electronics.

11.3. Connector Color Codes

The TIA 598 standard color code for connector bodies and/or boots is:

a. Beige for 62.5/125 micron multimode fiber (OM1) connectors
b. Black for 50/125 micron multimode fiber (OM2) connectors
c. Aqua for laser-optimized 50/125 micron multimode (OM3, OM4) fiber connectors
d. 4. Lime Green for wideband 50/125 micron multimode fiber (OM5) connectors
e. Blue for PC (physical contact) singlemode connectors
f. Green for APC (angle physical contact) singlemode connectors

Note: Do not mix multimode connectors with fibers of different core sizes as it may cause large insertion loss in the direction of larger to smaller fibers.

Note: Do not mix Blue (PC) and Green (APC) singlemode connectors. It causes high insertion loss and reflectance and may damage connectors.

These color codes should be used in addition to the cable color codes or colored strain-relief boots on the connectors to also designate which type of optical fiber is in the cable being connected.

11.4. Termination Processes

Fiber optic cable plants can be terminated in the field or prefabricated cable plants can be installed which require no field termination. Like splicing, termination is best done indoors or in a splicing trailer or van to prevent problems from weather, wind, dust, etc. Fiber optic cables installed without connectors may be terminated by installing connectors onto the fibers using different types of termination processes or by splicing preterminated pigtails or splice-on connectors (SOC) onto each fiber.
Prefabricated cables or cable plants can be installed with terminations completed in a factory and shipped to the job site ready to install.

11.5. Connector performance

Connector performance should be within industry standard limits from appropriate standards or may specified to be better than the worst-case values in the standards. Loss and reflectance limits specified in industry standards is often higher than achieved routinely by experienced installers or specified by manufacturers. Users may specify a more stringent requirement and if so, that specification shall be used for acceptance.

Connector Performance verification

Following completed installation and termination, all terminated cables must be tested. Section 7 provides more detail on testing requirements at the conclusion of installation.

Examine all connectors requiring polishing with a microscope for proper end finish, cracks, scratches or dirt per FOTP57 or ISO/IEC-61300-3-35. These standards are aimed at factory terminations and focus on the center of the ferrule. Manual inspections of connectors are recommended to ensure that dirt and contamination on a connector ferrule are diagnosed properly.

Test all fibers in all cables for loss using an OLTS power meter and source. Test cables using industry standards, e.g. TIA/EIA 526-14 for multimode, and TIA/EIA 526-7 for singlemode cables. Total loss shall be less than the calculated maximum loss for the cable based on appropriate standards or customer specifications as calculated in a loss budget for the cable. (See Annex A)

11.6. Fiber Connection Polarization

In most fiber networks, separate fibers are typically used for transmission in each direction, therefore it is necessary to identify the fiber connected to the transmitter and receiver at each end. The exception is a passive optical network that transmits bi-directionally over a single fiber, thereby not requiring identifying the polarity of the connection.

a. Duplex connectors such as the duplex SC or LC are polarized, that is they are keyed to allow connection in only one orientation. Follow the polarization rules given in TIA-568 and -569.
b. Simplex connectors should be documented for connections and when allocated to the transceiver of networking equipment, marked for transmit and receive at each end of the link.
c. Multifiber and array fiber connectors such as the MPO have 12 or 16 fibers in a row and may have 2 or more rows. Polarity for these connectors is complicated because of all the possible ways that many fibers can be arranged. Consult with the TIA 568 standard or the cabling manufacturer to determine the proper polarity of these cabling systems.

11.7. Connector Cleaning and Inspection

Fiber optic connection losses are extremely sensitive to dirt and contamination due to the small size of the light-carrying core of the optical fiber. All connectors should be protected with a protective cap when not connected. Before making a connection between two connectors or to equipment, each connector should be inspected with a microscope and cleaned if needed.

Note For Safety: Fiber optic inspection optical microscopes can focus power in the fiber into the eye. For safety when inspecting connectors, use a microscope with an infrared filter designed to remove harmful light or use a video microscope. When inspecting connectors on operating networks, checking for power in the fiber with a fiber optic power meter should be done before inspecting the connector with an optical microscope. Video microscopes do not focus light into the eye and are intrinsically safe, and in addition many will now automatically inspect for defects, dirt and contamination.

