Student Manual

STL academy

Subject

OSP Supervisor

Vol.01

Empowering Youth!

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Out Side Plant Technician

Submitted to :- **Bihar Skill Development Mission, Labour Resources Department, GoB**	Submitted By :- **Sterlite Technologies Ltd** Session : 2022-23

Course name:

- Course Id-
- Candidate Eligibility : Diploma/ Graduate
- Course Duration: (In hours) 550

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OUT SIDE PLANT (OSP) SUPEVISOR

STUDENT GUIDE

About the Student Guide

The student guide contains modules which will help you to acquire relevant knowledge and skills (generic and domain-specific skills) related to the 'OSP Supervisor' job role. Knowledge in each module is easily understood and grasped by you before you move on to the next module. Comprehensible diagrams & images from world of work have been included to bring about visual appeal and to make the text lively and interactive for you. You can also try to create your own illustrations using your imagination or taking the help of your trainer.

Let us now see what the sections in the modules have for you.

Section 1: Learning Outcome

This section introduces you to the learning objectives and knowledge criteria covered in the module. It also tells you what you will learn through the various topics covered in the module.

Section 2: Relevant Knowledge

This section provides you with the knowledge to achieve relevant skill and proficiency to perform tasks of the OSP Supervisor. The knowledge developed through the module will enable you to perform certain activities related to the job market. You should read through the textual information to develop an understanding on the various aspects of the module before you complete the exercise(s).

Section 3: Exercises

Each module has exercises, which you should practice on completion of the learning sessions of the module. You will perform the activities in the classroom, at home or at the workplace. The activities included in this section will help you to develop necessary knowledge, skills and attitude that you need for becoming competent in performing the tasks at workplace. The activities should be done under the supervision of your trainer who will guide you in completing the tasks and also provide feedback to you for improving your performance.

Section 4: Assessment Questionnaire

The review questions included in this section will help you to check your progress. You must be able to answer all the questions before you proceed to the next module.

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CONTENTS

MODULE 1
BASICS OF OPTICAL FIBER

Section 1: Learning Outcomes

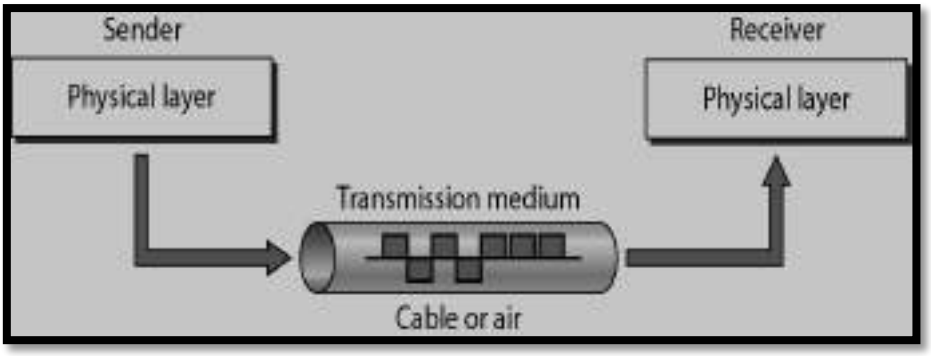
After completing this module, you will be able to:

- Differentiate between various types of Transmission Media
- Explain Geometry of Optical Fiber
- Explain Principle of Fiber Optics - Total Internal Reflection
- Describe Optical Fiber Communication System
- State Applications and Advantages of Optical Fiber
- Explain the Mode Theory and Waveguide Equations
- Explain concept of Cut-off Wavelength and Mode Field Diameter (MFD)
- Tell History of Fiber Optic Communication
- Classify Optical Fibers
- Describe Optical Fiber Communication Wavelengths and their properties
- Explain performance parameters of optical fiber viz. Attenuation and Dispersion
- Distinguish between characteristics and application of different Grades of Optical Fiber

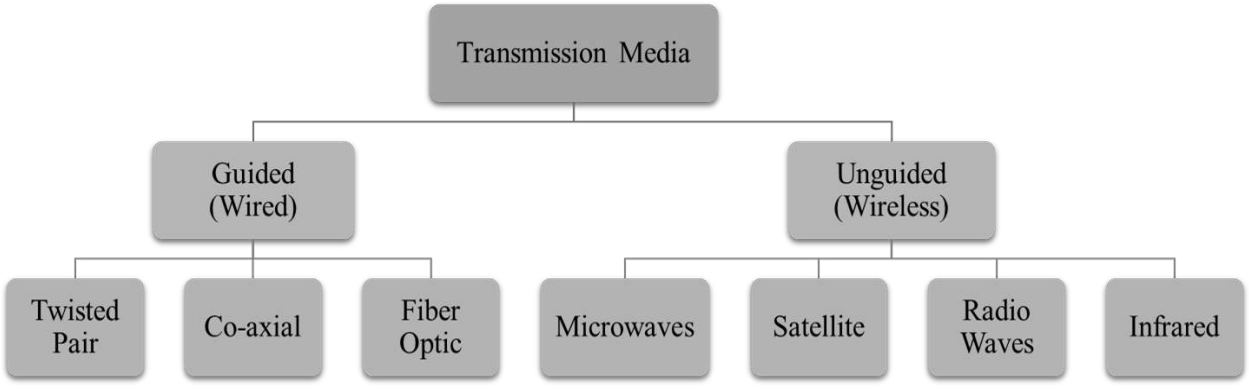
Section 2: Relevant Knowledge

1.1 Transmission Media

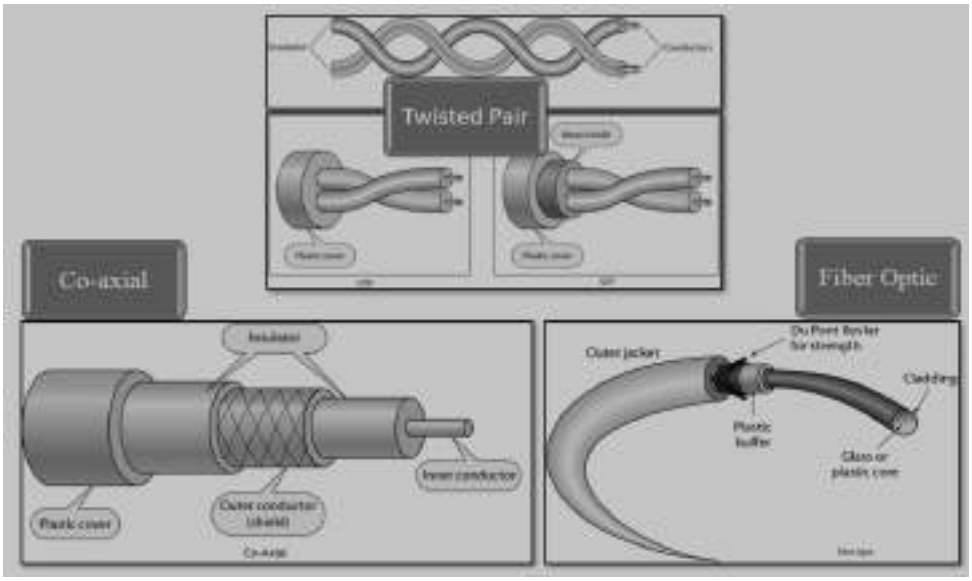
Transmission media or medium is a pathway that carries the information from sender to receiver.



Classification of Transmission Media



Guided (Wired) Media



Unguided (Wireless) Media

Band	Range	Propagation	Application
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

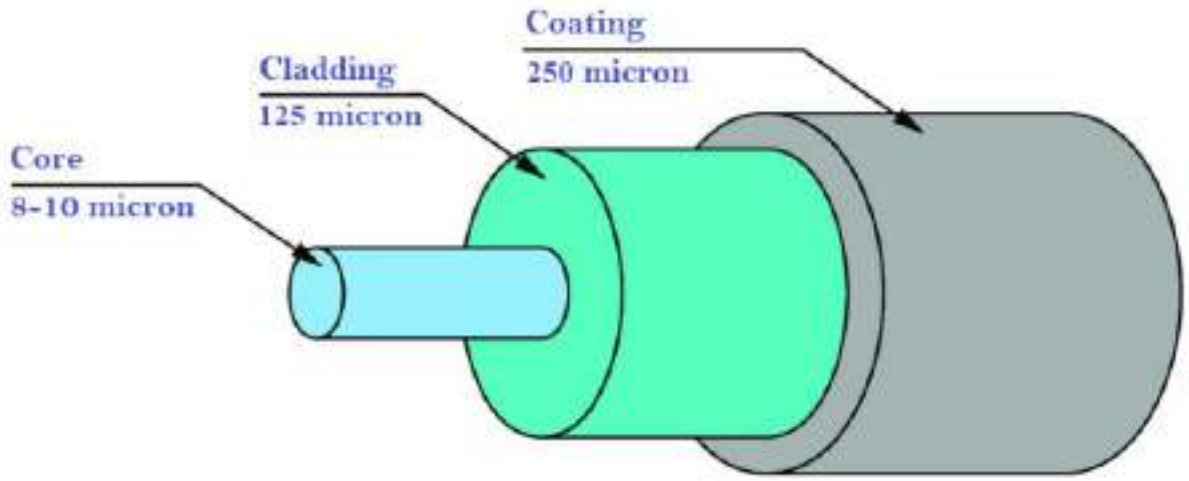
- Microwaves (6, 7, 10, 15, 18, 23 GHz)
  - Point to Point communication
  - Line of Sight (LOS)
- Satellites (C: 4-8 GHz, Ku: 10-18 GHz, K: 18-26 GHz, Ka: 26-30 GHz)
  - Commonly used for News channels, DTH television broadcast etc.
  - Very expensive
  - Delay in transmission
- Radio waves (300 MHz – 5 GHz)
  - Diversified applications – AM, FM, Mobile communication etc.
  - Used for mass communication
- Infrared (1-100 THz)
  - Remote controls, toys etc.
  - Used for Short distance applications
  - Prone to error

1.2 Geometry of Optical Fiber

Definition of Optical Fiber

Optical Fiber is a composite material, usually consisting of a silica-based core and cladding surrounded by one or two layers of protective polymeric material.

What is Optical Fiber?



- Ø An optical fiber is a waveguide for light.
- Ø It consists of a Core and a Cladding that surrounds the core.
- Ø Works on phenomenon of “Total Internal Reflection”.
- Ø Light signals are sent down a plastic or glass hair-thin fiber called the Core.
- Ø Each core is coated with a material called Cladding to prevent light from escaping.
- Ø The cladding is coated with additional material or a buffer, which protects the fiber from physical damage and moisture.

1.3 Principle of Fiber Optics - Total Internal Reflection

Refractive Index

- Ø Light travels at 299,792,458 meters per second in vacuum. This speed of light in vacuum is usually denoted by c.
- Ø But light travels more slowly when it passes through a transparent material.
- Ø The degree of slowing down depends on the material's refractive index.
- Ø Refractive index (n) of a transparent material (denoted by n) is defined as:

$$n = c / v$$

where **c** is the speed of light in vacuum, **v** is the speed of light (velocity) in this transparent material.

$$\text{Refractive Index} = \frac{\text{Speed of Light in Vacuum}}{\text{Speed of Light in Medium}}$$

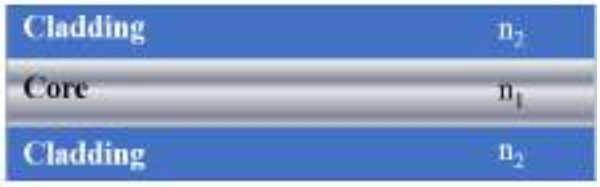
Medium	Refractive Index (Approx.)
Vacuum	1
Water	1.33
Glass	1.5
Plastic	1.3 to 1.6
Diamond	2.42

- Ø The refractive index of water is 1.33, meaning that light travels 1.33 times as fast in a vacuum than it does in water.
- Ø The refractive index of air at atmospheric pressure and room temperature is 1.000293.

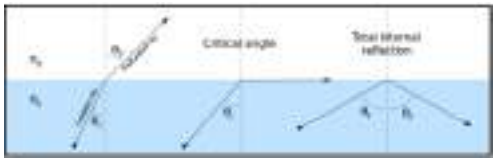
Clad : Glass with Lower Refractive Index (n_2)
Core : Glass with Higher Refractive Index (n_1)

$$n_1 > n_2$$

In typical optical fiber, the refractive index of the core is 1.68 and the refractive index of clad is 1.44.



- Ø When light is incident on a medium of lesser Refractive Index, the ray is bent away from the normal i.e. exit angle is greater than the incident angle.
- Ø On increasing the incident angle, the exit angle will approach 90°. This incident angle is called Critical Angle (θ_c).
- Ø For all incident angles greater than the critical angle, there will be Total Internal Reflection.



Critical Angle (θ_c) is the largest angle of incidence for which refraction can occur

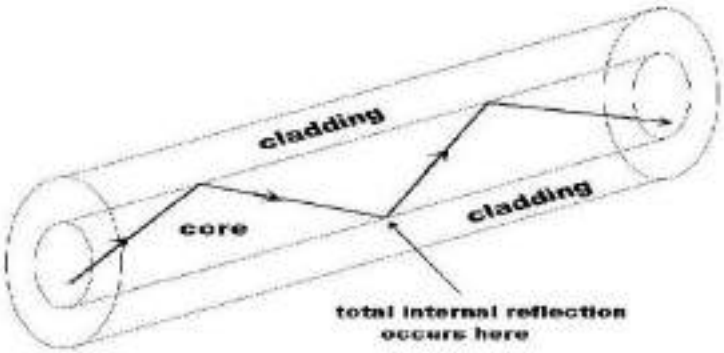
Total Internal Reflection

Ø There is a critical angle at which no light can be refracted at all, so 100% of the light is reflected.
Ø Light is trapped in the water and cannot escape into the air.
Ø This works with any dense medium, such as plastic or glass, the same way it works with water

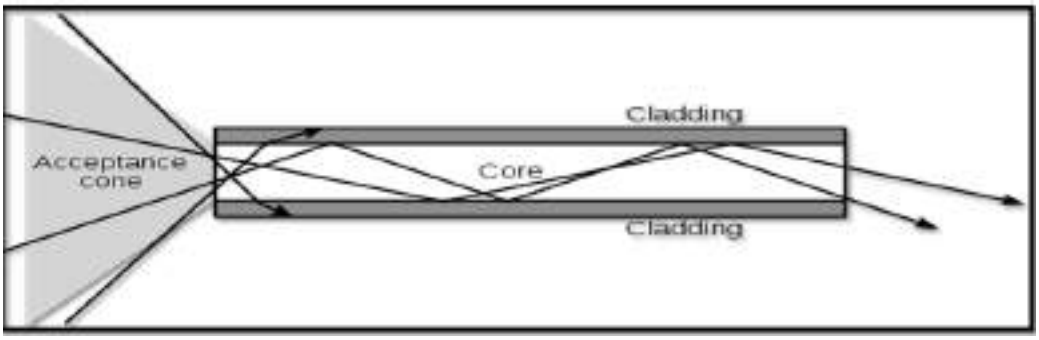
How Light Travels in Fiber

TIR conditions in Optical Fiber:

Ø The index of refraction of Core should be greater than Clad



Ø The angle of incidence of the light ray within the Acceptance Cone must exceed the Critical angle.

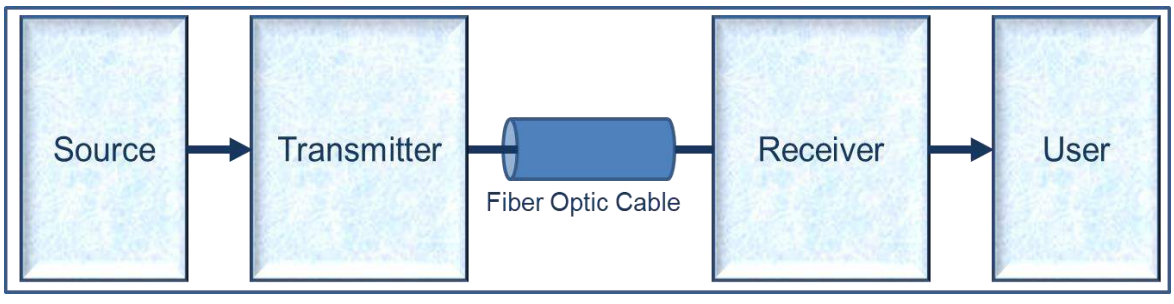


1.4 Optical Fiber Communication System

Typical Communications System

A basic communications system consists of:

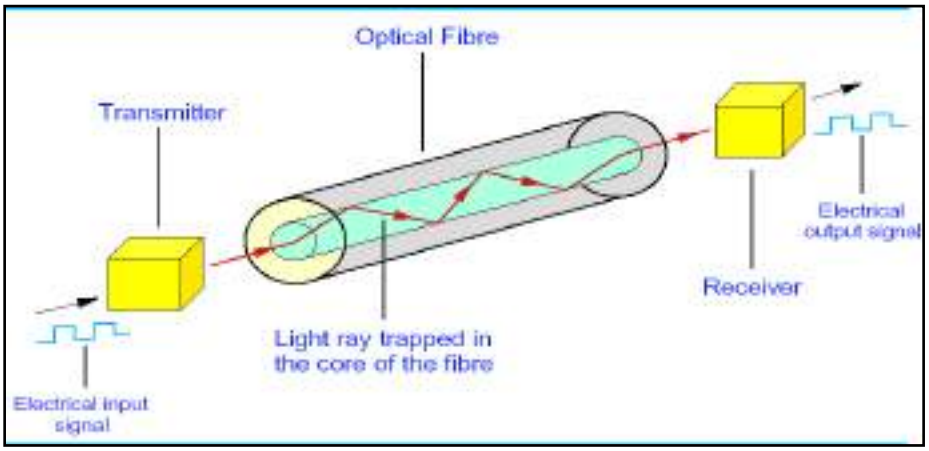
- A Transmitter
- A Receiver
- An Information Channel / Optical Fiber



Journey through the "Optical Tunnel"

Ø Light-Emitting Diode (LED) or Laser Diode (LD) acts as optical source that converts electrical signal-data rate-into optical signal.

Ø Avalanche Photodiode (APD) is generally used as optical detector.



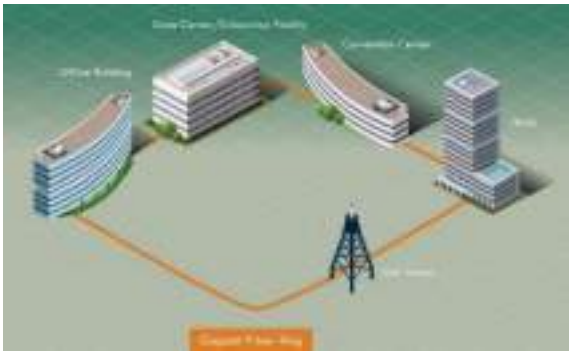
1.5 Applications and Advantages of Optical Fiber

Why Optical Fiber?

Application of Fiber Optics

Ø Telecommunication Networks (Terrestrial and Submarine)
Ø Electrical Power Line Communication
Ø Fiber To The Home (FTTH)
Ø Cable Television
Ø Medical Imaging Tools and Surgeries
Ø Computer Networking
Ø Control Systems

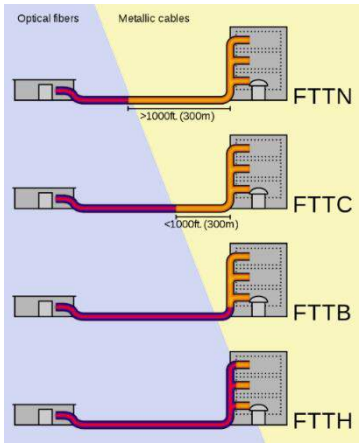
Submarine Cables



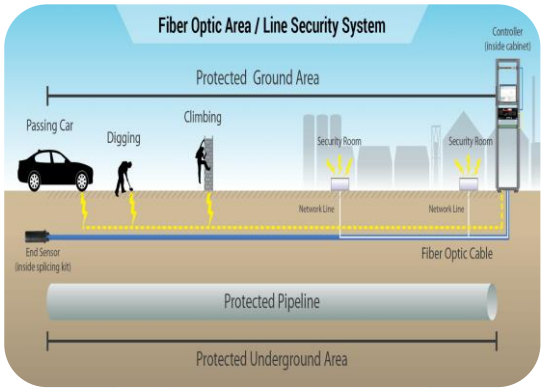
Telecom Network

Electrical Power lines Communication

Computer Networking

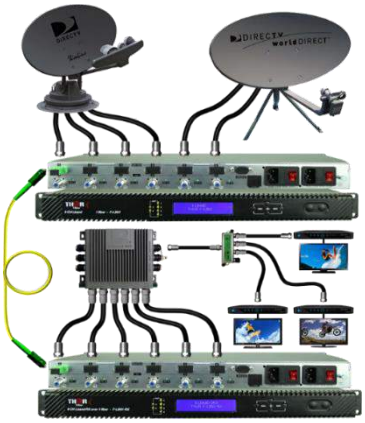


Customer Premise Communications Network



Control Systems

Medical Imaging Tools and Surgery

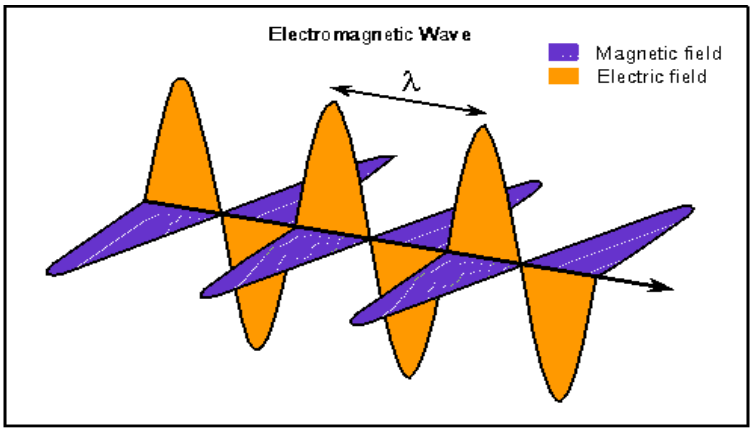


Cable Television

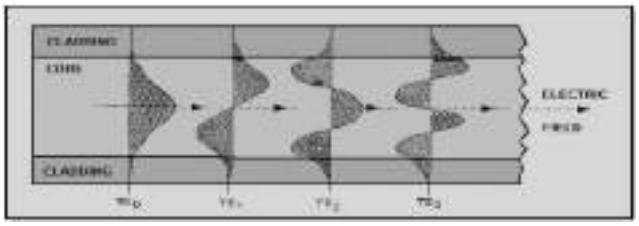
1.6 Mode Theory and Waveguide Equations

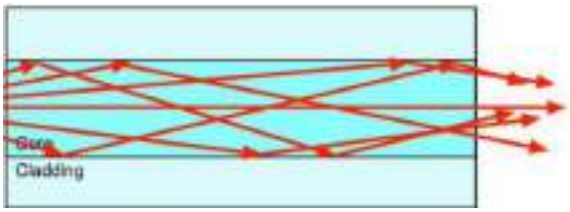
Mode Theory

- Ø The mode theory is used to describe the propagation of light along an optical fiber.
- Ø The mode theory uses electromagnetic wave behavior to describe the propagation of light in the fiber.
- Ø A set of guided electromagnetic waves is called the Modes of the fiber.
- Ø Light as a variety of EM vibrations: Electric and Magnetic field at right angle to each other and perpendicular to direction of propagation.