12. Testing the Installed Fiber Optic Cable Plant

12.1. General

After installation, test every fiber in all fiber optic cables for verification of proper installation, splicing and/or termination. Perform the following tests:

a. Continuity testing to determine that the fiber routing and/or polarization is correct and documentation is proper. Color codes may be used to verify polarization.
b. Microscope inspection of connectors to ensure connectors are clean and free of scratches or other damage. Inspection and cleaning are typically done before testing and when making connections to patch panels, patch cords or communications equipment.

c. End-to-end insertion loss using an OLTS power meter and source. Total loss shall be less than the calculated maximum loss for the cable based on appropriate standards or customer specifications as calculated in the loss budget. (See Annex A)
d. Optional OTDR testing may be used to verify cable installation, splice performance and troubleshoot problems.
e. If the design documentation does not include cable plant length, and this is not recorded during installation, test the length of the fiber using the length feature available on an OTDR or some OLTSs.
f. If testing shows variances from expected losses calculated in the loss budget (See Annex A), troubleshoot the problems and correct them.

12.2. Continuity Testing And Polarization

Perform continuity testing of optical fibers using a visual fault locator, or OLTS power meter and source. Trace the fiber from end to end through any interconnections to insure that the path is properly installed, and that polarization and routing are correct and documented.

In fiber networks, 2 separate fibers are typically used for transmission in opposite directions, therefore it is necessary to identify the fiber connected to the transmitter and receiver at each end for a single link. Single fiber networks, like FTTH PONs, operate bidirectionally on 1 fiber and only require identification for the link.

a. Duplex connectors such as the duplex SC or LC are polarized, that is they are keyed to allow connection in only one orientation.
b. Simplex connectors should be documented for connections and when allocated to the transceiver of networking equipment, marked for transmit and receive at each end of the link.

12.3. Microscope Inspection Of Connectors

Connectors should be inspected for cleanliness and damage before testing or connection to another connector or transceiver. Visual inspection is accomplished using a microscope that has a fixture to hold the fiber or connector steady in the field of view and a light source to illuminate the connector. Fiber optic inspection microscopes offer magnification os 100X to 400X, for closer inspection of polished ferrule ends. Most have lighting direct down the axis of the microscope to see the end clearly and at an angle which helps diagnose surface problems.

Microscopes are of two types, optical and video. Optical microscopes use lenses to focus on the connector for direct viewing by the eye. Video microscopes use a video camera to image the connector and display it on a screen. Video microscopes are safer (see below) and most offer automatic inspection of the connector for dirt and defects.

Note On Eye Safety: *Optical microscopes should have a built-in infrared filter to remove any signals being transmitted in the fiber for the protection of the eye of the user. An optical microscope can capture any light in the fiber and focus all of it into the eye, a potential danger to the user. Since the light in most fiber systems is in the infrared (IR) and invisible to humans, it will not be detected visually, even if the power level is high enough to be dangerous. Most fiber optic systems have power levels too low to be harmful, but some might - especially telecom and CATV systems with fiber amplifiers or WDM.*

12.4. Insertion Loss

Insertion loss refers to the optical loss of the installed fibers when measured with a test source and power meter (OLTS). Test multimode cables by using TIA/EIA 526-14, and singlemode cables using TIA 5267. *See Appendix B*.

a. Test multimode fiber at 850 and 1300 nm with LED sources, and singlemode fiber at 1310 and 1550 nm with laser sources, unless otherwise required by other standards or customer requirements.
b. Test reference test cables to verify quality and clean them often.
c. Some testing standards require the use of a mode conditioner to modify the mode power distribution in fibers when testing multimode cables. Follow the directions for its use to gain the proper test results.

12.5. OTDR Testing

The optical time domain reflectometer (OTDR) uses optical radar-like techniques to create a picture of a fiber in an installed fiber optic cable. The picture, called a signature or trace, contains data on the length of the fiber, loss in fiber segments, connectors, splices and loss caused by stress during installation.

OTDRs are used to verify the quality of the installation or for troubleshooting. However, OTDR testing is an indirect test that may not be comparable to transmission system loss and should ~~not~~ be used in combination with insertion loss testing to determine cable loss.

OTDR testing should only be performed by trained personnel using certified equipment designed for the purpose. The technicians performing the tests should be trained not only in operation of the OTDR equipment, but also in the interpretation of OTDR traces. See Annex B for more information on OTDR testing.

12.6. Fiber Characterization

All fibers intended for high speeds over long lengths should be tested for spectral attenuation (SA), chromatic dispersion (CD) and polarization mode dispersion (PMD) to ensure proper performance.

13. Administration, Management, and Documentation

13.1. General

Documentation of the fiber optic cable plant is an integral part of the design, installation and maintenance process for the fiber optic network. Documenting the installation properly will facilitate installation, allow better planning for upgrading, and simplify testing future moves, additions and changes.

Documentation of the premises fiber optic cable plant should follow TIA606, *Administration Standard for the Telecommunications Infrastructure of Commercial Buildings*. Documentation of outside plant cables should include similar information plus location data on the route of the cable plant, e.g. GIS data (geographic information systems.)

Fiber optic cables, especially those used for backbone cables, may contain many fibers that connect a number of different links going to several different locations with interconnections at patch panels or splice closures. The fiber optic cable plant should be documented as to the exact path that every fiber in each cable follows, including intermediate connections and every connector type.

Documentation should also include fiber type (multimode or singlemode and specific type), cable type and identification, connector and splice styles and locations,insertion loss data and optional OTDR traces.

13.2. Checklists

Final planning for the installation is a critical phase of any project as it involves coordinating activites of many people and companies. The best way to keep everything straight is probably to develop a checklist based on the design path. Here are examples of checklists to use in developing them for any project.

Pre-install checklist:

a) Main point of contact/project manager chosen
b) Link communications requirements set
c) Equipment requirements set and vendors chosen
d) Link route chosen, permits obtained
e) Cable plant components and vendors chosen
f) Coordination with facilities and electrical personnel complete
g) Documentation ready for installation, preliminary restoration plans ready
h) Test plan complete
i) Schedule and start date set for installation, all parties notified
j) Components ordered and delivery date set, plans made for receiving materials (time, place,) arrange security if left outside or on construction site
k) Contractor/installer chosen and start date set
l) Link route tour with contractor(s)
m) Construction plans reviewed with contractor(s)
n) Components chosen reviewed with contractor(s)
o) Schedule reviewed with contractor(s)

p) Safety rules reviewed with contractor(s)
q) Excess materials being kept for restoration reviewed with contractor(s)
r) Test plan reviewed with contractor(s)

Before starting the installation:

a) All permits available for inspection
b) Sites prepared, power available
c) All components on site, inspected, security arranged if necessary
d) Contractor available
e) Relevant personnel notified
f) Safety rules posted on the job site(s) and reviewed with all supervisors and installation personnel

During The Installation:

a) Inspect workmanship
b) Daily review of process, progress, test data
c) Immediate notification and solution of problems, shortages, etc.

After completion of cable plant installation:

a) Inspect workmanship
b) Review test data on cable plant
c) Set up and test communications system
d) Update and complete documentation
e) Update and complete restoration plan
f) Store restoration plan, documentation, components, etc.

Annex A: Calculating the Loss Budget for a Fiber Optic Cable Plant

Calculating the loss budget for a fiber optic link should be done as part of the initial design of the link. A loss budget will estimate the loss of the link to provide assurance that the link will support telecommunications equipment intended for use on the link. It should also be used to provide an estimated loss value to use when testing the link with a test source and power meter after installation to determine if the link has been installed properly.

Information Necessary to Calculate Loss Budget
Length of the link, end to end, in meters Number of connections, including one on each end Number of splices
Attenuation coefficients are given for TIA568, which is considered the worst-case, and for typical industry results. The table below shows typical loss for each component in an installed link.

Fiber Attenuation Coefficient

Fiber Type	**Wavelength (nm)**	**Max Attenuation Coefficient Per TIA-568 (dB/km)**	**Attenuation Coefficient (typical)(dB/km)**
Multimode 50/125	850	3.5	3
	1300	1.5	1
Singlemode (Premises)	1310	1.0	0.5
	1550	1.0	0.5
Singlemode (Outside Plant)	1310	0.5	0.4
	1550	0.5	0.3

Loss of Connections and Splices

	Max Loss Per TIA-568 (dB)	**Typical Loss(dB)**
Connection (2 mated connectors)	0.75	0.3 (Adhesive/polish type) 0.3-0.5 (fusion splice-on type) 0.5-0.75 (mechanical splice-on type) 0.75 (single ferrule multifiber)
Splice (fusion or mechanical)	0.3	0.05-0.15 (fusion) 0.3 (mechanical)

Process:

1) Calculate the loss of the fiber

2) Calculate the loss of all connections
3) Calculate the loss of all splices
4) Add all losses to get the total loss

Calculate The Fiber Loss:
Multiply the length of the fiber times the attenuation coefficient of the fiber at each wavelength of interest. Multimode fiber is calculated for 850 nm and 1300 nm. Singlemode fiber is generally calculated for 1310 nm for most premises applications and 1310 nm and 1550 nm for outside plant applications.
For example:
Multimode fiber at 850 nm