- Ø The TE (Transverse Electric) mode field patterns shown in below figure indicate the order of each mode.
- Ø The order of each mode is indicated by the number of field maxima within the core of the fiber.
- Ø For example, TE0 has one field maxima. The electric field is a maximum at the center of the waveguide and decays toward the core cladding boundary.
- Ø TE0 is considered the fundamental mode (Single Mode).
- Ø As the number of field maxima increases, the order of the mode is higher. (In below figure TE2 has 3 field maxima, that means it has 3 modes (Multimode) are propagating in the fiber.
- Ø Generally, modes with more than a few (5-10) field maxima are referred to as high-order modes.
- Ø High-order modes cross the axis of the fiber at steeper angles. Low-order and high-order modes are shown in below figure.





Types of Modes

Fibers can support different types of modes:

- Guided modes: Light distributions limited to the core and its immediate vicinity. Possess small propagation losses.
- Leaky Mode: Concentrated around the core but lose some power into the cladding.
- Cladding modes: Light intensity fill the full cladding region, thus also reaching the outer surface of the cladding, where they often experience large power losses.

In general, the number of guided modes increases with decreasing wavelength

Principle of Waveguiding in Optical Fiber

- A waveguide is a material structure that can “guide” light, i.e., let it propagate while preventing its expansion in one or two dimensions.
- Fibers are waveguides that guide in two dimensions and can effectively be used as flexible pipes for light.

Numerical Aperture

- Total internal reflection at the interface occurs, if the external beam angle θ (in air) fulfills the condition:

$$\sin\theta < NA \equiv \sqrt{n_{\text{core}}^2 - n_{\text{cladding}}^2}$$

- Where, NA is called the numerical aperture of the fiber and n is refractive index of the material

V Number

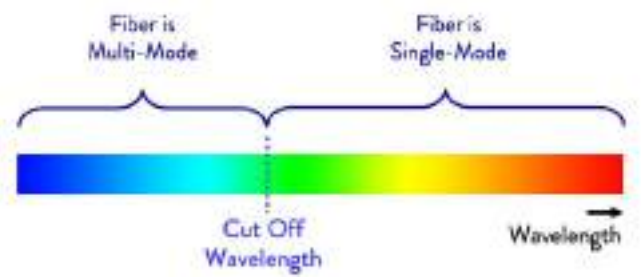
$$V = \frac{2\pi}{\lambda} a\ NA = \frac{2\pi}{\lambda} a \sqrt{n_{\text{core}}^2 - n_{\text{cladding}}^2}$$

The V number determines the number of guided modes in fiber at different wavelengths and refractive index of the fiber.

- For example, single-mode propagation is obtained when V is smaller than 2.405.
- The V number depends on the wavelength.

Cut-Off Wavelength

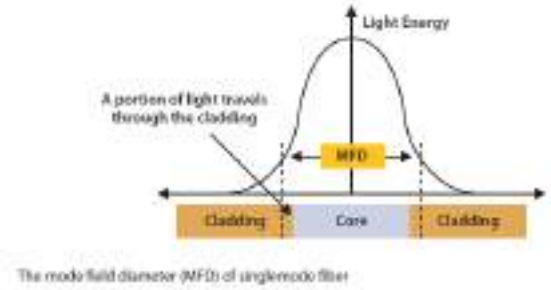
- Ø The cut-off wavelength of a single mode fiber is the wavelength below which the fiber propagates more than modes.
- Ø Above cut-off, the fiber will transmit only one mode.
- Ø An optical fiber that is single-moded at a particular wavelength may have two or more modes at wavelengths lower than the cutoff wavelength.



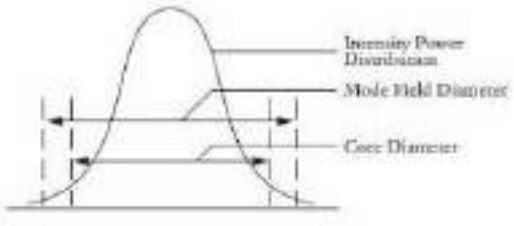
- Ø The effective cutoff wavelength of a fiber is dependent on the length of fiber and its deployment and the longer the fiber, the lower the effective cutoff wavelength.
- Ø The smaller the bend radius of a loop of the fiber is, the lower the effective cutoff wavelength will be.
- Ø If a fiber is bent in a loop, the cutoff is lowered.
- Ø The cutoff wavelength of a fiber is reduced when it is cabled.

Mode Field Diameter

- Ø The mode field diameter (MFD) describes the width of the fiber area in which light travels.



- Ø MFD is determined by the numerical aperture (NA) and cut-off wavelength of the fiber and is related to the diameter of the fiber core.
- Ø In general, MFD is greater than the physical diameter of the fiber core - which means that some optical power travels in the fiber cladding.
- Ø The MFD is typically larger than the core diameter.
- Ø For fiber operated above cut-off wavelength, the core diameter might be around 9 µm, and the MFD is around 10.4 µm.
- Ø From these equations, you can see that MFD increases as cut-off wavelength increases (as does core-size).

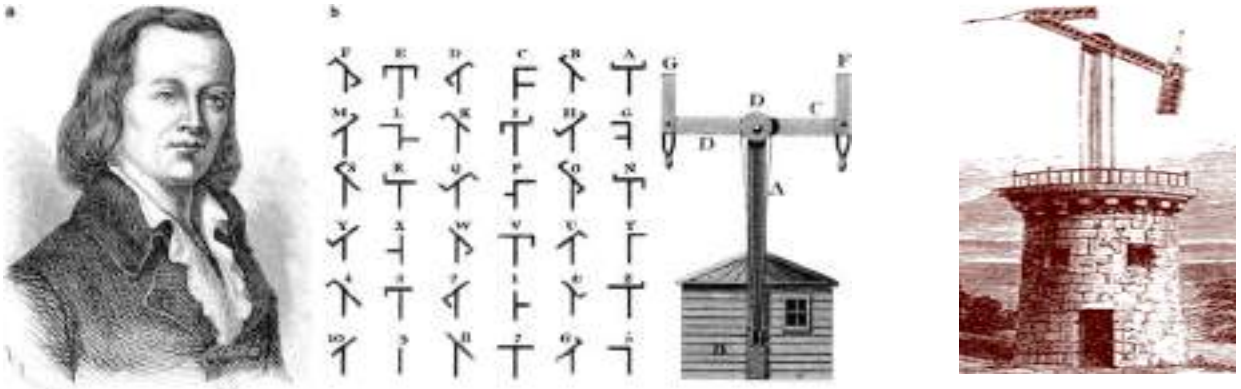


1.7 History of Optical Fiber Communication

1790 – Use of Semaphores

Ø The french used semaphores to transmit messages.

Ø Later systems also sent optical signals through the air, but clouds, rain, and other atmospheric disturbances can disrupt optical signals sent through the air.



Claude Chappe, his coding scheme and the mechanical device used for making optical telegraphs

1841 – Total Internal Reflection

Jean-Daniel Colladon, a 38-year-old Swiss professor at University of Geneva, demonstrated light guiding or TIR for the first time.

John Tyndall

1854 – Refraction through stream of water

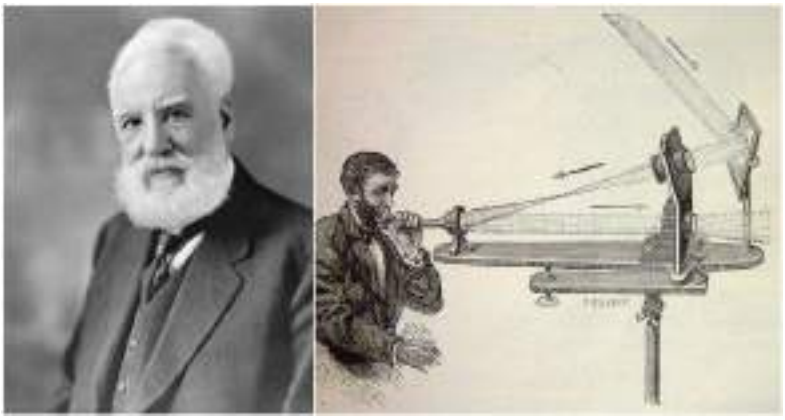
Ø John Tyndall demonstrated first guided transmission of light.

Ø He used basin with hole in bottom to direct stream of water.

Ø Sunlight was refracted through the stream of water.

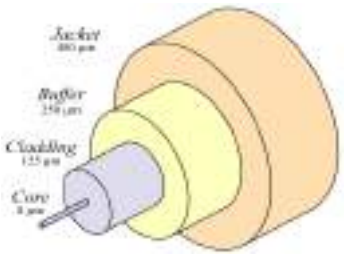
1880 - Photophone

Ø Alexander Graham Bell Invented the photophone, a device to carry voice signals through the air instead of wires. He transmitted a voice signal on a single beam of light.



Alexander Graham Bell with his Photophone

1920 - Television images through transparent pipes



- John Logie Baird (England) and Clarence W. Hansell (U.S.) demonstrated a method to carry television images through transparent pipes.
- Images were transmitted in 1933.
- It was a very short distance, but the quality was very, very low.

1954 – Fiber With Cladding

- Abraham Van Heel, Hopkins & Kapany invented modern optical fiber by covering a bare glass fiber with a transparent coating, later called cladding. It had a lower refractive index than the bare fiber. The result was that the light was contained in the fiber and did not leak out.
- The bundle, which the authors called the Fibroscope, had several hundred fibers of 75 cm in length. It Reduces cross-talk from fibers in bundles.
- Kapany coined the term fiber optics, wrote a 1960 article in Scientific American that introduced the topic to a wide audience, and wrote the first book about the new field.

Dr. Narinder Singh Kapany

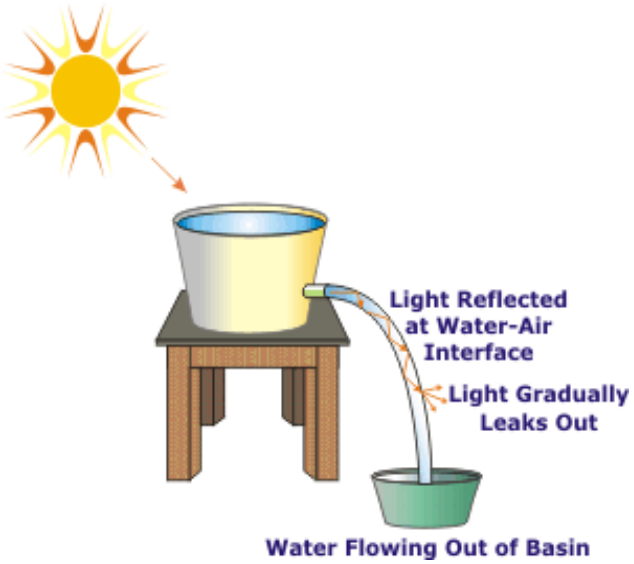
1960 - Medial Imaging Invention of the Laser Fiberscope

- Fibroscope allowed inspection of boilers and medical imaging. Glass-clad fibers were now available for medical instruments, to look inside the body.
- The glass was unable to transmit light far enough for communications, because of impurities.
- Optical Fibers had losses of 1 dB/meter.

Manfred Börner

1965 – First working fiber-optic data transmission system

The first working fiber-optic data transmission system was demonstrated by German physicist Manfred Börner at Telefunken Research Labs in Ulm.



1966 – Higher bit rate transmission

Charles K. Kao

- Charles K. Kao proposed that communications were possible with single mode fiber.
- He correctly and systematically theorized the light-loss properties for optical fiber and pointed out the right material to use for such fibers, that is, silica glass with high purity.
- He developed a fiber that could transmit 1 GHz (One billion bits per second).
- Attenuation of less than 20 dB/km was possible with optical fiber.
- This discovery earned Kao the Nobel Prize in Physics in 2009.

1968 – Fiber optics in the television cameras

NASA used fiber optics in the television cameras that were sent to the moon.

1970 – Low-attenuation silica glass fibers

- Corning scientists developed low-attenuation silica glass fibers.
- They used Single mode fiber at 633 nm wavelength.
- Attenuation was below 20 dB/km.

1977 – First metropolitan fiber optic cable deployment with repeaters

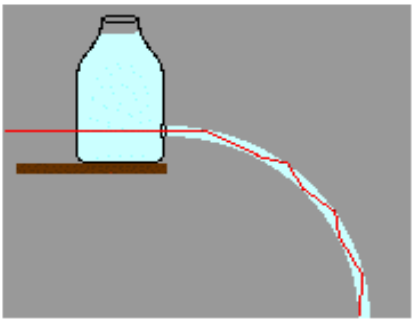
- The first metropolitan fiber optic cable being deployed in Turin, Italy in 1977 by Italian research center, CSELT working with Corning.
- Telephone signals used infrared light with a wavelength of 850 nm to send data at 6.2 Mbps and 45 Mbps. Loss was 2 dB per km.
- Repeaters were required every few kilometers. The repeaters were electro-optical – converting the light to electricity and then back to light.

1986 – Fiber Amplifiers

- Fiber was replacing the copper, microwave and satellite links.
- The erbium-doped fiber amplifier, which reduced the cost of long-distance fiber systems by reducing or eliminating optical-electrical-optical repeaters, was developed at Bell Laboratory.
- Fiber amplifier amplifies light without changing it to an electrical signal first.

1992 – Lower attenuation systems

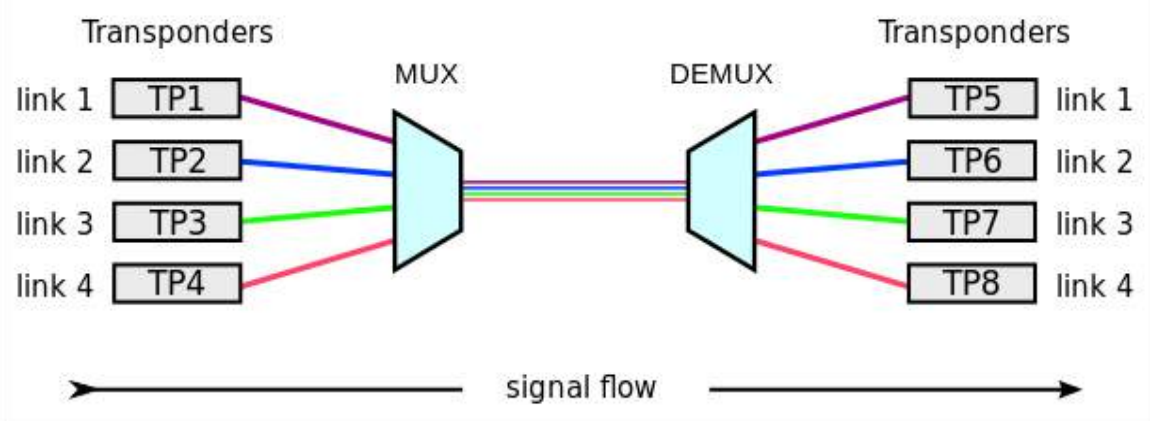
- 1550 nm systems appear for the first time.
- Fiber attenuation now at 0.2 dB/km at 1550 nm.
- Community antenna television (CATV) CATV started using fiber to enhance the reliability of their networks.
- CATV companies also discovered they could offer phone and Internet service on that same fiber and greatly enlarged their markets.



The laser beam stays internal to the water, continuously reflecting at each boundary.

1994 – Wave Division Multiplexing

Several signals can be sent through the same fiber simultaneously by using different wavelengths (colors) of light. That means, more bandwidth—more data per second.

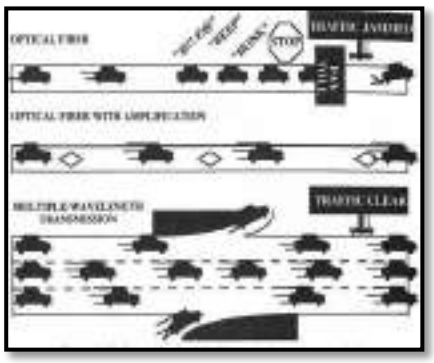


1996 - The Internet boom begins

- Ø Dense Wave Division Multiplexing (DWDM) systems become widely available.
- Ø Some systems have an aggregate capacity of 10 Gb/second.
- Ø Optical fiber is placed in the ground at phenomenal rates.
- Ø Digital Subscriber Lines become available at much faster rates than dial-up connections.
- Ø Dot.com boom shows no signs of stopping.

1980

- 565 Mbps
- Electro-optical repeaters



1996

- 2.5 Gbps
- Optical amplifiers

1998

- 20 Gbps
- WDM with 8 wavelengths

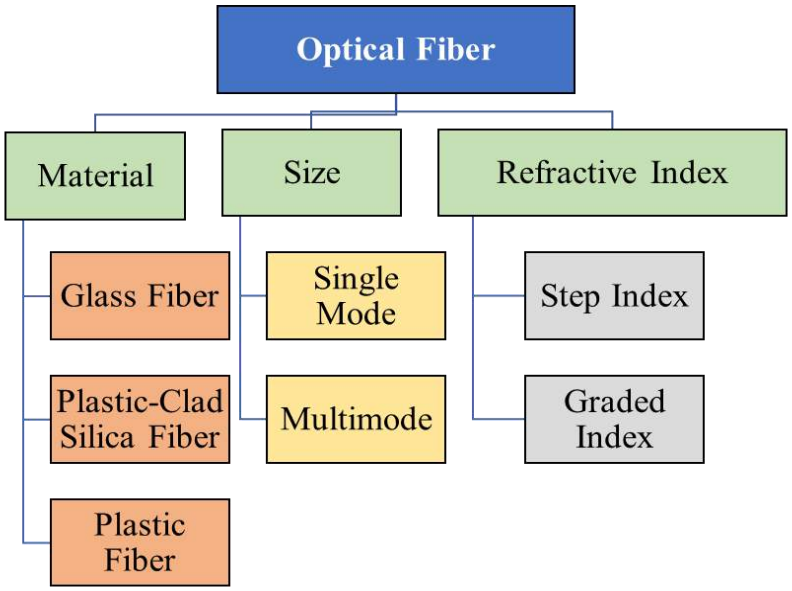
2000 - Photonic crystal fibers

- Ø The field of photonic crystals led to the development in 1991, which guides light by diffraction from a periodic structure, rather than by total internal reflection. The first photonic crystal fibers became commercially available in 2000.
- Ø Photonic crystal fibers can carry higher power than conventional fibers and their wavelength-dependent properties can be manipulated to improve performance.

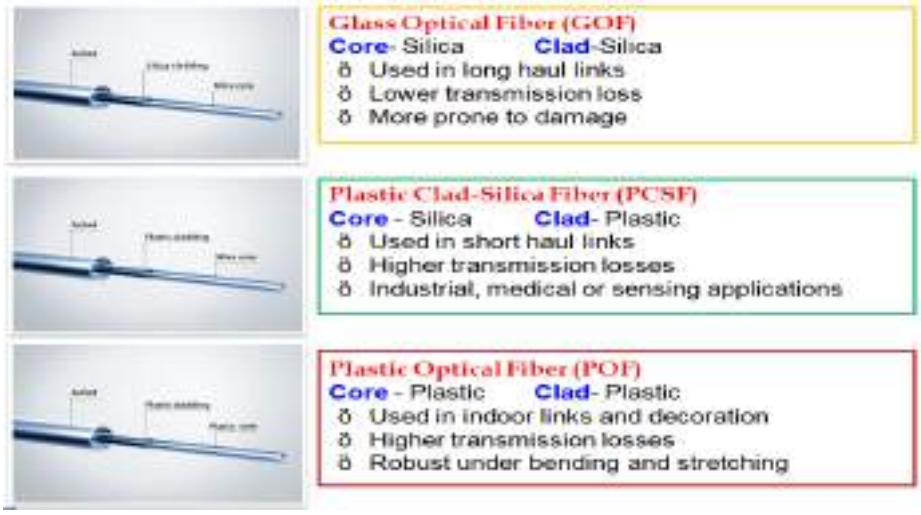
2022 - 100s of Gbps

- Ø Today, fiber is present in virtually every nation on the Earth, forming the absolute backbone of the modern communications infrastructure.
- Ø Attenuation in modern optical cables is far less than in electrical copper cables, leading to long-haul fiber connections with repeater distances of 70–150 kilometers. Maximum data rates achieved are in 100s of Gbps with minimum attenuation of 0.2 dB per km in long distance communication.

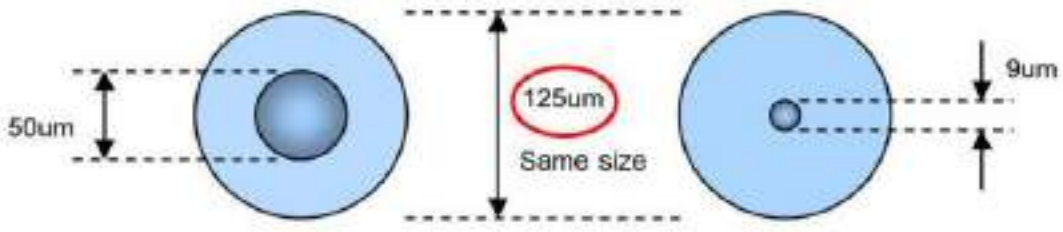
1.8 Classification of Optical Fiber



Classification According to Material



Classification According to Size



Ø Mode is a path for light ray through an optical fiber.

Ø If an optical fiber supports only one mode, it is called as single mode fiber. Multimode supports more than one mode.

Multi–mode Fiber

- Multi–mode Fiber are characterized by relatively large core diameters.
- Typical values of core diameters are 50 and 62.5 micrometers
- A multi–mode fiber supports more than one propagating mode.

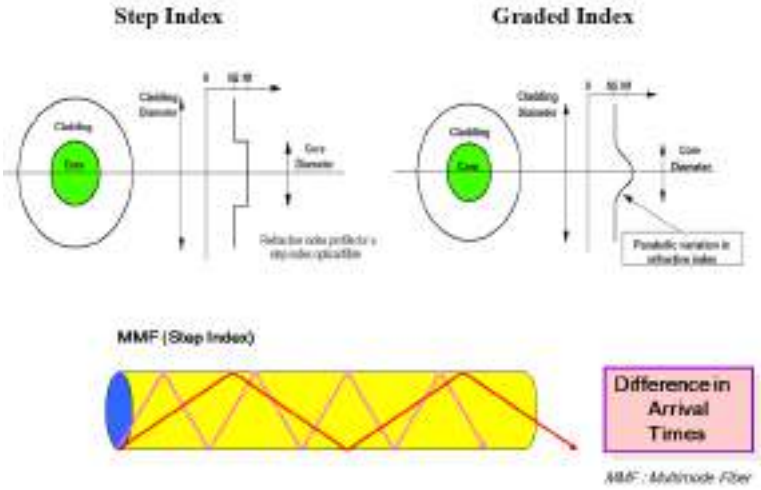
Single Mode Fiber

- Single Mode Fiber supports only a single propagating mode.
- It is characterized by small core diameters ranging from 3 to 10 micrometers.
- For the purpose of understanding the concept we shall define the mode simply as a path that a light ray can follow in traveling down a fiber.


Multimode Fiber	Single-mode Fiber
Large Core Diameter	Small Core Diameter
More Light Modes	Single Light Mode
High Loss	Low Loss
Used in Short Distance Links	Used in Long Distance Links

Classification According to Refractive Index

Step–Index Fiber

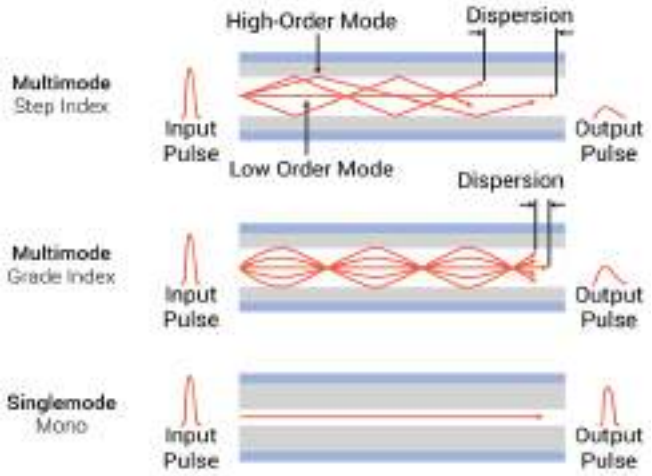


- In step-index fibers, the index of refraction changes radically between the core and the cladding.
- The step–index fiber is characterized by a uniform index throughout the core material.
- The profile shows a sharp step at the junction of the core and cladding.
- The step index fiber gets its name from the step like index profile of the core.
- The transmission capacity is limited by the modal dispersions (different modes travel through the fiber with different delays, causing signal distortion).
- Step-index fibers are available with core diameters of 100 to 1500 µm. They are well suited to applications requiring high power densities, such as medical and industrial laser power delivery.

Graded Index Fiber

- Ø In contrast, the graded index has a non–uniform core.
- Ø Graded-index fiber is a compromise multimode fiber, but the index of refraction gradually decreases away from the center of the core
- Ø Graded-index fiber has less dispersion than a multimode step-index fiber.
- Ø Graded Index Profile can only be designed for Multimode Fibers
- Ø The index is highest at the centre and it gradually decreases until it matches that of the cladding.
- Ø In graded index fiber, the light rays are also guided down the fiber in multiple pathways.
- Ø Due to the parabolic refractive index profile, modal dispersion is reduced to minimum (different modes propagate through the fiber with the same delay).
- Ø The modal dispersion can be reduced by using graded–index fiber.
- Ø The graded–index (or GRIN) fiber has a core material whose refractive index varies with distance from the fiber axis.
- Ø Index is maximum at the core center and decreases gradually towards the core–cladding interface.
- Ø Those rays that follow the longest path by travelling near the outside of the core, have a faster average velocity.
- Ø The light travelling near the axis of the core has the slowest average velocity.
- Ø As a result of this, all rays tend to reach the end of the fiber at the same time.

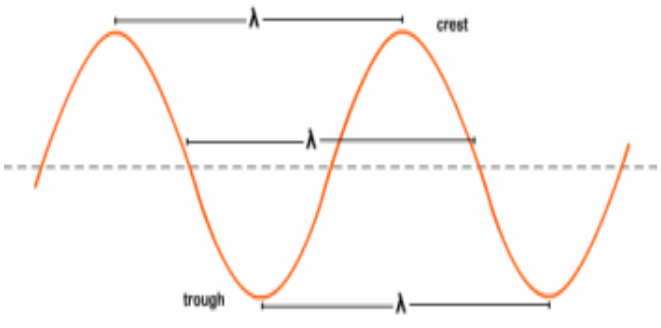
Optical Fiber Transmission Modes



1.9 Optical Fiber Communication Wavelengths

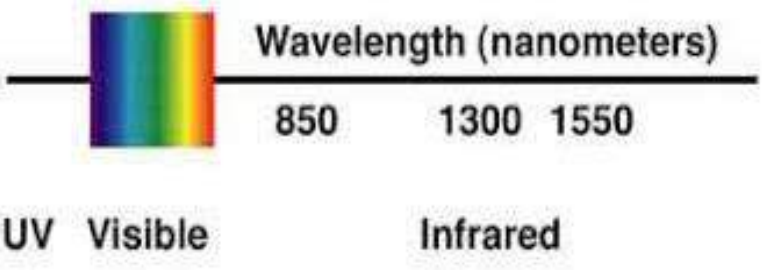
Wavelength

- Ø Wavelength is the distance between two nearest amplitude positive peaks.
- Ø The amplitude rises from 0 to a positive peak, goes through 0, goes to negative peak, then returns back to 0.
- Ø This is a complete cycle and the distance light travels during this cycle is called a wavelength.
- Ø It is usually represented by the symbol λ and defined in Nanometers (nm).

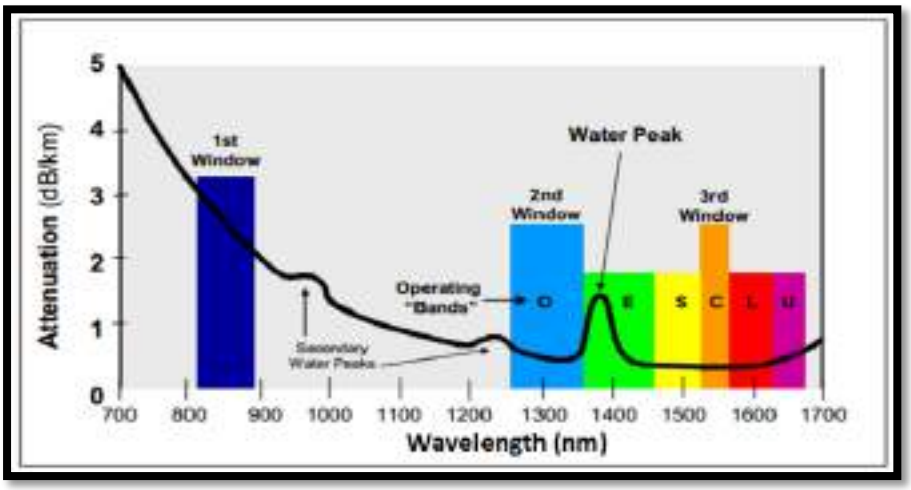


Optical Fiber Spectral Bands

- Ø Our eyes are sensitive to light whose wavelength is in the range of about 400 nm to 700 nm, from the violet to the red.
- Ø For fiber optics with glass fibers, we use light in the infrared region which has wavelengths longer than visible light.
- Ø The 850-nm-band is the primary wavelength for multimode fiber optical communication systems



- Ø The three main wavelengths used for fiber optic transmission are 850, 1310 and 1550 nanometers.
- Ø These wavelengths are used in fiber optics because they have the lowest attenuation of the fiber.
- Ø Multimode fiber is designed to operate at 850 nm and 1300 nm, while single-mode fiber is optimized for 1310 nm and 1550 nm.



Band	Wavelength (nm) Range
O – Original	1260-1360
E – Extended	1360-1460
S – Short Wavelength	1460-1530
C – Conventional	1530-1565
L – Long Wavelength	1565-1625
U – Ultra Long Wavelength	1625-1675

1.10 Attenuation in Optical Fiber

Decibel (dB)

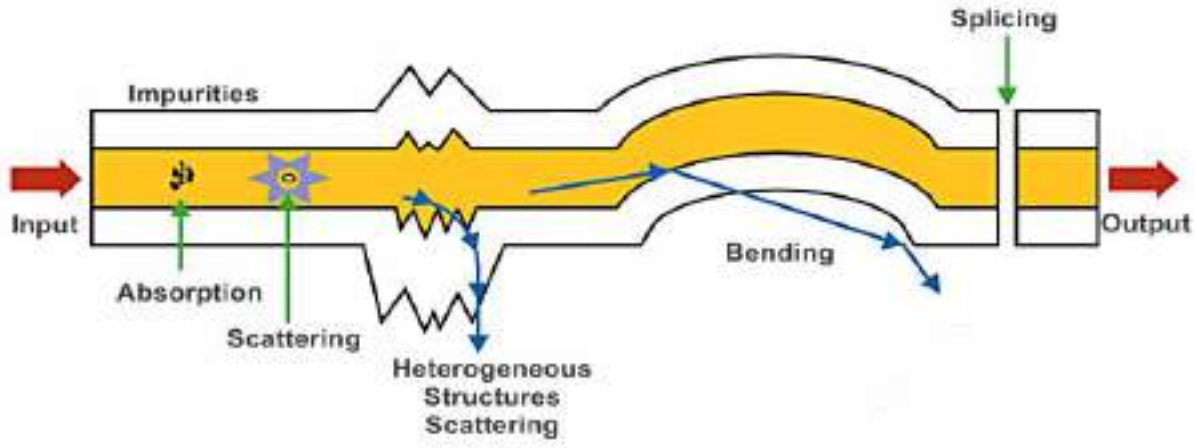
Ø A decibel (dB) is a unit used to express relative differences in signal strength.
Ø Decibel is a logarithmic scale of power abbreviated as dB.

$$dB = 10 \log \left(\frac{Measured\ Power}{Reference\ Power} \right)$$

Ø In the case of fiber optic cable, we compare the power injected (reference power) at one end of the cable to the power received (measured power) at the other end.
Ø A loss of 10 decibels means only 10% of the light is received.
Ø A loss of 20 dB means 1% of the light is received.

Attenuation

Ø Attenuation is the loss of optical power as light travels along the fiber. It is expressed in dB (decibel).
Ø Attenuation in an optical fiber is caused by:
- Absorption
- Scattering
- Bending



Ø If the optical power injected was -20 dBm and the power received at the other end -21 dBm, then the attenuation of the link would be -20 - (-21) = 1 dB

Signal attenuation is defined as the ratio of optical input power (Pi) to the optical output power (Po). Optical input power is the power injected into the fiber from an optical source. Optical output power is the power received at the fiber end or optical detector.

One cause of attenuation is through something called absorption. Light signals can be lost through absorption by small amounts of water vapor, or trace metals, present in the glass. The most absorption takes place in specific wavelengths, known as water bands. In between the water bands are windows where the wavelengths have the least attenuation. It just so happens that these wavelengths are also ideal for building transmission lasers and signal detectors.

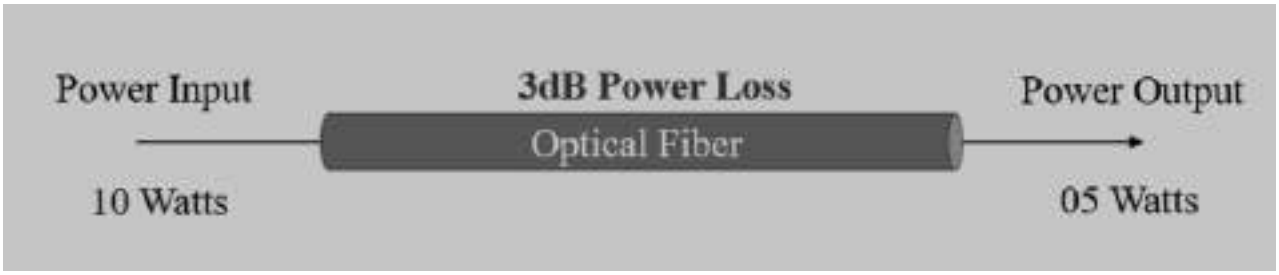
The attenuation of glass optical fiber is caused by two factors: absorption and scattering. Absorption occurs in several specific wavelengths called water bands due to the absorption by minute amounts of water vapor in the glass. Scattering is caused by light bouncing off atoms or molecules in the glass.

3dB Power Loss

Ø If light travels over 12 km of optical fiber with loss of 0.25 dB/km, what is the total loss?

3 dB

Ø On 3 dB loss in signal, the optical power is reduced by **Half**.



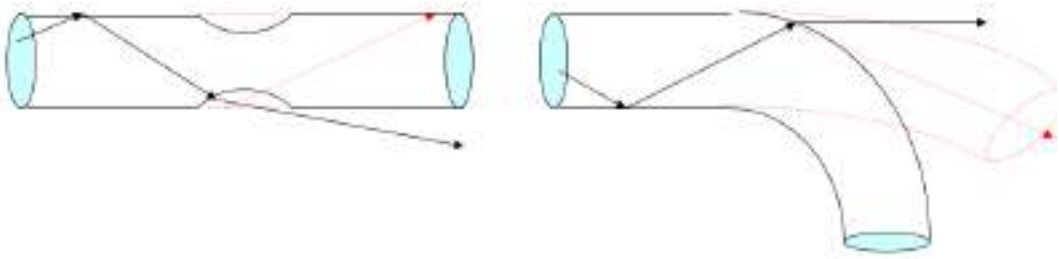
Fiber Bending

Micro Bending

Deformation of fiber axis (axial \ distortion) during fiber and cable manufacturing causes light to couple out of the fiber.

Macro Bending

Loss due to excessive bending manually.



Bends are bad for Single Transmission. Small Bends can increase loss. Bending the fiber also causes attenuation. Bending loss is classified according to the bend radius of curvature: microbend loss or macrobend loss. Microbends are small microscopic bends of the fiber axis that occur mainly when a fiber is cabled. Macrobends are bends having a large radius of curvature relative to the fiber diameter. Microbend and macrobend losses are very important loss mechanisms. Fiber loss caused by microbending can still occur even if the fiber is cabled correctly. During installation, if fibers are bent too sharply, macrobend losses will occur.

Microbend losses are caused by small discontinuities or imperfections in the fiber. Uneven coating applications and improper cabling procedures increase microbend loss.

External forces are also a source of microbends. An external force deforms the cabled jacket surrounding the fiber but causes only a small bend in the fiber. Microbends change the path that propagating modes take, as shown in figure 2-24. Microbend loss increases attenuation because low-order modes become coupled with high-order modes that are naturally lossy.

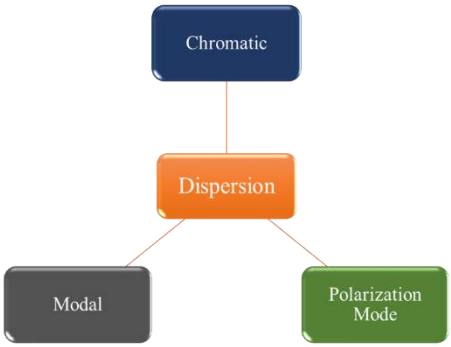
Macrobend losses are observed when a fiber bend's radius of curvature is large compared to the fiber diameter. These bends become a great source of loss when the radius of curvature is less than several centimeters. Light propagating at the inner side of the bend travels a shorter distance than that on the outer side. To maintain the phase of the light wave, the mode phase velocity must increase.

When the fiber bend is less than some critical radius, the mode phase velocity must increase to a speed greater than the speed of light. However, it is impossible to exceed the speed of light. This condition causes some of the light within the fiber to be converted to high-order modes. These high-order modes are then lost or radiated out of the fiber.

Fiber sensitivity to bending losses can be reduced. If the refractive index of the core is increased, then fiber sensitivity decreases. Sensitivity also decreases as the diameter of the overall fiber increases. However, increases in the fiber core diameter increase fiber sensitivity. Fibers with larger core size propagate more modes. These additional modes tend to be more lossy.

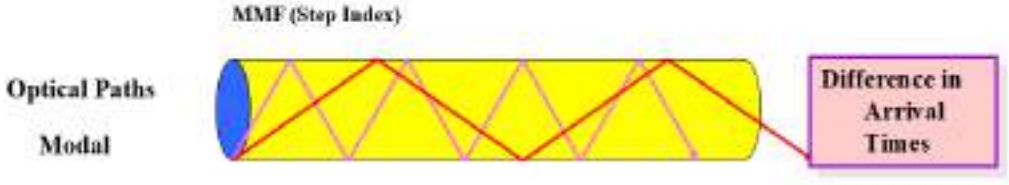
1.11 Dispersion in Optical Fiber

- Ø Dispersion is the spreading or broadening (distortion) of light pulses as they propagate through the fiber.
- Ø Too much dispersion gives rise to bit-errors at the receiver (i.e., the inability to distinguish a 0 from a 1).



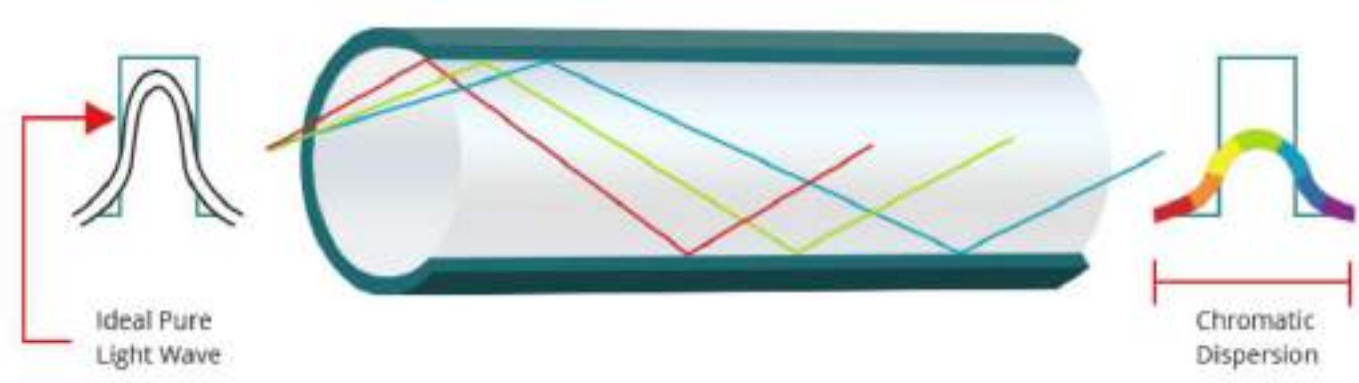
Modal Dispersion

- Ø Dispersion caused due to different paths the light rays take to travel from one end to the other.
- Ø This is prominent in Multimode Fibers.



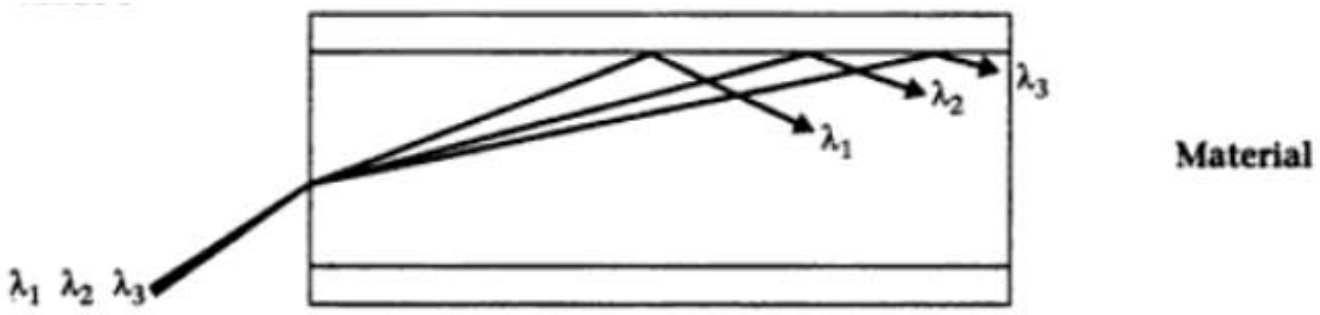
Chromatic Dispersion

- Ø Chromatic dispersion is a phenomenon of signal spreading over time resulting from the different speeds of light rays.
- Ø The chromatic dispersion is the combination of the Material and Waveguide Dispersion effects.