Estimated fiber loss = length in km X 3.5 dB/km (TIA Max Specification)
Or
Estimated fiber loss = length in km X 3 dB/km (Typical Specification)

Calculate The Connector Loss:
The loss of a connection is the loss of a joint created by mating a pair of connectors. Estimates should always include the loss of the two connectors on the end of the cable plant since they will be mated to reference cables when being tested. Count the number of connections and multiply by the estimated loss of each connection.
For example, a cable plant with 3 connections plus the end connectors,

Total connection loss = Number of connections (5) X 0.75 dB (TIA Max Specification) = 3.75 dB
Or
Total connection loss = Number of connections (5) X 0.3 dB (Typical Specification) = 1.5 Db

Calculate The Splice Loss:
If the cable plant has splices, count the number of splices and multiply by the estimated loss of each splice.
For example, a cable plant with 3 fusion splices,

Total splice loss = Number of splices (3) X 0.3 dB (TIA Max Specification) = 0.9 dB

Or

Total splice loss = Number of splices (3) X 0.05 dB (Typical Specification) = 0.15 dB

Calculate Total Cable Plant Loss
To calculate the total cable loss, add the losses calculated above:
Total fiber loss in dB = (fiber loss) + (connector loss) + (splice loss)

Interpreting the result:
Use these numbers as estimates for “pass/fail” limits for testing. If the field-measured

loss is significantly higher than the calculated value, troubleshoot the installation. Remember that the loss budget is an estimate, not exact, and that test results have uncertainty, so when interpreting test results compared to loss budget, some judgement is required.

Annex B: Field Test Requirements

B.1. General

Installed fiber optic cable plant performance depends on component quality and specifications, length of the fiber in the cables, number of connections and/or splices and the quality of the installation process itself. Testing each fiber in the cables verifies the quality of the components and the installation process. All fibers should be tested for insertion loss with a test source and power meter (also called an optical loss test set) and the test results compared to the loss estimated in the calculated loss budget. OTDR tests may be used for troubleshooting. All test data should be recorded and records maintained for reference in case of future problems or the need for restoration of damaged or failed links.

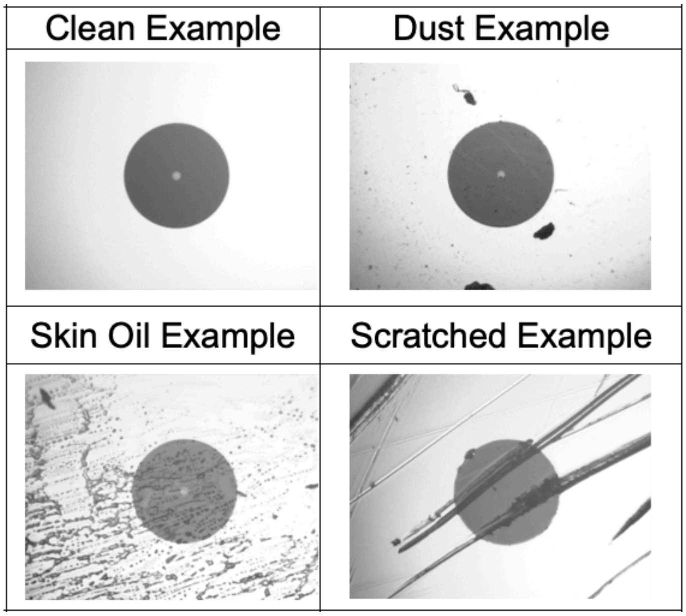
B.2. Optical Inspection Of Connectors with Microscopes

Connectors should be inspected for cleanliness and damage before testing or connection to another connector or transceiver. Visual inspection is accomplished using a microscope that has a fixture to hold the fiber or connector steady in the field of view and a light source to illuminate the connector. Fiber optic inspection microscopes offer magnification in the range 100X to 400X, for inspection of connector ferrule ends. Most have lighting direct down the axis of the microscope to see the end clearly and at an angle which helps diagnose surface problems.

Microscopes are of two types, optical and video. Optical microscopes use lenses to focus on the connector for direct viewing by the eye. Video microscopes use a video camera to image the connector and display it on a screen. Video microscopes are safer (see below) and most offer automatic inspection of the connector for dirt and defects.