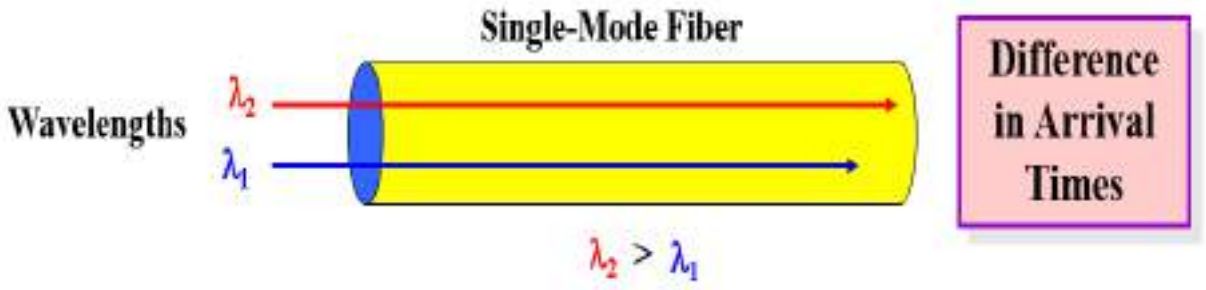
Material Dispersion

- Ø Material Dispersion is caused due to variation in refractive index of the fiber glass with respect to wavelengths.
- Ø Material dispersion is noted in the centre of the of the optical fiber (the core) due to its build.
- Ø Two rays of light that share the same wavelength and transfer through the same path length can be conveyed in different areas of the core.
- Ø This type of dispersion is seen in both single mode as well as multimode fiber types.

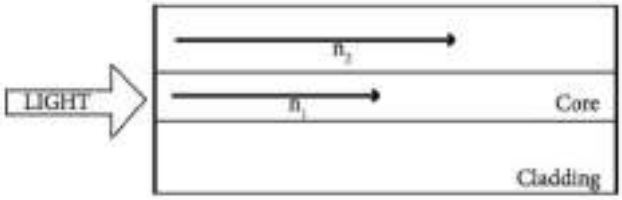


Waveguide Dispersion

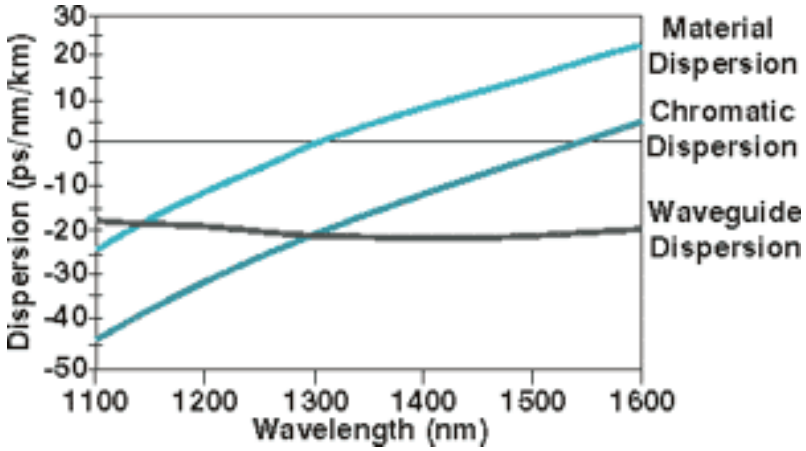
- It is caused by the fact that some light travels in the fiber cladding compared to most light travels in the fiber core.
- Since fiber cladding has lower refractive index than fiber core, light ray that travels in the cladding travels faster than that in the core.



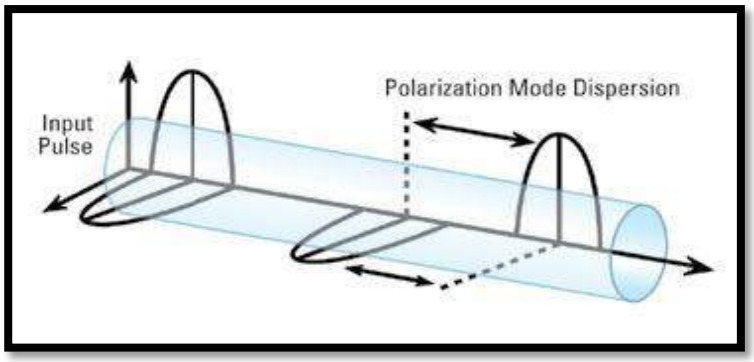
- It occurs due to dependence of the mode propagation constant on the fiber parameters. *(Core radius, difference between refractive indexes in fiber core and fiber cladding and signal wavelength).*
- This is prominent in Singlemode Fibers.



Chromatic dispersion isn't always a bad thing. Light travels at various speeds at different wavelengths or materials. These varying speeds cause pulses to either spread out or compress as they travel down the fiber, making it possible to customize the index of refraction profile to produce fibers for different applications.



Polarization Mode Dispersion



- Ø PMD effect occurs due to:
  - Asymmetry in Fiber Geometry
  - Mishandling of Fiber
  - Environmental Conditions
- Ø PMD is troublesome and affects High Data Rate Channel

Polarization mode dispersion (PMD) is a form of modal dispersion where two different polarizations of light in a waveguide, which normally travel at the same speed, travel at different speeds due to random imperfections and asymmetries, causing random spreading of optical pulses.

Total Dispersion

Total pulse spreading is given by the formula:

$$\Delta t_{total} = \sqrt{(\Delta t_{modal})^2 + (\Delta t_{chromatic})^2 + (\Delta t_{polarization\text{-}mode})^2}$$

In multimode fibers, polarization mode dispersion is negligible and the formula is given as:

$$\Delta t_{total} = \sqrt{(\Delta t_{modal})^2 + (\Delta t_{chromatic})^2}$$

In single-mode fibers, there is no modal dispersion hence the formula becomes:

$$\Delta t_{total} = \sqrt{(\Delta t_{chromatic})^2 + (\Delta t_{polarization\text{-}mode})^2}$$

In the above formula, dispersion is in the unit of time per unit distance (normally nanosecond or picosecond per kilometer) and pulse spreading is in the unit of time (usually nanosecond or picosecond).

1.12 Grades of Optical Fiber

Optical Fiber Grades

- Ø International Telecommunication Union - Telecommunication (ITU-T) is responsible for developing new standards and revising existing standards of telecommunications and Information Communication Technology (ICTs) on a worldwide basis.
- Ø The international standards that are produced by the ITU-T are referred to as "Recommendations", as they become mandatory only when adopted as part of a national law.
- Ø ITU-T optical fiber grades, describe the geometrical properties and transmissive properties of multimode and single-mode optical fiber.

Fiber Grade	Characteristics	Applications
G. 651.1	• Graded-index multimode fiber • Wavelength - 850nm and 1300nm	Fiber to The Home and other Indoor Applications
G. 652D	• Zero-dispersion at 1310 nm • Lower attenuation at 1550 nm	Public Network (Both Short and Long Distance)
G. 653 (Dispersion Shifted Fiber)	• Zero-dispersion at 1550 nm with minimum attenuation • Lower attenuation at 1550 nm	Long Distance Submarine & Terrestrial Networks
G. 654	• Zero-dispersion at1310 nm with minimized loss • Lower attenuation at 1550 nm	Long Distance Submarine & Terrestrial Networks
G. 655 (Non-zero Dispersion Shifted Fiber)	• Performance specified at 1550 nm and 1625 nm • Chromatic dispersion is less at 1550nm	WDM and Long Distance Systems
G. 656	• Attenuation is low at 1460nm -1625nm • Not suitable for 1460nm to 1530nm wavelengths	WDM Systems
G. 657	• Bend-insensitive single-mode fiber • Bend Radius of G675A < G657B	Fiber to The Home and other Indoor Applications

G652D and G655 Losses and Dispersion

		Fiber Grade	
Attributes	Wavelength (nm)	G652D	G655
Attenuation (dB/km)	1310	≤ 0.36	Doesn't Support*
	1550	≤ 0.22	≤ 0.24
	1625	≤ 0.25	≤ 0.26
Chromatic Dispersion (ps / (nm x km))	1310	≤ 3.5	Doesn't Support*
	1550	≤ 18	2 – 6
	1625	≤ 22	4.5 –11

Below 1450nm, G655 Single-mode fiber behaves like Multimode Fiber

Optical Fiber Grades – Comparison

- Ø G.651.1, G.657A, and G.657B all define bend-insensitive fibers made for FTTH systems. However, G.651.1 multimode fiber has higher data rates for short-distance communications.
- Ø G.657A fiber is backward compatible with the existing G.652D fiber.
- Ø A full installation is needed when deploying G.651.1 and G.657B fibers, thereby an increase in cost.
- Ø The advantage of G.657B fiber is its superior bend-insensitivity.
- Ø G.652D, G.655, and G.656 fibers support either CWDM or DWDM systems, each fiber has its weaknesses and strengths in long-haul transmission.
- Ø G.655 fiber has low chromatic dispersion and supports long-haul systems that use CWDM in the
- Ø wavelength range from 1550 nm to 1625 nm

Section 3: Exercises

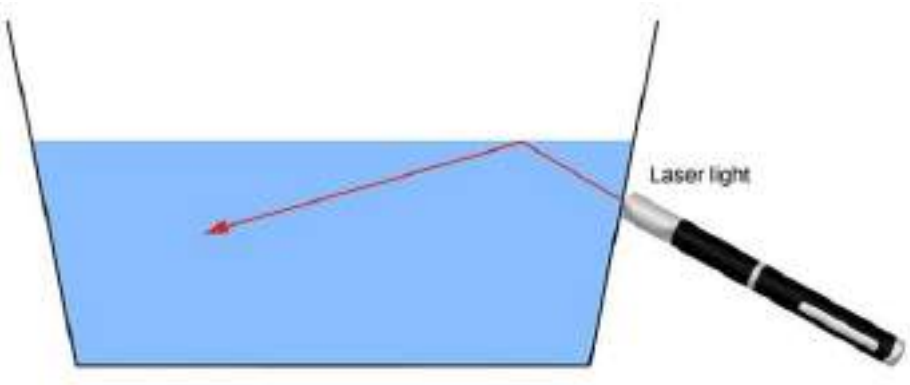
Exercise 1: Match the Column

Exercise 2: On a plain paper, make a chart showing classification of transmission media.

Exercise 3: Perform experiment of Total Internal Reflection Phenomenon.

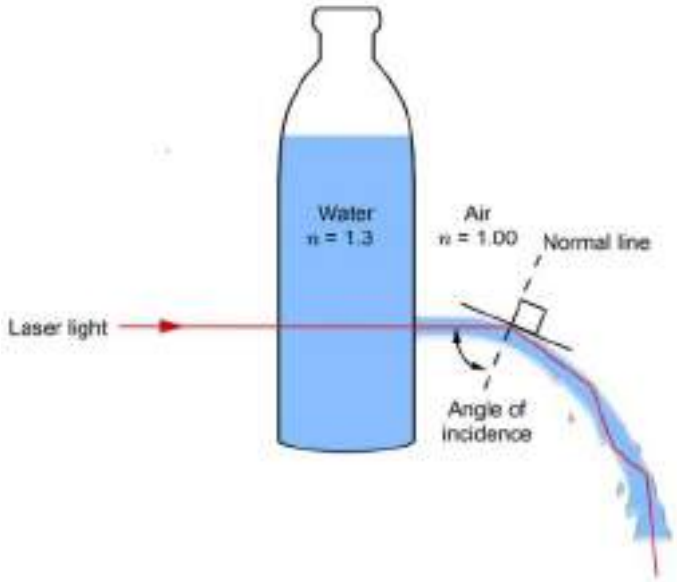
a) Tank of water

Fill a perspex tank with water. Angle a directed ray of light to the underneath of the surface and total internal reflection can be seen (it is easier to see with the lights off).



b) Large bottle of water

Take a large plastic bottle, drill a hole in the side and fill the hole with a cork. Fill the bottle with water, shine a laser through the bottle and pull out the cork. Direct the laser light into the stream of water, as shown below.



Exercise 4: Make a chart of the grade of the optical fibers showing their characteristics and applications.

Section 4: Assessment Questionnaire

1. _____ is a pathway that carries the information from sender to receiver.
2. Which type of media is Fiber optic communication?
3. Unguided Transmission media is also known as:
4. Which Unguided Transmission media has highest frequency range?
5. On which principle, Optical Fiber works?
6. What is speed of light in vacuum?
7. What is Formula of Refractive Index?
8. What is Refractive index in Vacuum?
9. When light is incident on a medium of lesser Refractive Index, the ray is bent away from the normal, then exit angle is _____ than the incident angle.
10. For occurrence of Total Internal Reflection, Index of refraction of clad should be _____ than clad.
11. What is full form of LED?
12. Is APD a transmitter or a receiver?
13. Give any application of Optical Fiber.
14. What is expanded form of FTTH?
15. A set of guided electromagnetic waves is called _____of the fiber.
16. Which types of waves are used in Mode theory?
17. As per mode theory, at what angle Electric and Magnetic field travel?
18. Write formulae for V Number.
19. The V number depends on the wavelength of light. True or False?
20. In what year, Semaphores were used?
21. Who invented Semaphores?
22. Who gave theory of Total Internal Reflection (TIR)?
23. Who demonstrated the refraction of light through stream of water?
24. Who invented photophone?
25. When was photophone invented?
26. _____ demonstrated a method to carry television images through transparent pipes.
27. When was Fibroscope invented?
28. The first working fiber-optic data transmission system was demonstrated by:
29. Who proposed that long distance communications were possible with single mode fiber?
30. The first metropolitan fiber optic cable was deployed in:
31. What is full form of CATV?
32. Wavelength Division Multiplexing (WDM) was first time used in:
33. Dense Wave Division Multiplexing (DWDM) was first time used in:
34. What is core size of Single mode fiber?
35. What is core size of Multimode fiber?
36. Which mode of fiber has higher loss?
37. Which fiber are used for long distance transmission?
38. _____is the distance between two nearest amplitude positive peaks.
39. What is unit of wavelength commonly referred in fiber optics?

40. Match the following.

Band	Wavelength (nm) Range
O – Original	1360-1460
E – Extended	1260-1360
S – Short Wavelength	1625-1675
C – Conventional	1565-1625
L – Long Wavelength	1530-1565
U – Ultra Long Wavelength	1460-1530

41. What is unit of Attenuation?
42. _____is the loss of optical power as light travels along the fiber.
43. If light travels over 20 km of optical fiber with loss of 0.25 dB/km, what is the total loss?
44. What is the typical optical power loss of G. 652D fiber at 1550nm?
45. Deformation of fiber axis (axial \ distortion) during fiber is example of which type of bending?
46. Spreading of light pulses in a fiber is called:
47. If you bend a fiber, what will happen, attenuation or dispersion?
48. Dispersion caused due to different paths the light rays take to travel from one end to the other is called:
49. In which mode of fiber Chromatic Dispersion occurs?
50. Modal Dispersion occurs in:
51. What is full form of PMD?
52. What is full form of ITU-T?
53. Where can we use G.657 Fiber?
54. Which fiber is commonly used in long distance optical communication?
55. The chromatic dispersion is the combination of the _____ and _____ Dispersion effects.
56. _____dispersion is caused due to variation in refractive index of the fiber glass with respect to wavelengths.
57. Fiber cladding has lower refractive index than fiber core, light ray that travels in the cladding travels _____ than that in the core.
58. What is unit of dispersion in optical fiber?
59. In single-mode fibers, there is no _____ dispersion.
60. On which fiber parameters, Waveguide Dispersion depends?

----------End of the Module----------

MODULE 2
FIBER OPTIC CABLE TYPES & HANDLING PRACTICES

Section 1: Learning Outcomes

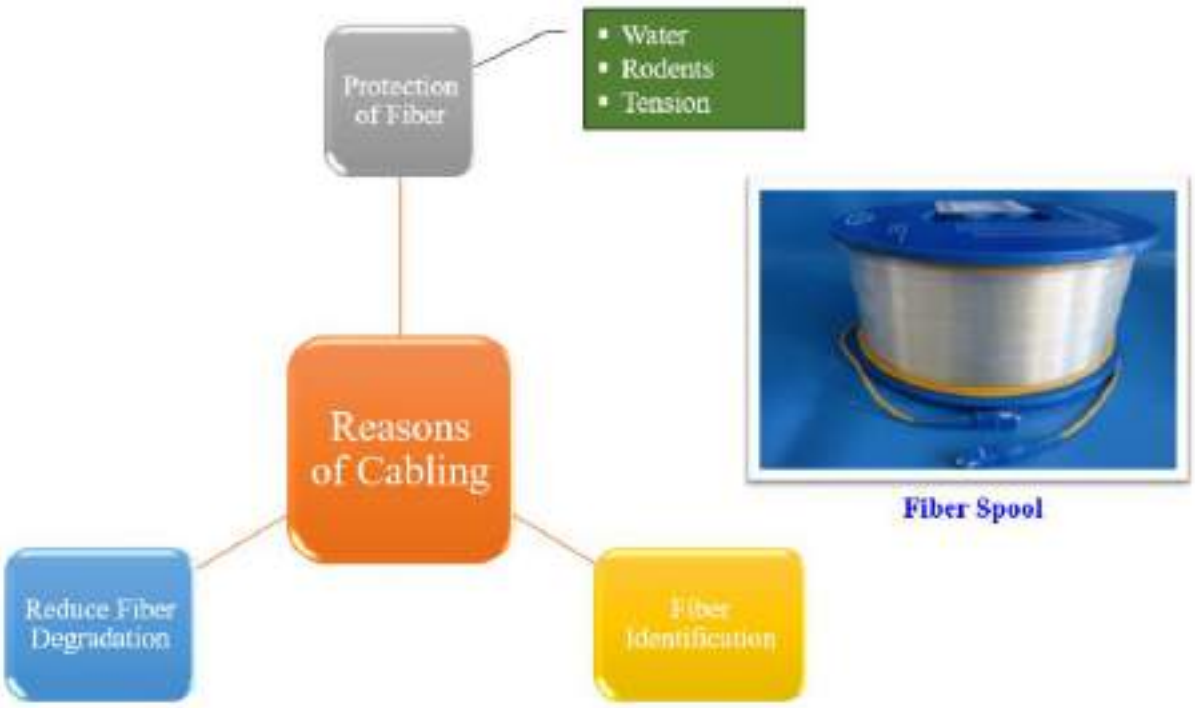
After completing this module, you will be able to:

- Describe the components of optical fiber cable and their properties
- Identify colour codes of optical fiber, cable jackets
- Classify fiber optic cables
- Describe construction of various types of fiber optic cables
- Explain the cable selection criteria
- Describe good practices of cable drum handling & storage
- Explain the concept of cable bending radius and pulling tension

Section 2: Relevant Knowledge

2.1 Components of Optical Fiber Cable

Reasons of Cabling



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Key Design Parameters of Cable

Fiber optic cable core:

Ø A fiber optic's center is made of glass, and this tube carries the cable's light signals.

Ø Depending on the type of fiber optic cable (single mode or multi-mode), the core varies in size.

Fiber optic cable cladding layer:

Also constructed of glass, this "core cover" is used to keep the light in the core.

Fiber optic cable buffer:

Ø Also called the buffer coating, this sleeve protects the core and cladding from foreign material such as outside light, moisture, dirt and other substances.

Ø More often than not, the buffer is made of plastic.

Strength Members:

Ø Strength members which are typically used in fiber optic cable include Tapes, Binders, Aramid yarn, Fiberglass Epoxy Rods (FGE), and Steel Wire.

Ø It also plays a vital role in enhancing the tensile strength of the cable.

Aramid Yarn

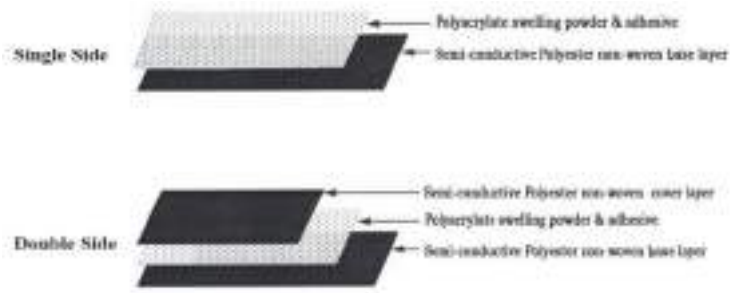
- Ø Aramid yarn is a yellow color, fiber looking material.
- Ø It is strong and is used to bundle and protect the loose tubes or fibers in the cable.
- Ø It is the strength member to provide tensile strength along the length of the cable during and after installation.
- Ø When a cable is pulled into a duct, the tension is applied to the aramid yarn instead of the fibers.

Fiberglass Reinforce Plastic (FRP)

- Ø FRP is a Fiberglass-Reinforced Plastic material that has the strength of steel at the fraction of the weight. FRP won't corrode, rot, warp, attract insects, or rust.
- Ø FRP is a common reinforcement to provide strength and durability in fiber optic drop cable.
- Ø FRP reinforcement is not the messenger, but in a common configuration will straddle the optical cable within the jacket.

Water Blocking Tape:

- Ø It is a combination of tape, yarn, or coating to prevent penetration of water into the cable.
- Ø Water blocking tapes and water swellable tapes rapidly absorb liquid at the point of insulation failure and quickly swell to block any further ingress.