Note On Eye Safety: Optical microscopes should have a built-in infrared filter to remove any light being transmitted in the fiber for the protection of the eye of the user. An optical microscope can capture any light in the fiber and focus all of it into the eye, a potential danger to the user. Since the light in most fiber systems is in the infrared (IR) and invisible to humans, it will not be detected visually, even if the power level is high enough to be dangerous. Video microscopes are recommended for their safety.

Inspect connectors for dirt or contamination and if not clean, use appropriate tools and cleaners, then inspect the connector again to ensure it was properly cleaned.



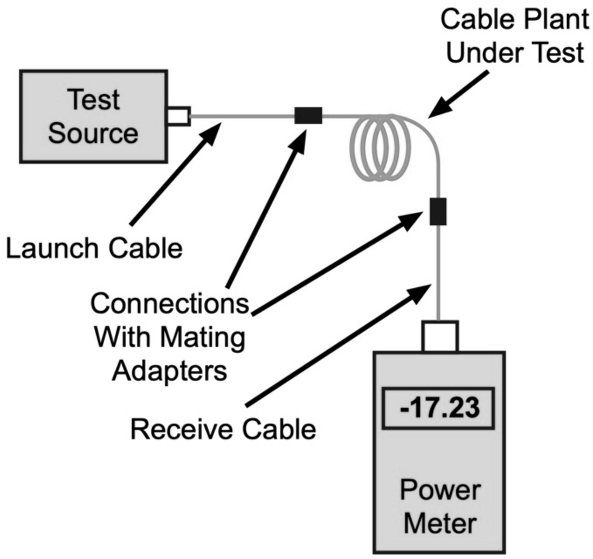
Examples of dirt and contamination on a fiber optic connector.

B.3. Insertion Loss Of Fiber Optic Cables

Once installed, all optical fiber cables and cable plants shall be tested for insertion loss using the double-ended method. Insertion loss refers to the optical loss of the installed fibers when measured with a test light source and power meter (OLTS) using reference test cables which simulates the way the cable plant will be used for transmission by a communications system. These are called double-ended test since both a launch reference cable attached to the source and a receiver reference cable attached to the power meter are used to test connectors on both ends of the cable plant.

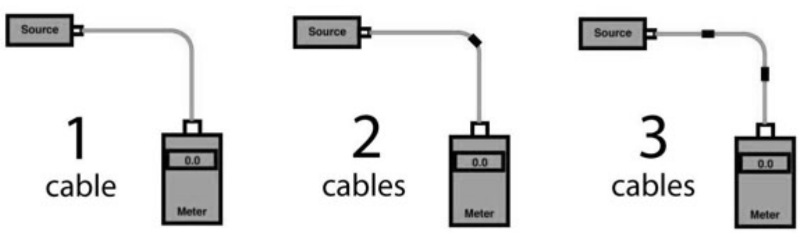
There are many standards that cover testing of the installed cable plant. All of which include the procedures shown here, including IEC 61280-4-1 or TIA 52614 for multimode cable, or IEC 61280-4-2 or TIA 5267 for singlemode cable.

Test Procedure
Insertion loss is tested by connecting a test source through a mating reference cable (launch reference cable) to the cable plant under test and measuring the loss with a power meter attached to the cable plant with another cable (receive reference cable) using the following procedure.



Insertion Loss Test - Double Ended

Setting The "0dB" Reference
Insertion loss requires setting a reference for "0dB" loss before making the actual test. Standards allow setting a "0 dB" reference value for measuring loss in three different ways, which should be used either as required by the standard or as necessary due to cable plant and test instrument compatibility. The method-used should be included in the documentation since the measured loss varies with each method.



a) 1-Cable Reference: Many standards call for using a one cable reference (formerly TIA 52614, Method B) which measures the output of the launch reference cable with a power meter and sets this as the "0 dB" reference. This method is preferred and will work when the cable plant connectors are compatible with the test equipment or can be adapted using hybrid mating adapters, e.g. ST to SC mating.

b) 2-Cable Reference: If the cable plant connectors are not compatible with the test instruments, e.g. LC connectors on the cable plant and SC connectors on the instruments, a two-able reference method (formerly TIA 52614, Method A) can be used. Use hybrid reference cables with SC connectors to mate with the instruments and LC connectors on the other end to mate with the cable plant. Attach the SC connector ends of the reference cables to the instruments then mate the LC ends with a mating adapter to set the "0 dB" reference. When making the measurements of loss, the value measured will be lower by the loss of the connection between the reference cables included in setting the reference.

c) 3-Cable Reference: If the cable plant connectors are “plug and jack” type and not compatible with the test instruments, e.g. MPO connectors on the cable plant and SC connectors on the instruments, a three-cable reference method (formerly TIA 526-14, Method C) must be used. In this method, the reference cables attached to the test source and power meter are mated to a third reference cable, a short version of the cable plant to be tested for setting the “0 dB” reference. When making the measurements of loss, the value measured will be lower by the loss of the two connections included between the reference cables in setting the reference.

Note: After the "0 dB" reference has been set, the launch cable must not be removed from the test source since removing it and connecting it again may not couple the same amount of light into the cable

Note: The reference method used in making the insertion loss test is important in interpreting the test results because it affects the value of the loss measurement so it must be included in the test documentation.

Making Insertion Loss Measurements

To measure the loss after the 0dB reference has been set, the light source is coupled to one end of the cable under test with a launch reference cable and the optical power meter is coupled to the cable under test using a reference cable (receive cable.)

The light from the test source is attenuated by the cable under test, beginning at the connection to the launch cable, while passing through all fiber in the cable, connectors and splices, and finally the connection to the receive cable.

The loss of the cable is the difference of the 0 dB reference set and the output of the cable being tested as measured by the power meter, expressed in dB.

Note: Test multimode fiber at 850 and 1300 nm and singlemode fiber at 1310 and 1550 nm or as required by other standards or customer requirements.

Note: Clean reference cables between every measurement and test reference cables frequently to verify quality.

Test instruments

Test Source

The test source must be of the proper type of source and wavelength for the cabling system being tested.

a. Use LED sources to test multimode fiber at 850 and 1300 nm and laser sources to test singlemode fiber at 1310 and 1550 nm.
b. Multimode test sources should meet appropriate standards for mode power distribution or be used with appropriate mode conditioners when specified by the

standard.

Optical Power Meter
The optical power meter shall be of the proper type for the cabling system being tested.

a. The optical power meter shall be calibrated at the wavelengths appropriate for the test source.
b. The optical power meter shall have a measurement range appropriate for the loss ranges being tested.
c. Adapters for connector types being tested shall be available.
d. The optical power meter shall have been calibrated by an appropriate calibration laboratory within the manufacturer's recommended recalibration interval.

Note: When using an optical power meter and light source to test insertion loss, the loss measurement will be a negative number. When testing with an optical loss test set, a combination instrument of light source and power meter, the measurement of loss will generally be displayed as a positive number.

Reference Test Cables
Reference test cables shall be compatible with the cable plant being tested, of high quality and properly handled.

a. Cables shall match the type (multimode or singlemode) of fiber being tested and, if multimode, the core size (50 or 62.5 micron).
b. Cables shall be of good quality and tested to verify low loss. Unless otherwise specified, losses of reference cables should not exceed 0.5 dB when tested according to TIA/EIA455-171 Method A, a single-ended insertion loss test that does not require a receive reference cable on the power meter.
c. Once attached to the test source and the "0 loss" reference measurement made, the launch reference cable should not be removed from the source as it may invalidate the reference.
d. Cables should be cleaned before each measurement, inspected with a microscope and tested periodically to verify quality.

Insertion Loss Measurement Uncertainty
Insertion loss testing has several sources of measurement uncertainty that should be understood by personnel making the test.

a. Insertion loss measurements depend on the quality and condition of the launch and receive reference cables since the connectors on these cables mates to the connectors on the cable under test. Poor quality, wear, scratches or dirt on these connectors will cause the measurement of loss to be higher and may not represent the actual quality of the cable being tested. Cables used as reference cables should be cleaned, inspected and tested regularly.
b. Optical sources will affect loss measurements in several ways. Fiber attenuation varies with wavelength, so the wavelength of the source will affect the loss of long cables. LED sources used for multimode testing will affect the loss of both the fiber and any joints in the fiber according to how the source launches light into the modes of the fiber. Standards describe several ways to condition the

modal distribution that may be relevant to the cable being tested.