Fiber Optic Cable Jacket:

- Ø The cable jacket is typically made of tough, durable polyurethane.
- Ø It resists water entry
- Ø It provides a smooth, low friction surface for cable placement.
- Ø It is made of material that will allow the cable to remain flexible and serviceable
- Ø It resists abrasion during installation. It also provides, along with the cable's strength members, the mechanical strength required to survive its environment and installation forces.

Popular Cable Jacketing Materials

Sheath Material	Features
PE - Polyethylene MDPE – medium density PE HDPE – high density PE	• Primary outside jacket material. • Good resistance to UV (sunlight) due to carbon black. • Good flexibility over wide range of temperatures. • Good abrasion and crack resistance.
Anti-tracking PE	• Use in all dielectric self-supporting cable in high voltage aerial fields exceeding 12 kV, but not exceeding 50 kV applications. The anti-tracking jacket withstands a condition known as dry arcing.
PVC - Polyvinyl chloride	• Provides good mechanical protection. • Flexible at normal installation temperatures. • Flame retardant. (typical riser material) • Used for many indoor applications. • Can be protected against sunlight with various UV inhibitors.
LSZH - Low smoke, zero halogen	• Flame Retardant with low smoke and no halogenated materials. • For use in unventilated areas exposed to public, e.g., subways and tunnels. • Good mechanical performance.
PVDF - Polyvinyldifluoride	• Flame retardant. (typical plenum material) • It produces low smoke and low flame propogation.

Most Outside Plant optical cables are made from medium density or high-density polyethylene with carbon black for UV stabilization

Fiber Optic Cable Fire Rating

Ø There are three kinds of cable jacket fire ratings:
- Plenum
- Riser
- General purpose

Ø A Plenum area is a building space used for air flow or air distribution system (drop ceiling and raised floors).

Ø A Riser area is a floor opening, shaft or duct that runs vertically through one or more floors.

Ø A general-purpose area is all other areas that are not plenum or riser and on the same floor.

Cable Marking	Cable Type
OFNP	Optical Fiber Nonconductive Plenum
OFCP	Optical Fiber Conductive Plenum
OFNR	Optical Fiber Nonconductive Riser
OFCR	Optical Fiber Conductive Riser
OFNG/OFN	Optical Fiber Nonconductive General-purpose
OFCG/OFC	Optical Fiber Conductive General-purpose

Ø For a small, in-building deployment, using a riser – OFNP, OFCP, OFNR, OFCR, OFNG, OFCG

Ø Within an existing, fabricated duct inside a building – OFNP, OFCP

Ø In a plenum space that is used for environmental air inside a public building – OFNP, OFCP

Ø Inside a fireproof shaft using a riser within any type of building – OFNP, OFCP, OFNR, OFCR, OFNG, OFCG

Ø When using a metal raceway for in-building deployments covering multiple floors and rooms/apartments – OFNP, OFCP, OFNR, OFCR, OFNG, OFCG

Ø For vertical runs between floors within a riser – OFNP, OFCP, OFNR, OFCR

Ø Within a riser cable routing assembly inside a building – OFNP, OFCP, OFNR, OFCR

Ø For in-building deployments with routing only on 1 floor – OFNP, OFCP, OFNR, OFCR, OFNG, OFCG

2.2 Optical Fiber Colour Codes

Fiber Identification: Colour Coding

Ø Colors are used to identify the fibers and Buffer tube in the cable.

Ø Color codes are important when making connections by splicing.

Fiber No.	Color	Fiber No.	Color
1	Blue	7	Red
2	Orange	8	Black
3	Green	9	Yellow
4	Brown	10	Violet
5	Slate	11	Pink
6	White	12	Aqua

Outer Jacket Colour Code

Ø Colored outer jackets or print may be used on outside plant and premises fiber cables, e.g., fiber distribution cables, fiber optic patch cords, etc.

Ø In EIA/TIA-598, the fiber color code defines the jacket color codes for different fiber types.

Fiber Type	Patch Cord / Cable Outer Jacket Color Code
OM1 62.5/125µm Multimode	Orange
OM2 50/125µm Multimode	Orange
OM3 50/125 µm (850 nm Laser-Optimized) Multimode	Aqua
OM4 50/125µm (850 nm Laser-Optimized) Multimode	Aqua/Violet
100/140µm Multimode	Orange
OS1/OS2 Single Mode	Yellow
Polarization Maintaining Single Mode	Blue

Inner Tubes Color Code

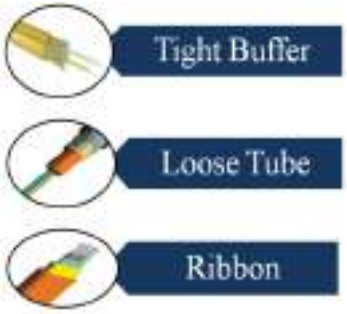
- Ø Inside a multi-fiber cable, individual fibers are compliant to fiber color code and they are distinguished from one another by color-coded of tubes.
- Ø Inner fibers are color coded in a group of 12 fibers and they are counted in a clockwise direction.

There are two situations for multi-fiber cables:

- Ø For cables that consist of multiple buffer tubes each with 12 or less strands, each tube will be numbered or colored following the same fiber color code, e.g., 1st tube is blue, 2nd is orange, etc.

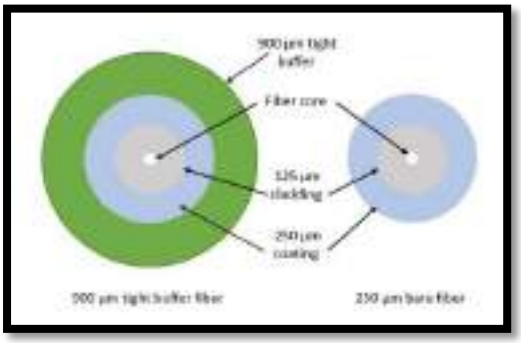
- Ø For cables that consist of more than 12 strands, the fiber optic cable color code repeats itself. Each group of 12 fibers is identified with some other means. For example, 24 strand groups are with the fiber color code repeating with some variation, e.g., the 1st group of 12 strands are solid colors and the 2nd group is a solid color with a stripe or some other identifying marks.

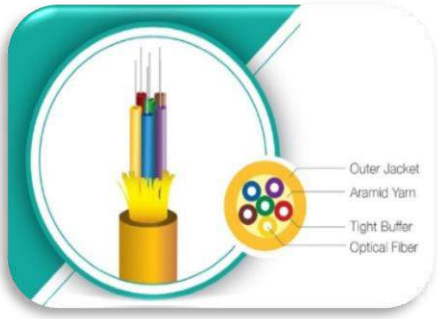
2.3 Classification of Fiber Optic Cable



Tight Buffer Structure

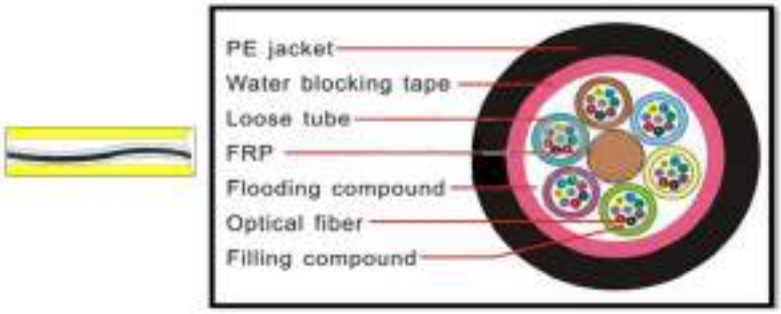
- Ø Useful in Indoor applications, such as Pigtail and Patch Cord
- Ø Higher flexibility
- Ø Easy to connectorize and terminate





Loose Tube Structure

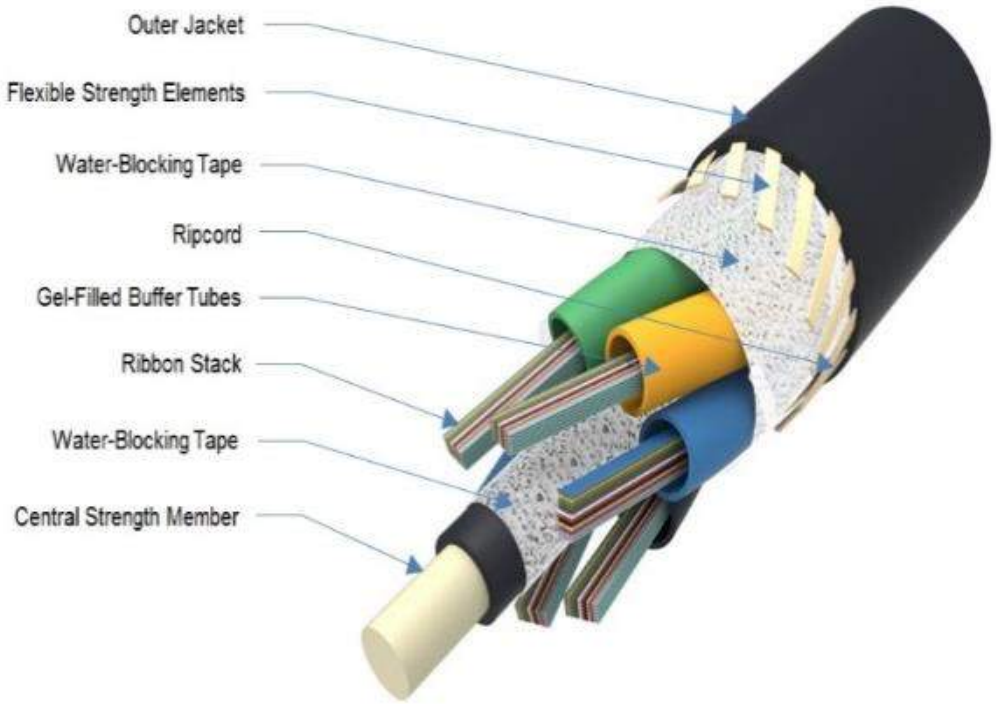
- Ø Useful in outdoor applications.
- Ø Long term reliability due to Jelly filled design. Jelly is a cable filling compound that provides a watertight environment and protection against corrosion and potential dielectric problems in the fiber.
- Ø Fiber is protected from moisture and temperature.
- Ø Best suited for Armoured Applications, Direct Buried Applications, Underground and Aerial applications.



PE: Poly Ethylene
FRP: Fiber Reinforced Plastic

Ribbon Cable

- Ø Fibers are arranged in strips
- Ø Provides higher fiber density within a cable
- Ø All fibers in the Ribbon can be spliced together using ribbon fiber splicing machine.

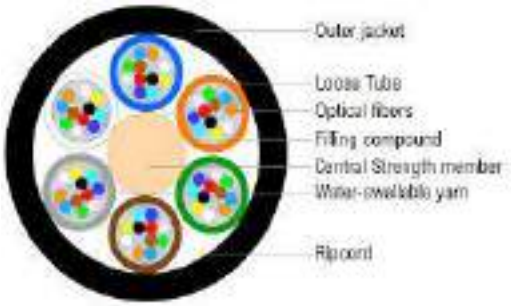


Ribbon Identification

2.4 Types of Fiber Optic Cables

Microcable Cable

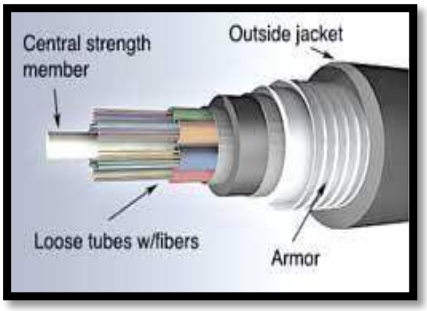
- Ø Microcables are very high-density cables with greatly reduced cable diameter and high fiber count.
- Ø Used to make deployment faster and less costly, especially in locations where space is minimum.
- Ø Microcables are specifically optimized for air-blown applications.

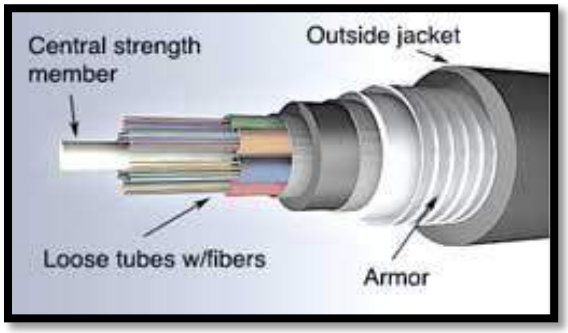


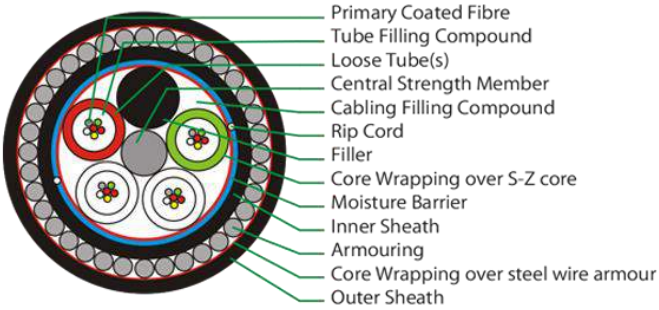
- Ø A 144 fiber loose tube cable is typically 15-16mm diameter while a comparable micro cable is only about 8 mm diameter - half the size and about one-third the weight.
- Ø Microcables are available for both premises and outside plant installations.
- Ø Microcables generally have a large stiff strength ember in the center to allow installation by blowing the cable into microducts.

Armoured Cable

- Ø Contains Aluminium or steel alloys for armouring
- Ø Provide rugged, rodent and crush resistance
- Ø Armoured cable is conductive, so it must be grounded properly
- Ø It's applications includes:
  - Direct burial application
  - Need of high cable life
  - Protection of cable from animal, human or harsh environment







All-Dielectric Self-Supporting (ADSS) Cable

- Ø Non-metallic cable with small diameter and light weight
- Ø Supports its own weight without the use of wires or messenger cables
- Ø Protection from UV rays and moisture
- Ø Used for aerial installation over short, medium and long span distances

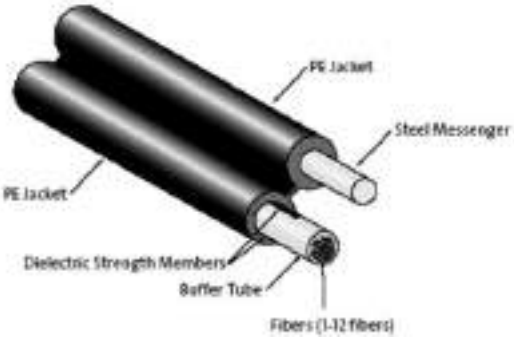
Tight Buffer Drop Cable

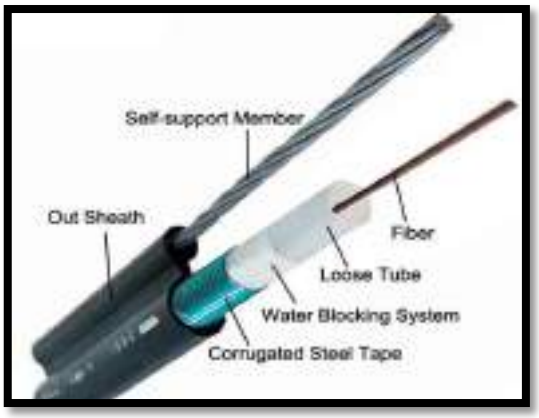
- Ø Small size and light weight cable
- Ø Contains several tight-buffered fibers bundled under the same jacket with Kevlar strength members.
- Ø Used in FTTX and indoor applications

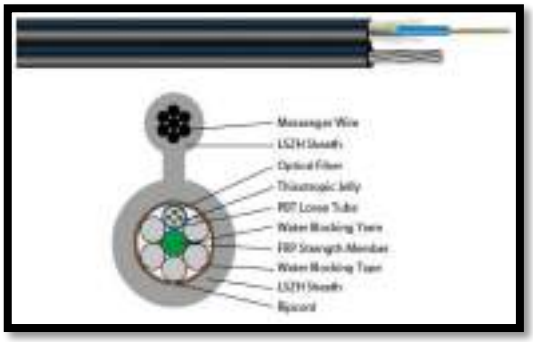
Figure-8 Drop Cable

- Ø It features a built-in support wire for tensile strength and stability.
- Ø The support wire is typically galvanized steel messenger, flooded to inhibit corrosion.
- Ø It provides robust self-support aerial deployment and quick one-step installation.

- Ø Figure-8 optical drop cables are composed of two distinct subcomponents, a central tube cable fixed to a steel wire.
- Ø This cable design is to combine the installation of the messenger wire and optical cable into a single process.
- Ø This cable is typically used in aerial applications.



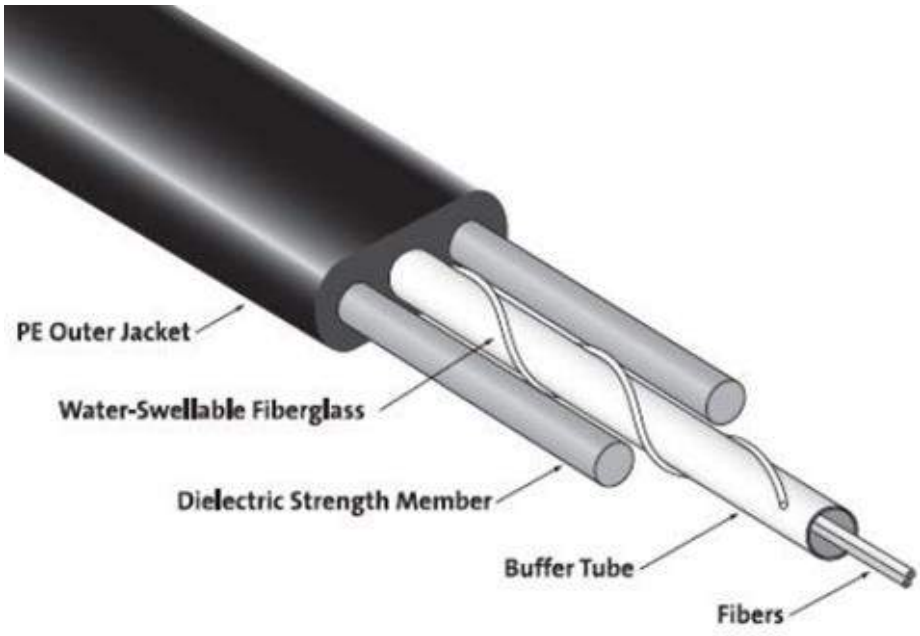




- Ø Easy Cable Entry and Preparation
- Ø Flexible Routing and Termination
- Ø Quick Installation & Robust
- Ø Reliable Lifetime Performance

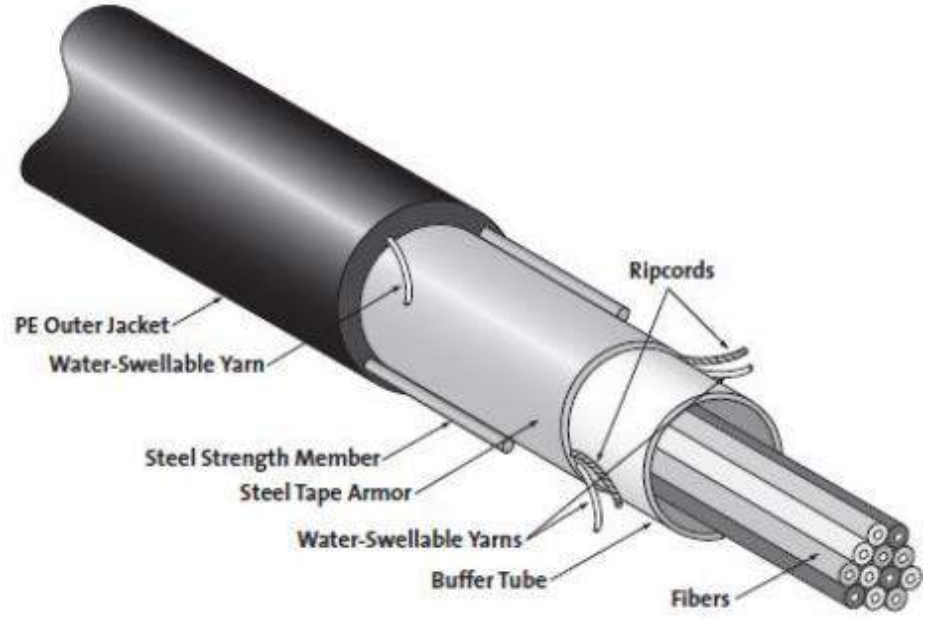
All-dielectric Optical Drop Cable

- Ø All-dielectric optical drop cables have the optical fibers placed in a centrally located buffer tube.
- Ø This drop cable design supports direct buried, conduit and aerial self-support application.



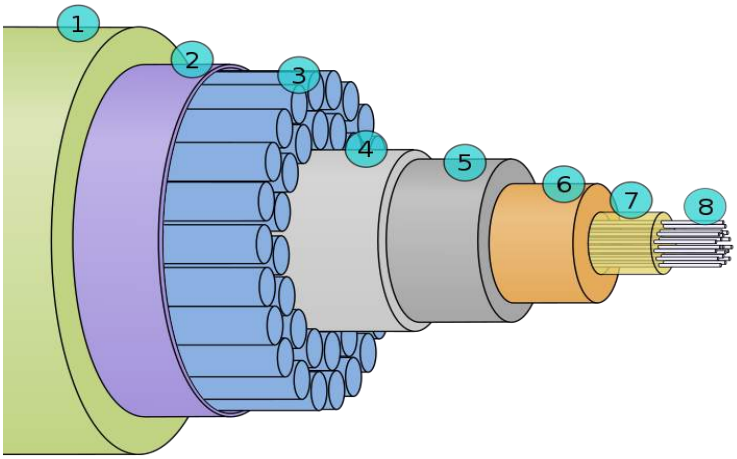
Armoured Optical Drop Cable

- Ø Armored optical drop cables also have the optical fibers placed in the centrally located buffer tube.
- Ø A protective metallic foil surrounds the buffer tube and provides an additional protective barrier for the optical fibers.

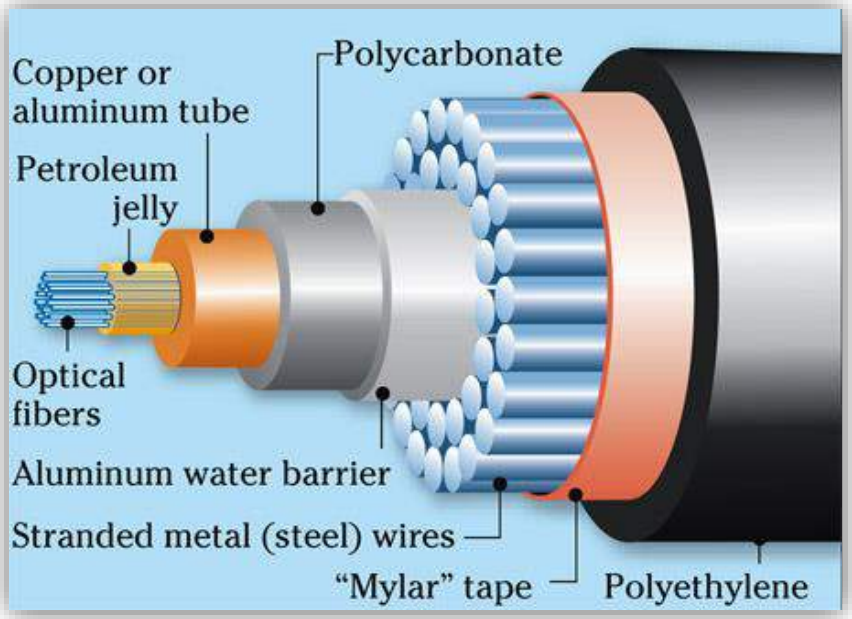


Submarine Cable

- Subsea or submarine cables are fiber optic cables that connect countries across the world via cables laid on the ocean floor.
- Most long-distance undersea cables contain six or eight fiber-optic pairs.



1. Polyethylene
2. "Mylar" tape
3. Stranded metal (steel) wires
4. Aluminium water barrier
5. Polycarbonate
6. Copper or aluminum tube
7. Petroleum jelly
8. Optical fibers

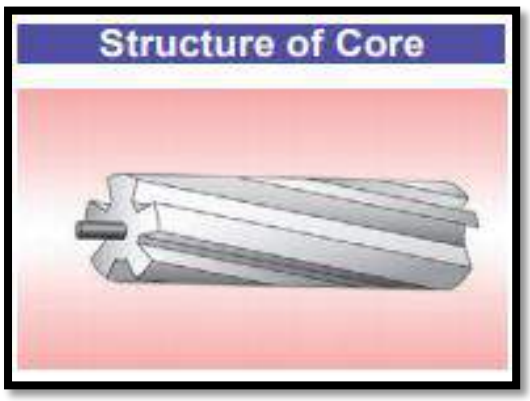


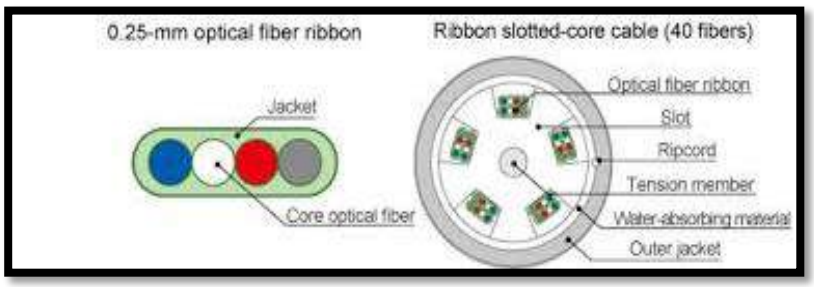
Breakout Cable

- Ø Breakout fiber cable consist of two or more simplex cables bundled with a strength member and central member covered with an outer jacket.
- Ø These cables are ideal for routing in exposed trays or any application requiring an extra rugged cable that can be directly connected to the equipment.
- Ø Breakout cable is often used for short riser and plenum applications, as well as for use in conduits instead of a splice box or fiber pigtail.

Slotted Core Cable

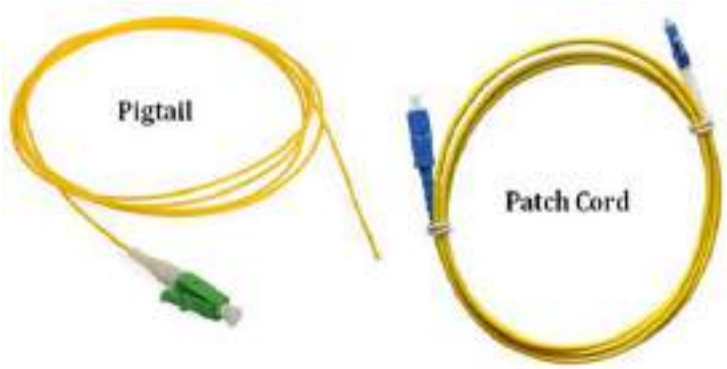
- Ø In this cable ribbon fibres are laid in the slotted core without tubes.
- Ø This cable enables high fiber packing density within a small cable diameter which in turn helps with limited duct space.
- Ø This gives far better protection to the fibres against mechanical action such as pressure, impact, twisting or bending.
- Ø It is suitable for all underground, undersea and suspended installation, and also indoors in mains supply networks, on cable ladders, in ducts etc. where the cable is subjected to long-term mechanical action from suspension and tensioning devices.





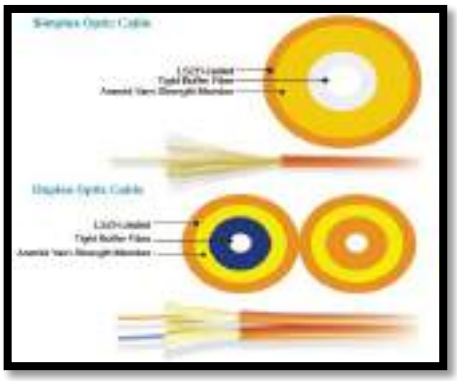
Pigtail & Patch Cords

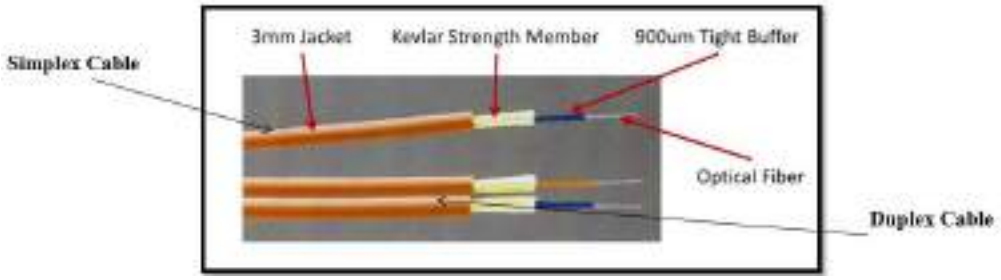
A patch cord is a fixed length piece of cable with fiber connectors on each end while fiber pigtail has fiber connectors on only one end of the cable. Fiber optic patch cords can be cut into shorter lengths to make two pigtails.



Simplex Cable & Duplex Cables

- Ø Simplex fiber optic cable consists of a single fiber and used in applications that only require one way data transfer.
- Ø Duplex fiber optic cable consists of two fibers and used in applications that require simultaneous, bidirectional data transfer.





Cables & their Applications

Cables	Applications
Tight Buffer Cables	*Indoor communication system*
	Jumpers, Pigtails, Patch cords
Loose Tube Cables	*Outdoor Applications*
	NLD Routes
ADSS / Fig-8 Cables	*Aerial Deployment*
	FTTX
Armoured Cable	*Direct Buried Applications*
	Rodent Protection Requirement
	Physical Damage Prone Areas (Mechanical Protection)
Distribution Cables	*Indoor Applications (FTTX)*

2.5 Cable Selection Criteria

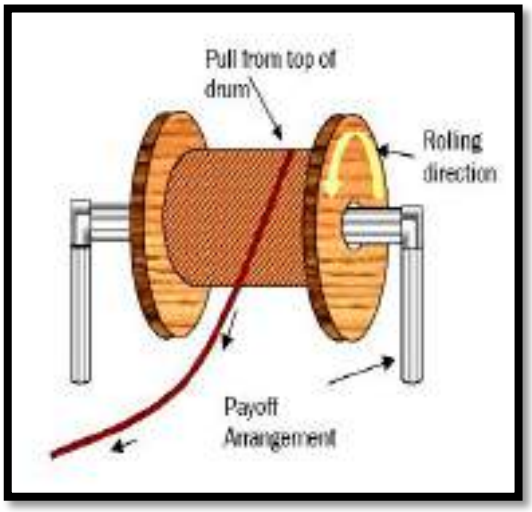
- Ø Length of the Link
- Ø Data Rate Requirements
- Ø Type of the Network (Long Haul, FTTX, etc.)
- Ø Network Construction and Maintenance Budget
- Ø Fiber Route Terrain
- Ø Ease of Installation
- Ø Number of Communication Channels Required
- Ø Future Expansion Needs
- Ø Environmental Factors

Cable Drum Handling & Storage

- Ø Generally, underground fiber optic cable in a drum for long distance routes are supplied in length of 1, 2, 3 and 4 Kms.
- Ø Aerial cable drums are of shorter length i.e.1 or 2 Kms.
- Ø It is ensured that cable should not be twisted and bent while uncoiling and to be mounted on cable drum jack.

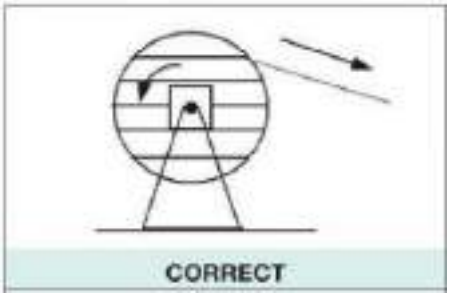
Drum Mounting

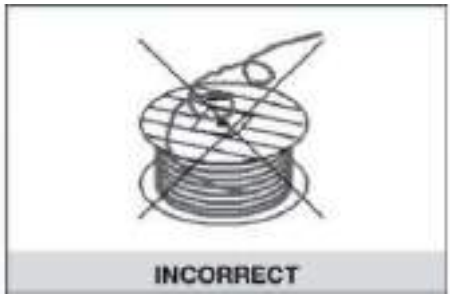
- Ø The drum is jacked up with a drum axle to such a height that the plank needed for breaking cannot jam.
- Ø Heavy drums should jacked up with hydraulic drum pedestals.
- Ø To prevent the product rubbing against drum flanges keep the drum leveled.
- Ø Orient the drum so that the natural payoff direction is towards pulling direction.
- Ø Pull the product from the top of the drum
- Ø The maximum recommended unwinding speed is 35 meters per minute.
- Ø Suitable provisions should be made to break the drum.

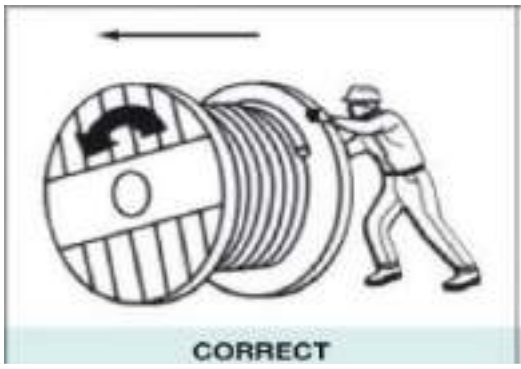


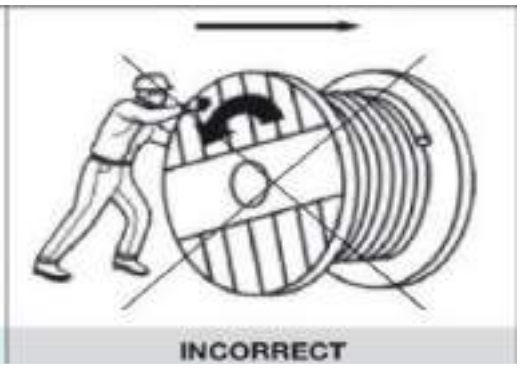
2.6 Cable Drum Handling and Storage

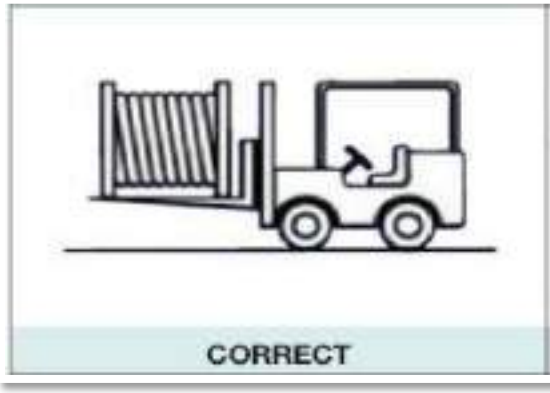
- Ø Drum should never be given any shock by dropping.
- Ø Drum should not be rotated on flanges.
- Ø Cable should not be twisted and bent while uncoiling.

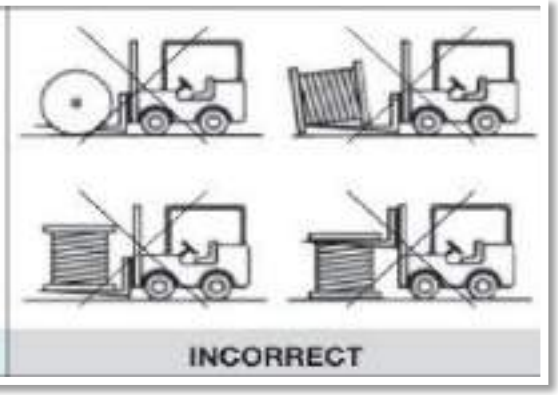








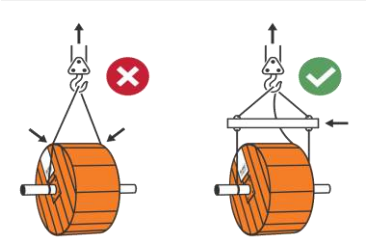




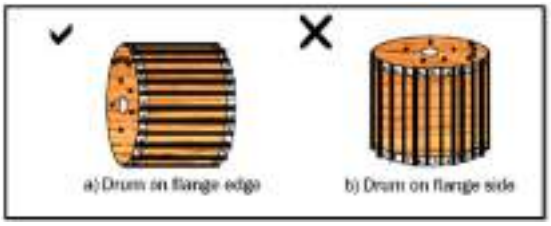
Drum Storage Environment

- Ø Drums should be on the area free from up-down surface, water, mud, stone etc.
- Ø Due to environment surrounding the drums, the wood degrades over a period of time, so, indoor storage is recommended.
- Ø If drums are stored outdoor, the storing surface should be hard and no moist soil should come in contact with wood.
- Ø During storage, the drum should be rolled once in every three months.

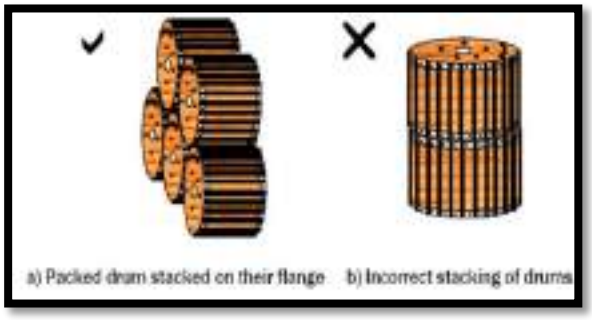
Drum Storage



- Ø The drums should always be stored in an upright position. Storage of drums in an alternative position can lead to winding defects.



- Ø If storage place is limited and it becomes necessary to stack, stack completely wrapped drums on their flanges edge.



- Ø Rolling edge should be lined up in rows with the flanges touching each other so that the flanges do not overlap with the product and accidentally damage it.

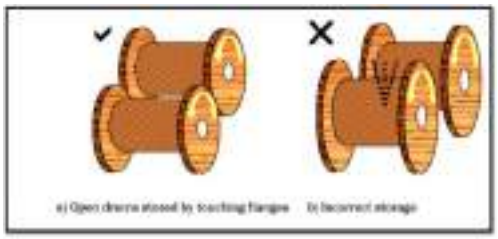


Figure Eight

Ø Mark two adjacent circles of 1.5 to 2 meter diameter on floor in such a way that it makes figure eight.

Ø Loop requires minimum three persons one at center & one at each end of circle.

2.7 Cable Bending Radius and Pulling Tension

Cable Bending Radius

Ø Bend radius is the curvature an optical fiber can bend without damage or shortening its lifespan via kinking.

Ø The smaller the bend radius, the more flexible the fiber.

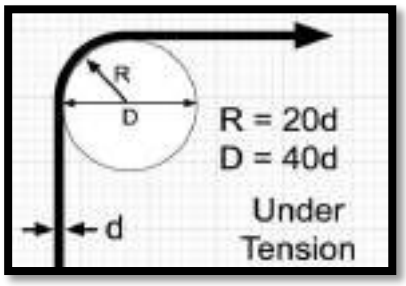
Ø If no recommendations are available from the cable manufacturer, the cable should not be installed into a bend radius smaller than 20 times the cable diameter.

Ø After completion of the pull, the cable should not have any bend radius smaller than 10 times the cable diameter.

Ø For example, a cable with an outer diameter of 5mm, should not be bent smaller than 100mm radius during installation.

Cable Pulling Tension

Ø Exceeding the Cable Pulling Tension above the defined value in the Cable Data sheet / Specification can alter cable's and fiber's characteristics leading to increased attenuation.



Ø Tensile strength is maximum load that a cable can bear without fracture when being stretched.

Ø The tensile strength for stranded loose tube cable and ribbon cable is approx. 2,700 Newtons (2700 Kg.m/s2 in MKS system).

Section 3: Exercises

Exercise 1: Make a chart of optical fiber colour codes.

Exercise 2: Participate in group discussion on following topics:

a) Classification of Fiber Optic Cable
b) Various Types of Fiber Optic Cable

Exercise 3: Determine cable bend radius (After Pulling and Under Tension) of following cables:
Cable Diameter:

a) 20mm
b) 14mm
c) 16mm
d) 23mm
e) 12mm

Exercise 4: Fill the cable type in following tables.

Cable Marking	Cable Type
OFNP	
OFCP	
OFNR	
OFCR	
OFNG/OFN	
OFCG/OFC	

Section 4: Assessment Questionnaire

1. How to identify fibers and buffer tube in a cable?
2. What is the colour code of fiber number 4?
3. What is colour for jacket of OM2 50/125µm Multimode fiber?
4. In which direction colour coding is placed in loose tube cable?
5. Classify Optical Fiber according to its structure?
6. Which type of fiber cable is used for higher flexibility and indoor deployment?
7. Where we should use Loose Tube Fiber?
8. Can a ribbon consist of any numbers of fibers?
9. What are advantages of Armoured Optical Fiber Cable?
10. What material is used for Armouring?
11. What are uses of distribution fiber cable?
12. Jacket of which cable used in serial deployment provides protection from UV rays and moisture?
13. What are the applications of Figure 8 Cable?
14. ADSS cable does not support its own weight without the use of wires or messenger cables. True /False.
15. Which cable has a built-in support wire for tensile strength and stability?
16. Which material is used for supporting wire in Figure-8 Cable?
17. What are features and benefits of Figure-8 Cable?
18. In which fiber cable, ribbon fibres are laid in the slotted core without tubes?
19. What are the benefits of Slotted Core Cable?
20. Where can we use Slotted Fiber Cable?
21. Give some points for cable selection criteria?
22. Should we rotate drum on flanges?
23. Cable should be pulled less than the recommended tensile strength. True or False?
24. _____is the curvature an optical fiber can bend without damage or shortening its lifespan via kinking.
25. What do you call the cable that has bare fiber at one end and connector at other end?
26. What are the reasons of cabling?
27. What are the key parameters to be considered while designing optical fiber cable?
28. Name some strength members used in the optical fiber cable.
29. What are some properties of FRP?
30. How water blocking tape works?
31. Fill in the blanks:
    a) A Plenum area is _____ .
    b) A Riser area is _____ .
    c) A general-purpose area is _____ .
32. What are the types of optical fiber drop cables?
33. Where should you use Figure-8 cable?
34. In armoured optical cable protective _____ surrounds the buffer tube and provides an additional protective barrier for the optical fibers.
35. What are the properties of Aramid Yarn?