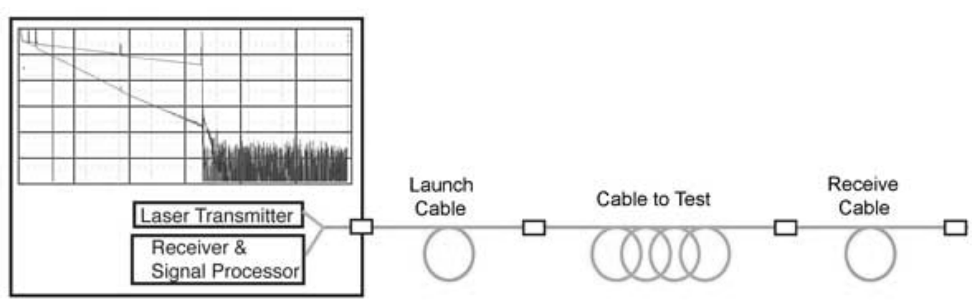
c. Setting the “0 dB reference” using the two or three cable reference method may cause increased uncertainty in the loss value, even showing a “gain” if the reference was set improperly or the connections on the reference cables were dirty.

B.4. OTDR Testing

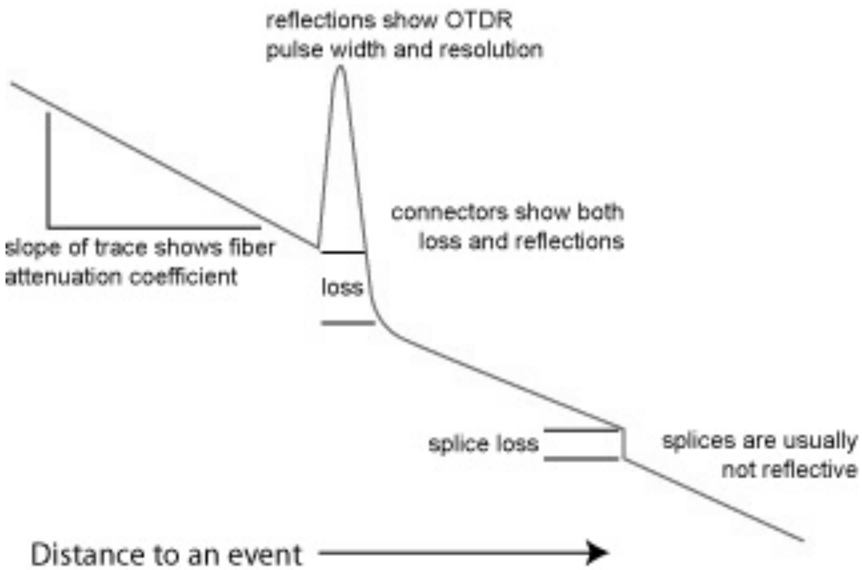
Testing with an optical time domain reflectometer (OTDR) may be performed to verify the quality of the installation, or for troubleshooting. However, it shall not be used as a measurement of the loss of the cable plant. OTDR measurements should follow procedures outlined in IEC 60793-1-40 (backscatter method) or TIA455-59, 60 and 61.

OTDR Test procedure

OTDR testing uses backscattered light from the optical fiber to create a diagram, called a “trace” or “signature,” of the cable plant being tested. The OTDR needs access to only one end of the optical fiber to perform testing, but reference cables are needed at both ends of the cable plant to allow testing connectors on each end of the cable.



a. Attach the OTDR to the fiber in the cable plant to be tested through a launch cable of a fiber type and size that matches the cable under test. The launch cable, also called a “pulse suppressor cable,” must be of adequate length to allow the OTDR to overcome the overload caused by the test pulse (also called a “dead zone”) and The launch cable will also provide a mating connector to the cable under test. A similar cable shall be used on the far end of the cable under test to provide a reference connection for testing the loss of the end connector.
b. Adjust the OTDR settings appropriately for the cable under test.
c. Obtain a trace of the fiber being tested.
d. Analyze the OTDR trace for fiber length and events (connectors, splices, locations of stress losses.)
e. Test in each direction and average to obtain absolute loss values of splices and connectors.



Information in the OTDR trace

Store a copy of the trace for submission with other test data and cable plant documentation.

Using OTDR Automatic Testing
OTDRs generally have an automatic testing function that sets up the OTDR measurement parameters, takes a trace and provides analysis. Many of these OTDRs provide excellent data for most testing, but before using it for all measurements, a test trace should be analyzed by an experienced technician to ensure the tests are properly set up and analyzed.