----------End of the Module----------

MODULE 3
FIBER OPTIC CONNECTORS

Section 1: Learning Outcomes

After completing this module, you will be able to:

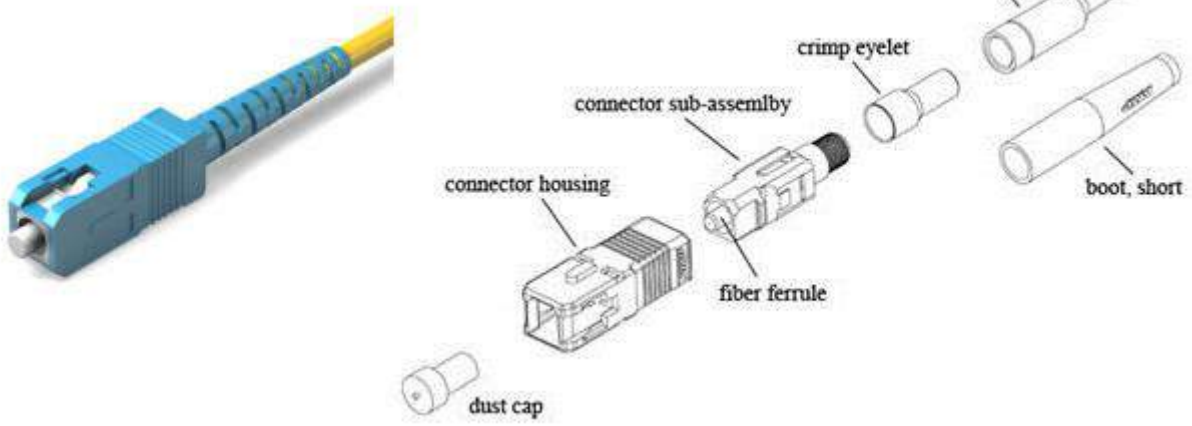
- Describe the construction of fiber optic connectors
- Explain fiber connector polishing and insertion loss characteristics
- Interpret criterion for fiber connector performance
- Analyze the effect of polish type on connectors
- Examine causes of attenuation on connectors
- Identify colour codes of optical fiber connectors
- Identify and distinguish between various types of fiber optic connectors and their properties
- Perform inspection and cleaning of optical connectors

Section 2: Relevant Knowledge

3.1 Introduction to Fiber Optic Connectors

Fiber Optic Connectors

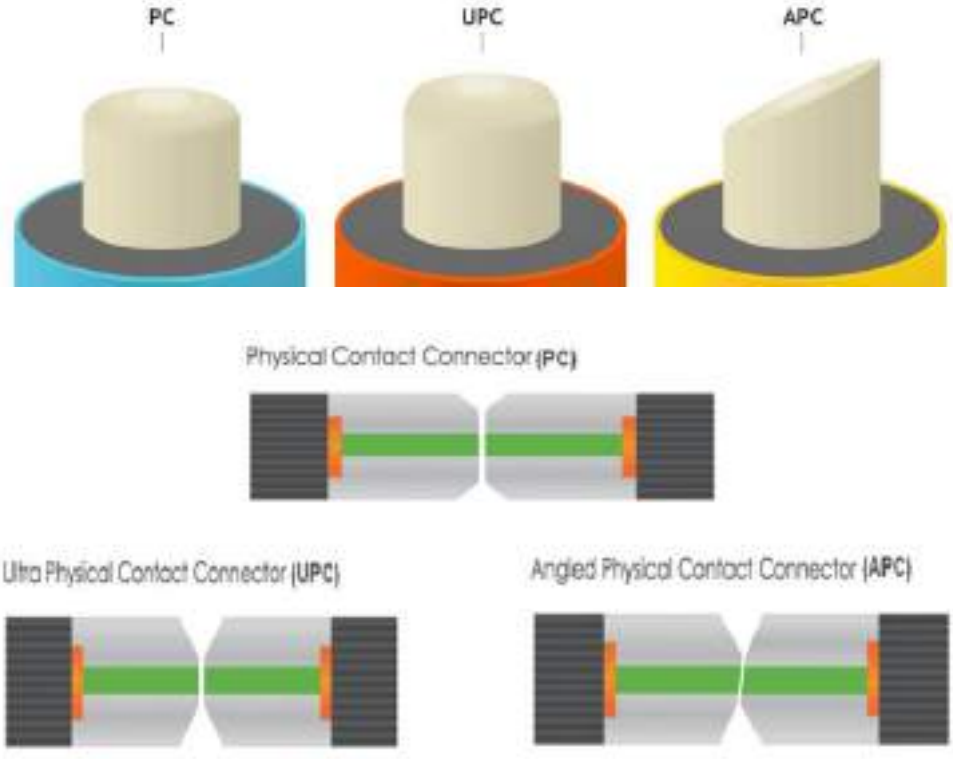
Ø An optical fiber connector terminates the end of an optical fiber.
Ø The connectors mechanically couple and align the cores of fibers so light can pass.
Ø Fiber Optic Couplers are used to align two connectors facing each other.



Fiber Optic Coupler

- An A fiber optic coupler is an optical device capable of connecting one or more fiber ends in order to allow the transmission of light waves.
- They also have high directivity and low insertion loss.

3.2 Connector Polishes and Insertion Loss



Connector Polishing: Attenuation and Return Loss

- Optical loss (for connectors), sometimes called attenuation, is simply the reduction of optical power induced by transmission through a medium such as a pair of fiber optic connectors.
- Return loss is the amount of light reflected from a single discontinuity in an optical fiber link such as a connector pair. Return loss is also called reflectance. For perfect transmission, optical loss and reflected power should be zero.

The equations for optical loss, return loss and reflectance are as follows:

Optical Loss = 10*log(input power/output power) in +dB

Return Loss = 10*log(incident power/reflected power) in +dB

Reflectance = 10*log(reflected power/incident power) in -dB

- Return loss and reflectance are both used to describe back reflection at a connector pair.
- One has a negative dB sign and one has a positive dB sign.
- Perhaps reflectance has its origins in the electrical world where return loss having a negative sign is more properly called the reflection coefficient.

Connector Polish	Nominal Reflectance (dB)	Nominal Reflectance (%)
FLAT	-20 dB	1%
PC	-40 dB	0.01%
UPC	-50 dB	0.001%
APC	-60 dB or higher	0.0001%

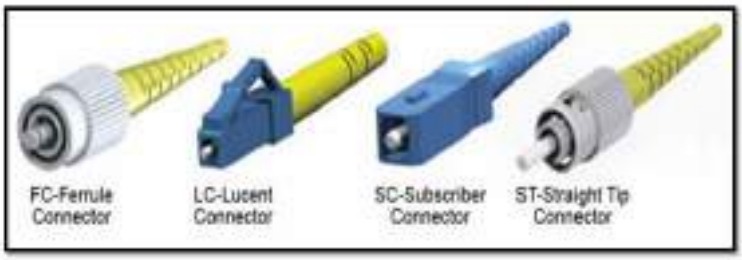
Connector Colour Codes (TIA 568)

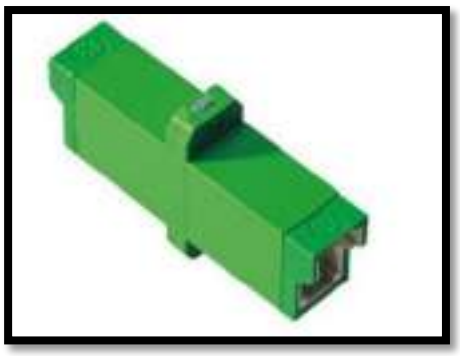
- Multimode connectors are beige for 62.5/125 OM1 fiber, black for 50/125 OM2 fiber, aqua for laser-optimized 50/125 OM3 and OM4 fiber and lime green for wideband OM5 fiber.
- Singlemode connectors are blue, angle-polished singlemode are green and outlets are also color coded accordingly.

Fiber Type	Connector Body	Strain Relief / Mating Adapter
62.5/125 µm	Beige	Beige
50/125 µm	Black	Black
50/125 µm Laser Optimized	Aqua	Aqua
9/125 µm Single Mode PC/UPC	Blue	Blue
9/125 µm Single Mode APC	Green	Green

- Multimode connectors are beige for 62.5/125 OM1 fiber, black for 50/125 OM2 fiber, aqua for laser-optimized 50/125 OM3 and OM4 fiber and lime green for wideband OM5 fiber.
- Singlemode connectors are blue, angle-polished singlemode are green and outlets are also color coded accordingly.

3.3 Types of Fiber Optic Connectors





Polarization	Connector Type	Coupling Type	Fiber Type	Polish	No. of Fibers	Typical Applications	Comment
	ST	Twist on	Single mode Multimode	PC, UPC	1	LANs	Keyed
	FC	Screw on	Single mode Multimode	PC, UPC, APC	1	Datacom, Telecommunications	Keyed
	SC	Snap on	Single mode Multimode	PC, UPC, APC	1	CATV, Test equipment	Keyed
	LC	Snap on RJ45 style	Single mode Multimode	PC, UPC, APC	1	Gigabit Ethernet, Video Multimedia	Small Form Factor (SFF)
	MU	Push/Pull	Single mode Multimode	PC, UPC, APC	1	Medical, Military	Small Form Factor (SFF)
	MT-RJ	Snap on RJ45 style	Single mode Multimode	NA	2	Gigabit Ethernet, Asynchronous Transmission Mode (ATM)	One of Mating Connectors must have Alignment Pins
	MPO (MTP)	Push/Pull	Single mode Multimode	NA	4, 8, 12, 16, 24	Active Device Transceiver, Interconnect-ions for CAD Modules	One of Mating Connectors must have Alignment Pins

1. Lucent Connectors (LC)

- Ø LC connectors have some of the smallest ferrules, measuring 1 1/4 mm, which is approximately half the size of an ST connector.
- Ø Their tiny size puts them into the small form factor category of terminations.
- Ø These connectors work well for multimode transceivers and single-mode cables.

2. Standard Connectors (SC)

- Ø SC connectors have a 2 1/2 mm ferrule.
- Ø This connector has high levels of performance with low price. It is most common in use.

3. ST Connectors

- Ø ST connectors are among the oldest of fiber cable connector types.
- Ø The design of ST connectors is a 2 1/2 mm ferrule that has a bayonet-style connection between the fibers through an adapter.
- Ø These ferrules use a spring-load design that can make installation difficult unless the parts have precise seating, though a keyed slot assists with aligning the ferrules for connection.

4. Ferrule Core (FC) Connectors

- Ø FC Connector use a keyed, screw-in type ferrule. However, the process of screwing in the ferrule requires extra time and effort compared to SC connectors.
- Ø The screw-in design prevents the connection from interruptions, even when someone pulls the cable or the system has applications in areas with a lot of movement.
- Ø Like ST and SC connectors, FC terminations use a 2 1/2 mm ferrule.

5. Multi-Position Optical (MPO) Connectors

- Ø MPO connectors usually connect ribbon cables with multiple fibers. These connectors have two to six rows of 12 or 16 fibers.
- Ø This type of connector has applications in either high-speed links that use multimode or for pre-terminated cable groupings.

6. MT-RJ Connectors

- Ø Today, MT-RJ connectors have disappeared from use. However, some systems may still require these connectors for repairs.

7. MU Connector

- Ø MU fiber connector has square shape and push-pull mating mechanism and uses 1.25mm pull-proof designed ferrule.
- Ø Size of the MU fiber optic connector is about half of the SC.

Connector Insertion Loss and Its Causes

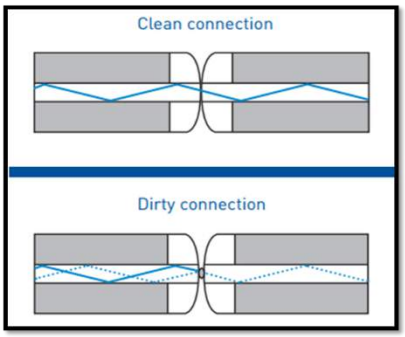
Name	Mating Cycles	Ferrule Size	Typical Insertion Loss (dB)
SC	1000	Ø2.5mm Ceramic	0.25 - 0.5
LC	500	Ø 1.25mm Ceramic	0.25 - 0.5
FC	500	Ø 2.5mm Ceramic	0.25 - 0.5
ST	500	Ø 2.5mm Ceramic	0.25 - 0.5
MPO/ MTP	1000	6.4 x 2.5mm molded	0.25 – 0.75

Causes of Connector Insertion Loss:

- Ø Dust on Ferrule
- Ø Scratch of Ferrule
- Ø Improper Alignment
- Ø Poor Mating
- Ø Ferrule Polishing Mismatch
- Ø Fiber Mode Mismatch

Particulars	PC	APC
Expanded Name	Polished Connector	Angular Polished Connector
Body Colour	Blue	Green
Insertion Loss (per connector pair)	0.5 dB (Approx.)	0.35 dB (Approx.)
Fiber Polishing	Straight	Angular (8°)

3.4 Inspection and Cleaning of Connectors



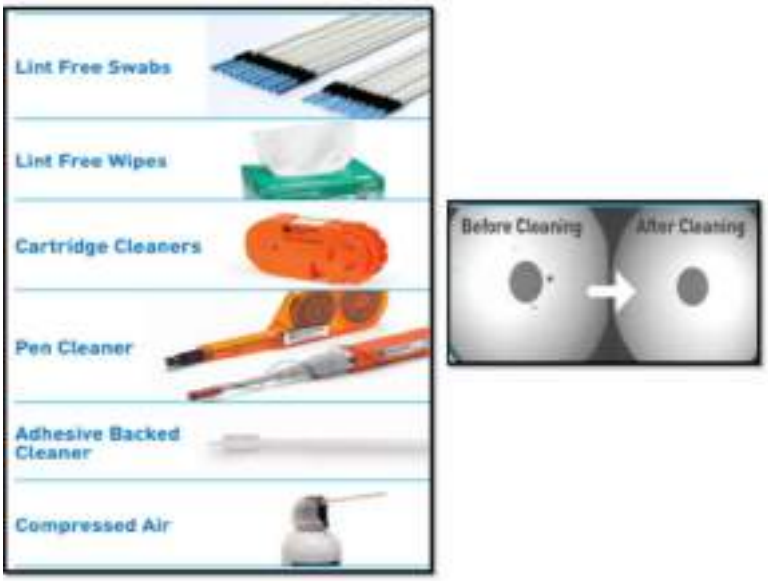
Fiber Optic Connector Hygiene

Common Mistakes:

- Ø Leaving a connector uncapped
- Ø Touching the connector end face
- Ø Using unsuitable cleaning methods or products
- Ø Assuming that connectors protected by dust caps are clean
- Ø Not cleaning both connector end faces before making a connection

Inspection of Optical Connector

- Ø Fiber Optic Microscope Scope 400x Magnification
- Ø Handheld fiber microscope can check out depression, scratches, contamination and other conditions on fiber connectors
- Ø The image of fiber end is very clear
- Ø It not only can test PC end, but also can test APC end



Section 3: Exercises

Exercise 1: Identify the types of optical fiber connectors in following image:

Exercise 2: Identify following couplers.

Exercise 3: Participate in a group discussion on following topics:

a) Connector Polishes and Insertion Loss
b) Inspection and Cleaning of Connectors
c) Types of optical connectors
d) Optical Connector Colour Codes

Section 4: Assessment Questionnaire

1. What is colour of PC connector?
2. Which connector has green Colour?
3. What is the insertion loss of PC and APC connector?
4. What are some common mistakes which affect hygiene of fiber optic connector?
5. Which equipment is used to inspect optical connector?
6. Which connector has larger exposed ferrule size?
7. The screw-in design of ____ connector prevents the connection from interruptions, even when someone pulls the cable or the system has applications in areas with a lot of movement.
8. _____ connectors have some of the smallest ferrules.
9. _____ connectors usually connect ribbon cables with multiple fibers.
10. If you connect PC connector with APC connector, the insertion loss will be higher. True or False?
11. Is Fiber Microscope a battery-operated device?
12. Lint free wipes are not recommended for cleaning the connectors. True or False?

----------End of the Module----------

MODULE 4
HDPE DUCT, ITS ACCESSORIES & STORAGE

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Explain the properties, advantages and disadvantages of HDPE
- Describe the dimensions, use and specifications of HDPE duct
- Identify and use HDPE duct and its accessories
- Couple two HDPE ducts efficiently using Pushfit Coupler
- Distinguish between different duct protection pipes
- Explain working of Micro Ducts and Its Accessories
- Store the HDPE ducts using best practices

Section 2: Relevant Knowledge

4.1 Introduction to High Density Polyethylene (HDPE)

Ø High-density polyethylene (HDPE) is thermoplastic polymer.
Ø It exhibits attributes of toughness, flexibility, chemical resistance and non-conducting electrical properties.
Ø It is used in highway drainage pipes since the early 1970s.
Ø Since then, growing out of applications for agricultural drainage, Toys, utensils, films, bottles and processing equipment. Wire and cable insulations.

HDPE – Advantages and Disadvantages

Advantages:

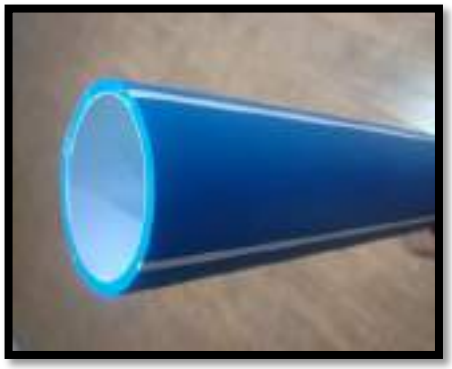
Ø Low cost
Ø Impact resistant from -40 °C to 90°C
Ø Moisture resistance
Ø Good chemical resistance
Ø Readily processed by all thermoplastic methods

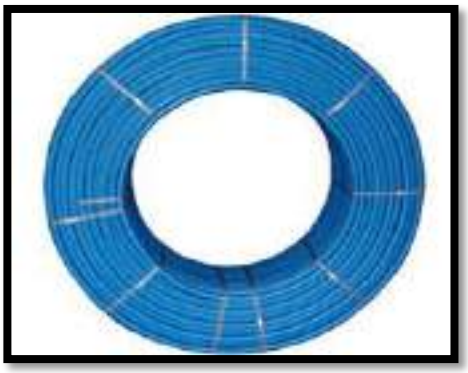
Disadvantages and Limitations:

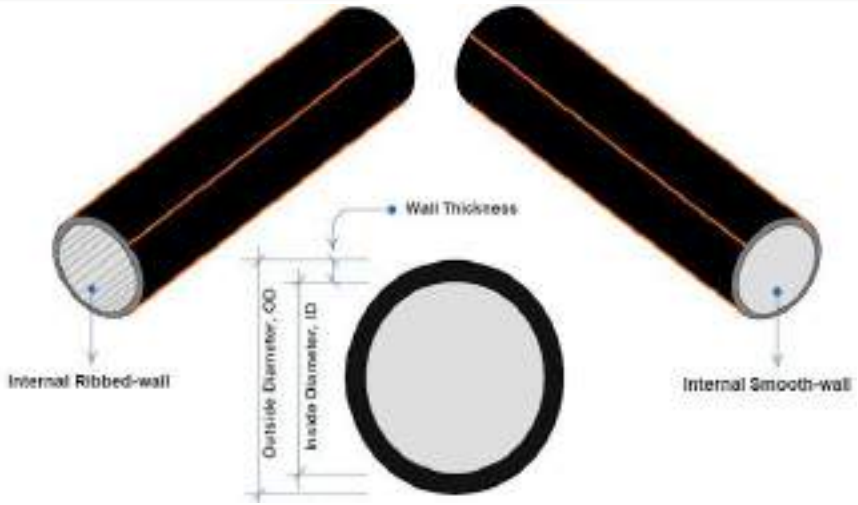
Ø High thermal expansion
Ø Subject to stress & cracking
Ø Difficult to bond
Ø Flammable
Ø Poor temperature capability

4.2 High Density Polyethylene (HDPE) Ducts

- Ø HDPE (High Density Poly Ethylene) Duct is a pipe, used to protect fiber optic cable.
- Ø Outer layer being HDPE and Inner layer is a solid permanent lubricant (PLB) to reduce the cable friction during cable blowing.
- Ø In telecom, HDPE duct is laid underground and optical fiber cable is blown inside the HDPE duct.







Commonly used HDPE duct in telecom has:

- Ø Outer diameter: 40mm
- Ø Wall Thickness: 3.5mm
- Ø Duct roll length: 500m and 1000m
- Ø Colour: As desired

Marking on Duct

Distinct, clear and easily visible size of ink marking with following information at every meter of interval:

User Name :
Duct Manufacturer Name:
Duct Type :
Duct Size :
Duct Serial/Part Number
Date of Manufacture
Length Marking in Meters

Check Points for Ducts

During inspection of duct, ensure that duct is:

Ø Smooth, rounded and clean

Ø Free from defects like holes and damage
Ø Uniformly colored
Ø Marked as per standard

4.3 HDPE Duct Accessories & Tools

Duct Decoiler

How to use Decoiler?

- Ø Place the decoiler along the side of the trench
- Ø Duct should be uncoiled from the bottom
- Ø Drive the reel slowly to avoid over spinning
- Ø Avoid the twist and kinks

End Cap and End Plug

- **End Cap:** Made of hard rubber/suitable plastic material, fitted onto both end of duct coil after manufacturing the duct.
- **End Plug:** Used for sealing of ends of the empty duct prior to installation of OFC to prevent entry of dirt, water moisture etc.