OTDR Measurement Uncertainty
OTDR measurements may have errors associated with the nature of the backscatter measurement, the setup of test parameters or the interpretation of the traces. It is recommended that OTDRs only be used by trained personnel who know how to set up the instrument and interpret the results. It is recommended that users not use any automatic testing option until several fibers have been tested and interpreted by a knowledgeable operator to ensure the data is correct.

a. OTDRs use an indirect method of measurement that depends on the backscatter coefficient of the fiber and may not correlate with direct insertion loss testing.
b. Joints between dissimilar fibers (splices or connections) with different backscatter coefficients will show different losses when tested in both directions, even showing a gain in one direction. Average the readings to get a loss that has less uncertainty.
c. OTDRs have a distance resolution limited by the width of the test pulse. Set the pulse as short as possible for the range needed to reach the end of the cable plant being tested for best resolution.
d. OTDRs may not be useful for short cables. If the trace does not show a flat trace of fiber loss after a connection, it is not an appropriate cable to test.

e. High reflectance events may cause spurious events called “ghosts.” Ghosts look like connectors but have no loss.

Annex C: References And Standards

Additional References For Training and Study For FOA Certification or Additional Knowledge
As with any fast-moving technology, keeping abreast of the latest technology, techniques and products can be a daunting task. FOA has many options to help you. Here are some references that will assist you.

QR codes link to the relevant FOA websites.

FOA Websites
The FOA website, www.foa.org, can be your starting page for links to other FOA resources.

Home Page
The FOA home page has links to all the FOA online sites.

FOA Home Page

Technical Reference Pages
FOA has the Online Fiber Optic Reference Guide (www.foaguide.org) with almost 1,000 pages of technical material about fiber optics.

FOA Guide

Online Learning
The FOA has an online learning site, Fiber U (www.fiberu.org) that offers free self-study programs on topics aligned to FOA certifications. These programs are perfect for learning more about fiber optics and cabling, studying for FOA certifications or preparation to taking a course from an FOA approved schools. The programs are free and each one offers a “Certificate of Completion” examination at a small cost.

Fiber U

Videos
The FOA has over 100 YouTube Videos including many lectures on fiber optics and premises cabling, demonstrations of how fiber actually works and directions for hands-on installation. The FOA YouTube channel is “thefoainc” and links to the videos are on the Table of Contents of the FOA Online Reference Guide.

FOA YouTube Channel

FOA Textbooks
The FOA has published other Reference Guides that are the references for FOA certifications.

The FOA Reference Guide to Fiber Optics, Second Edition, is the general reference guide for fiber optics and the basic study guide for the CFOT certification. It is also available in Spanish, Portuguese and French.

The FOA Reference Guide to Premises Cabling is a reference guide for copper and fiber optic cabling and wireless as used in indoor applications and the basic study guide for the CPCT certification. Also available in Spanish.

The FOA Reference Guide to Outside Plant Fiber Optics is a reference guide for fiber optic cabling as used in outdoor applications and the basic study guide for the CFOS/O certification.

FOA Reference Guide To Fiber Optic Testing is a comprehensive guide to fiber optic testing including test requirements, instruments, test methods and measurement uncertainty. This is the study guide for the FOA CFOS/ T certification.

FOA Fiber to the Home Handbook is a comprehensive guide to fiber to the home/premises or business networks. This is the study guide for the FOA CFOS/ H certification. Also available in Spanish.

Lennie Lightwave's Guide To Fiber Optics is the "comic book" introduction to fiber optics. Lennie has been available for three decades and has been the most popular way of getting started in fiber optics.

FOA Guide To Fiber Broadband. Every communications network today depends on fiber optics, especially the Internet. This book explains not only what fiber broadband is and how many ways it is used, but how it was developed. It is perhaps as much a history book as a textbook.

All FOA textbooks are available for purchase from most booksellers and Amazon.

FOA Standards

Concise versions of industry standards

- FOA Standard FOA-1: Testing Loss of Installed Fiber Optic Cable Plant, (Insertion Loss, TIA OFSTP-14, OFSTP-7, ISO/IEC 61280, ISO/IEC 14763, etc.)
- FOA Standard FOA-2: Testing Loss of Fiber Optic Cables, Single Ended, (Insertion Loss, TIA FOTP-171, OFSTP-7, , ISO/IEC 14763)
- FOA Standard FOA-3: Measuring Optical Power (Transmitter and Receiver Power, FOTP-95, Numerous ISO/IEC standards)
- FOA Standard FOA-4: OTDR Testing of Fiber Optic Cable Plant (TIA FOTP-8/59/60/61/78, ISO/IEC 14763, etc.)
- FOA Standard FOA-5 Fiber Optic Datalinks
- FOA Standard FOA-6: Fiber Optic Cable Plant
- FOA Standard FOA-7: Mode Conditioning For Testing Multimode Fiber Optic Cables
- FOA Standard FOA-8: Inspection and Cleaning of Fiber Optic Connectors