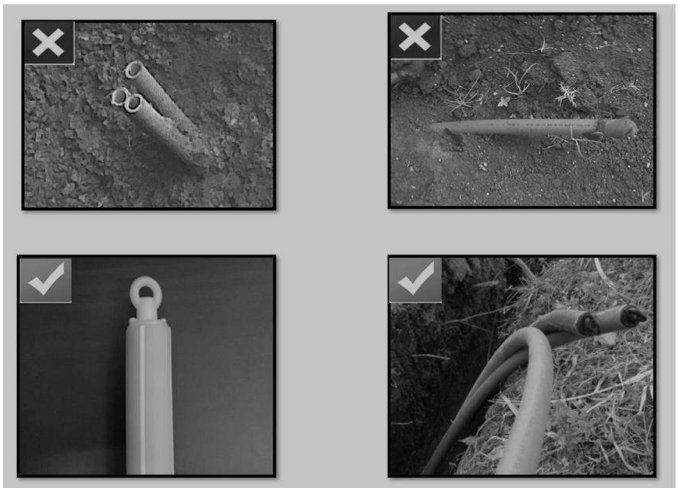
End Cap

End Plug

Simplex Plug

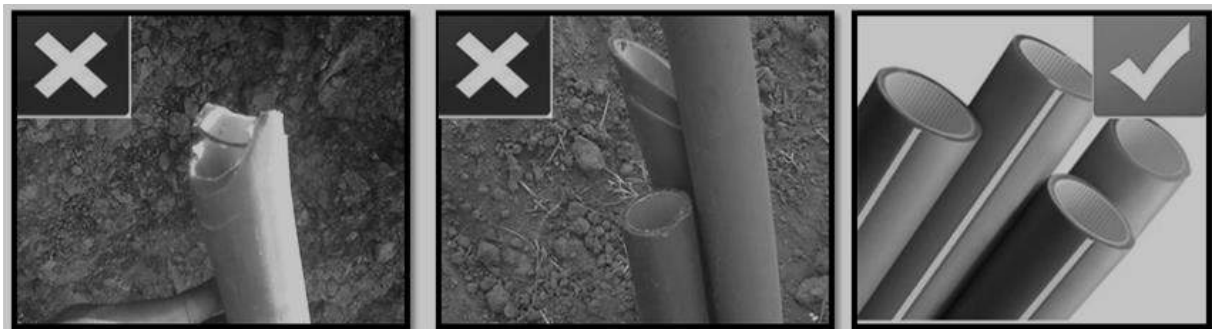
Simplex Plug: Used to seal the end of the duct, after cable is installed. It is required, where cable has come out of duct.

Use of End Plug



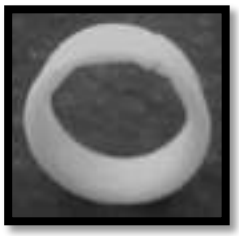
Rotator Duct Cutter

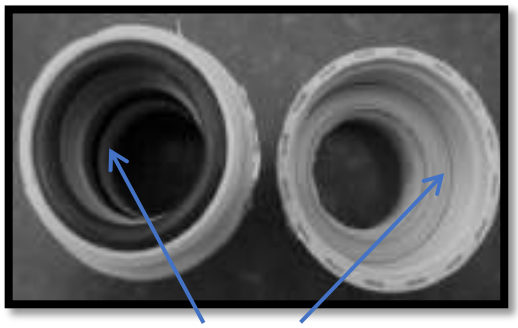
Used to cut duct ends squarely without any burr or notch.



Push Fit Duct Coupler

Ø Used to couple two duct ends. They are easy to install and provide air/water tight joint between two duct ends.





Ø C Spanner is used to tighten/open push fit coupler.

Chamfering Tool

The Chamfering Tool must be used to sharpen the face of duct so that the duct is inserted into the push fit coupler easily without damaging the rubber (O-Ring) inside coupler.

Using the Chamfering Tool

Ø Chamfering tool reduces the outer dia of the duct to less than inner dia of the “O-Ring”.

The duct now enters the O-Ring without any damage to the O-Ring

On pushing the duct, O-Ring slips over the unchamfered portion of the Duct and provides leak-proof seal

Duct Spacer

Ø Duct Spacer is used for duct separation in multi-duct installations.

Ø It is non-metallic duct accessory.

4.4 Duct Coupling

Cutting the Ducts

Ø Duct should be cut with about 30mm overlap with duct cutter at 90 degrees. Mark the “Cut Mark” using a Measuring Tape and a Marker.

Ø The duct overlap is to allow duct shrinkage while pressing down.
Ø If ducts are cut neck to neck, then while pushing the ducts into the coupler duct may come out.
Ø Use chamfering tool

Remember: <u>Before cutting the duct push it towards the root</u>

Cleaning and Lubricating the Duct

Ø Clean both the duct-ends with water and waste cloth. There should be no dirt on the duct-ends.
Ø Mark both duct-ends with 60mm “Insertion Mark”, with a permanent marker pen.
Ø Apply “a drop of shampoo”, as a soap-based lubricant, on the inner side of O-Ring inside the coupler, without opening the coupler.

Coupler Fitting.....

Ø Initially, insert one duct-end into the coupler with a gentle push.
Ø Duct-end should slip inside the rubber O-Ring with a “tik” sound and come to the center of the coupler.

Ø Confirm that “Insert Mark” line is just outside the coupler.
Ø Repeat the process from other end of the coupler.

Cutting of duct without proper planning:

Ø **Gap in ducts**- due to this the duct-ends will not cross the “O” Ring and leakage will occur. Plan for an overlap of 20~30 mm.
Ø **Shrinkage**- Avoid the coupling immediately just after pulling the duct by HDD, possibility of shrinkage may appear and leakage can occur.
Ø Do not use the **“Chinese Figure”** applied portion in the duct coupling.
Ø Coupler shall not be installed along the bent portion of duct/trench in both horizontal as well as vertical direction.
Ø Avoid the coupler installation in Horizontal or Vertical Zigzag portion of the duct.
Ø Couplers should not rotated while fitting otherwise the Teeth & O-Ring of the coupler will got damaged. Do not use hammer on Coupler while installing.
Ø Damaged Teeth Ring may weaken the joint and tightness of coupler will be affected.
Ø Coupler shall not be opened during fitting as it is designed for “Push-Fit”.

What are the reasons of leakage in couplers during DIT??

Ø Most likely reason for coupler leakage is the Damaged “O-Ring”

Reasons of Leakage:

Ø Use of incorrect tools, specially “Hacksaw Blade”. An unclean cut damages the O-Ring.
Ø Duct cut exactly at 90 degrees (Square-Cut) can damage the O-Ring.
Ø Not Chamfering and using heavy force to push the duct can damage the O-Ring.
Ø Penetration of dust while coupler fitting/handling. The duct should be properly cleaned before starting the coupling process.

Can we open the coupler and reuse successfully?

Ø Yes, coupler can be opened and re-used using opening tool (C Spanner).
Ø Coupler teeth-ring is widened and removed so that teeth remained sharp enough for grip and same. way while closing, precaution should be taken for placing the teethed ring over the duct.

4.5 Duct Protections

Double Walled Corrugated Pipe

Ø DWC pipe (a Pipe within a Pipe) is a double layer pipe with the outer layer having corrugation and the inner layer with a smooth surface.

DWC Pipe DWC Coupler

Material	Anti Rodent Plastic
Nominal Dia (mm)	50/38, 63/50, 77/63, 90/76, 120/103, 145/126, 160/136, 175/148
Length	3 and 6 meters
Colour	Orange or Blue

RCC/GI Pipe

Ø RCC and GI pipe is also used to protect the duct at less depths or crossings
Ø Commonly preferred specifications of RCC and GI pipe in telecom are:

RCC Pipe

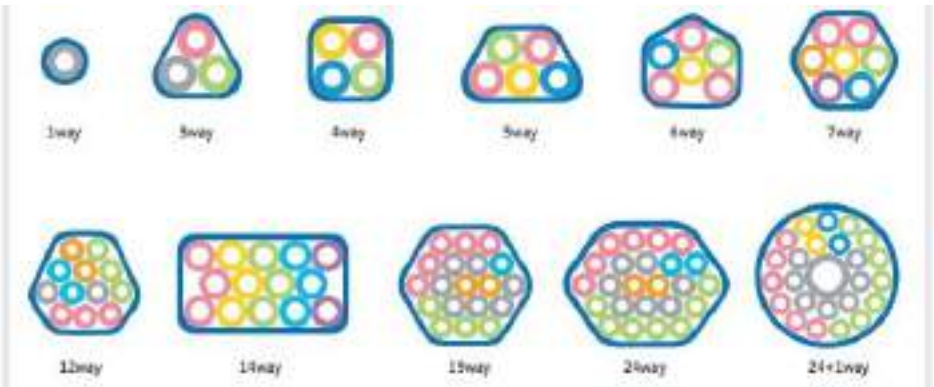
GI Pipe

Particular	GI Pipe	RCC Pipe
Material	Galvanized Iron	Reinforced Cement Concrete
Outer Dia	65mm or 76 mm	100 / 150 mm
Length (mtrs)	2 or 3 Meters	2 or 3 Meters
Class	B (Medium duty)	NP3 (Medium duty)

4.6 Micro Ducts & Its Accessories

Micro ducts

Ø Micro ducts are small ducts, used for the installation of small microduct fiber optic cables.
Ø Micro ducts are typically small-diameter, flexible, or semi-flexible.
Ø It provides clean, continuous, low-friction paths for placing optical cables that have relatively low pulling tension limits. (Generally, it has low friction antistatic inner surface)
Ø Micro ducts can be pre-installed within a larger conduit, or simply pushed into existing conduits already in place.



- **DIRECT BURIED (DB):** In applications, where the Micro ducts will be directly buried, or bundled, it is recommended to use thicker walled Micro ducts to maintain the optimum fill ratios and have faster, easier installations.
- **DIRECT INSTALL (DI):** In applications, where the Micro ducts are placed inside an existing conduit, it is recommended to use thinner walled product where protection is provided by the existing conduit and space is more sensitive.

Microcables in micro ducts compared to a normal cable in duct

Micro Ducts: Anti Rodent (Direct Bury)

- The Anti-Rodent (Direct Bury) type ducts:
- Are designed to withstand and repel rodent attacks.
- Have a fiber glass layer encased in inner and outer PE sheaths prevents rodents from causing costly damage.

Micro Ducts: Anti Termite (Direct Bury)

- Are used where termite activity is likely
- Have Nylon12 and aluminum layers encased in inner and outer PE sheaths to provide mechanical and chemical protection against attach by termites and ants (and their formic acid).

Micro Ducts: Chemical Resistant

- Are used in environments at risk of chemical contact.
- Have maximum chemical resistance provided through four layers of protection; an initial aluminum layer, an inner PE sheath, a chemical resistant layer and an outer PE sheath.

Micro Ducts: Direct Install Metal Free

- Can be installed directly into a duct or sub-duct where a non-metallic solution is required (such as an area with a risk of lightening).
- Have single PE sheath.
- Have optional non-metallic moisture barrier (water blocking tape).

Micro Ducts: Direct Install Aluminum

- Ø Can be installed directly into a duct or sub-duct
- Ø Can be provided with moisture protection by a 150-micrometre layer of aluminum
- Ø Have single PE sheath
- Ø Are integral ripcord for easy sheath removal

Micro Ducts: Low Smoke Zero Halogen (LSZH) Tubes

- Ø Fire retardant and halogen free tubes which meet indoor fire regulations
- Ø Permanent low friction inner coating for enhanced blowing performance
- Ø Smooth or ribbed inner wall
- Ø Solid white colour as standard

Micro Ducts: Aerial

- Ø Are used for aerial installation where underground access is not possible or would be less economical
- Ø Are self-supporting
- Ø Are UV stabilized
- Ø Have figure of 8 construction with steel strength member

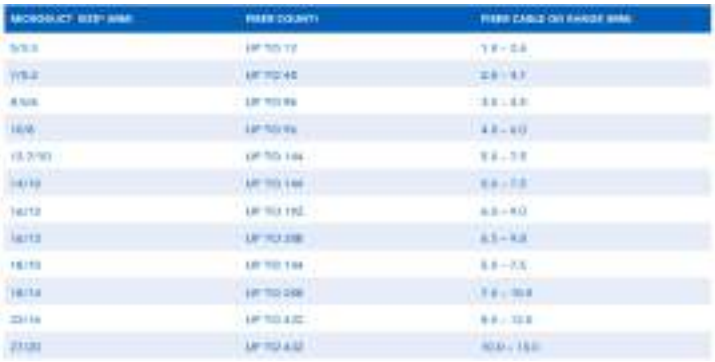
Cable Fill Ratio in Duct

Calculate (d/D) * 100 = % Cable Fill Ratio

(OD CABLE / ID MICRODUCT) * 100 = % CABLE FILL RATIO

- Ø To calculate the fill ratio, divide the cable diameter (d) by the interior dimension (D) of the Micro duct.
- Ø To achieve maximum jetting performances, it is recommended to maintain a fill ratio between 50% and 75%.
- Ø Several factors impact jetting performance, including the condition of route, bends, and equipment.

Recommended Fiber Fill Ratios



Micro Couplers

Ø Micro Couplers are used to join two segments of Micro ducts.
Ø They are available in multiple sizes, starting from 5 mm dia.
Ø Micro Couplers are designed specifically for Fiber to the Home (FTTH) networks.

Features:

- Easy assembly/disassembly, no tools required
- Provide an air and water tight connection
- Color coded by size
- Resistant to high pressures for blowing micro cables through guide tubes
- Resistant to corrosion and most chemicals

Micro Duct Cutter

The Micro Duct cutter is used to make a 90° cut of the Micro Duct.

Micro End Caps

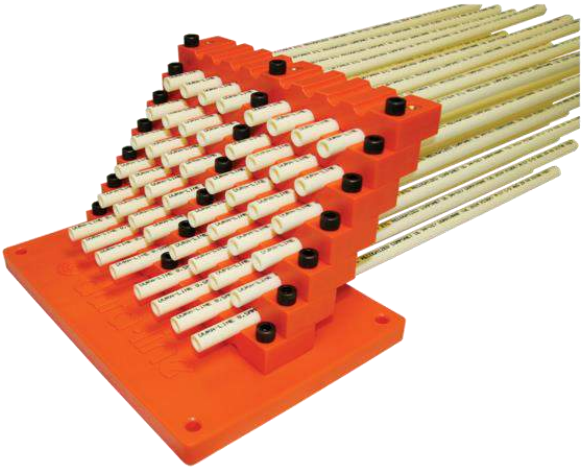
Ø Micro end caps are used to seal the ends of the Micro Ducts.
Ø Easy assembly/disassembly, no tools required.
Ø Provide an air and water tight connection; keep debris out of Micro Duct pathway.
Ø Color coded by size.

Divisible Duct Seal Kits

- Ø Divisible Duct Seals provide an air and water tight seal between the cable OD and Micro duct ID.
- Ø The hard outer cover is divisible so it can be easily installed around an existing cable.
- Ø Inner seals are color coded to quickly differentiate between cable OD's.
- Ø Available for Micro duct sizes 5mm - 18mm.

Micro Duct Mounting Bracket

- Ø The Micro duct mounting bracket is designed to organize Micro ducts at termination.
- Ø It's small and compact, requiring a minimum amount of mounting space.
- Ø The modular design allows ordering additional brackets as needed.



Gas Block Connector

- Ø The Gas Block Connectors provide a simple and effective gas seal between the Micro Duct and the fiber cable.
- Ø Its size ranges from 5mm - 16mm accommodating different fiber cable size ranges.

Duct Branch Closure

- Ø The Duct Branch Closure is intended for fast and easy branching of direct buried micro duct assemblies for air blown fibers.
- Ø The Duct Branch Closure minimizes installation cost by eliminating the need for time consuming fiber splicing in various branch points.
- Ø The closure is intended for mounting directly into the ground or in manholes, but can also be installed above ground.

4.7 Duct Storage

- Ø Place the material in the manufacturer's premises (till it is required in field) so that it will not affect the performance of the product.
- Ø Coil the duct in suitable size for delivery.
- Ø Use standard moving equipment for loading, unloading and handling.

Section 3: Exercises

Exercise 1: Identify following HDPE duct accessories.

a) End Plug
b) Simplex Plug
c) Duct Coupler
d) C Spanner
e) Duct Cutter
f) Chamfering Tool

Exercise 2: Participate in group discussion on following topic.

a) HDPE Duct Protections (DWC, GI and RCC Pipe)
b) HDPE Duct Dimensions, Marking and Check Points

Section 4: Assessment Questionnaire

1. What are qualities of HDPE Duct?
2. What are applications of HDPE Duct?
3. What are advantages of HDPE?
4. What are Limitations of HDPE?
5. What is marked on HDPE Duct used in telecom cable conduiting?
6. What are check points during inspection of HDPE Duct?
7. Which equipment is used to unwind the duct roll?
8. Identify the item shown in image below.

9. _____ is used to seal the end of the duct, after cable is installed.
10. What can be Used to cut duct ends without any burr or notch?
11. Why Chamfering tool is used?
12. Can we open the coupler and reuse?
13. _____is a double layer pipe with the outer layer having corrugation and the inner layer with a smooth surface?
14. _____is also used to protect the duct at less depths or crossings.
15. Which tool is used to open the duct coupler?
16. _____are installed in micro ducts.
17. In which application thicker walled micro ducts are installed?
18. In which application thinner walled micro ducts are installed?
19. What is formula for % cable fill ratio?
20. The _____is intended for fast and easy branching of direct buried micro duct assemblies for air blown fibers.

----------End of the Module----------

MODULE 5
UNDERGROUND OFC LAYING PRACTICES

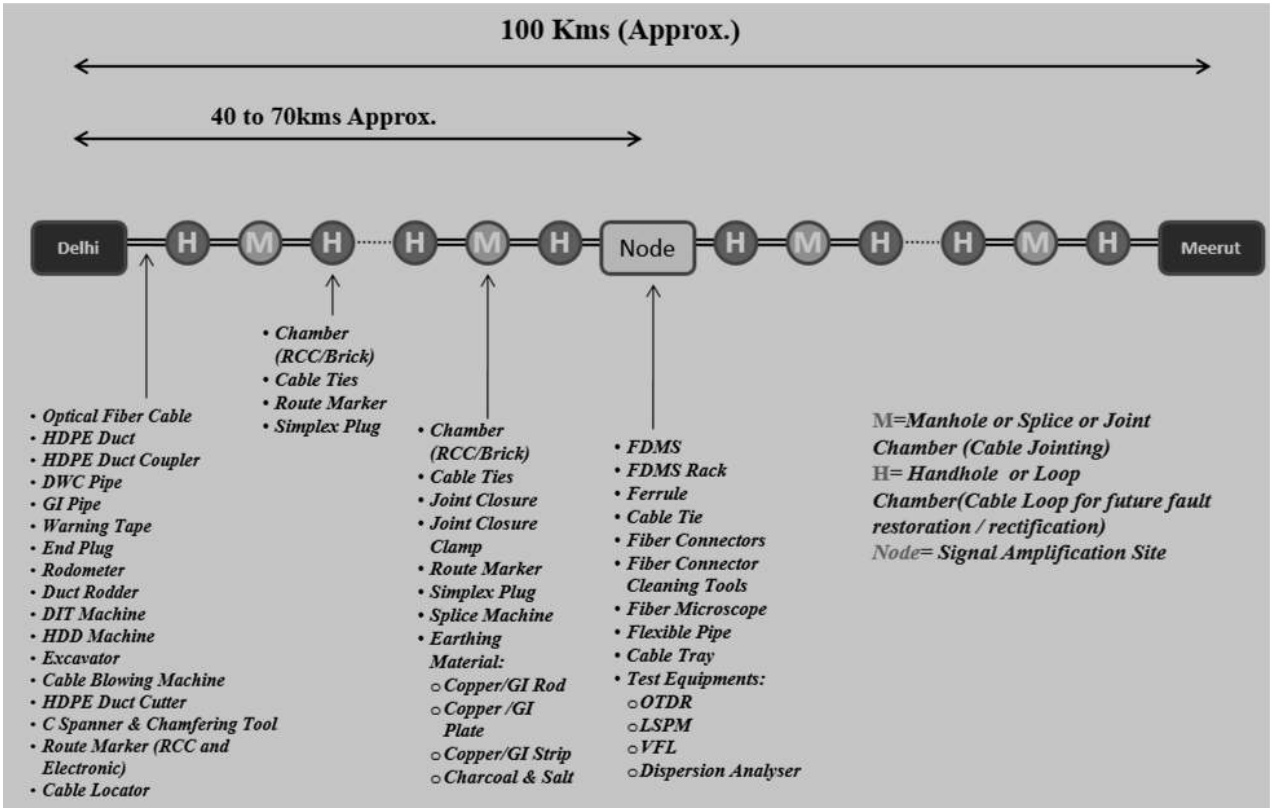
Section 1: Learning Outcomes

After completing this module, you will be able to:

- Explain the fundamentals of OFC Route Survey and Right of Way (RoW)
- Describe the various process of Trenching viz. Open, Micro, HDD and Moling
- Explain the procedure of Direct Buried Cable Installation
- Describe the process of Ducting and Backfilling
- Use duct protections at different types of crossings (Bridge/Culvert/Road/Railway)
- Install Manhole and Handhole chambers
- Install Route Markers
- Perform Duct Integrity Test (DIT)
- Pull and blow cable in installed duct
- Terminate the fibers in patch panels

Section 2: Relevant Knowledge

OFC Link Illustration



5.1 Flowchart of Optical Network Construction Process

5.2 OFC Route Survey

Survey shall cover the following:

- Details of Route
- Right of Way (RoW) Demarcation
- Soil Strata
- Crossings (Bridge/Road/Railway)
- Existing Underground Utilities
- Cost Estimation
- Any other Criticalities or Risk Factors

Survey Report

Route Description

This route starts from Point A…. and goes …… through …….. then from ……. goes to …….. road via ……..and turn left …… and route is proposed left……..upto point …… and then turns right towards …… road and then turns left …… road and then goes to …… and then turns right and goes to …… and route from …….. is proposed ……..RHS …… end point of B.

Soil Strata of OFC Route

The general condition of the soil is varies from Normal to Soft & hard rocky. On the basis surface survey and as per strata seen visually, the tentative length and depth Chart as given below:

Type of Soil	Length in KM
Normal	
Mix Soil	
Sandy	
Hard Rock	
Other (if any)	
TOTAL	

Depth Bifurcation

Chainage (in Kms)	Bifurcation of Depth in CM					Aerial Cable
	Culvert/ Bridge/ Road Crossing	Less than 60 CM	Greater than and equal to 60 CM and less than 120CM	Greater than and equal to 120 CM and less than 165 CM	Greater than and equal to 165	
0-10						
10-15						

Crossing Details

SN	Type of Crossing	Details of Location	Method (HDD/OT/ Clamping)	Length in Mtr
	Culvert	At chainage 15.2		
	Gas			
	Railway			
	Road			
	Any other			
	TOTAL			

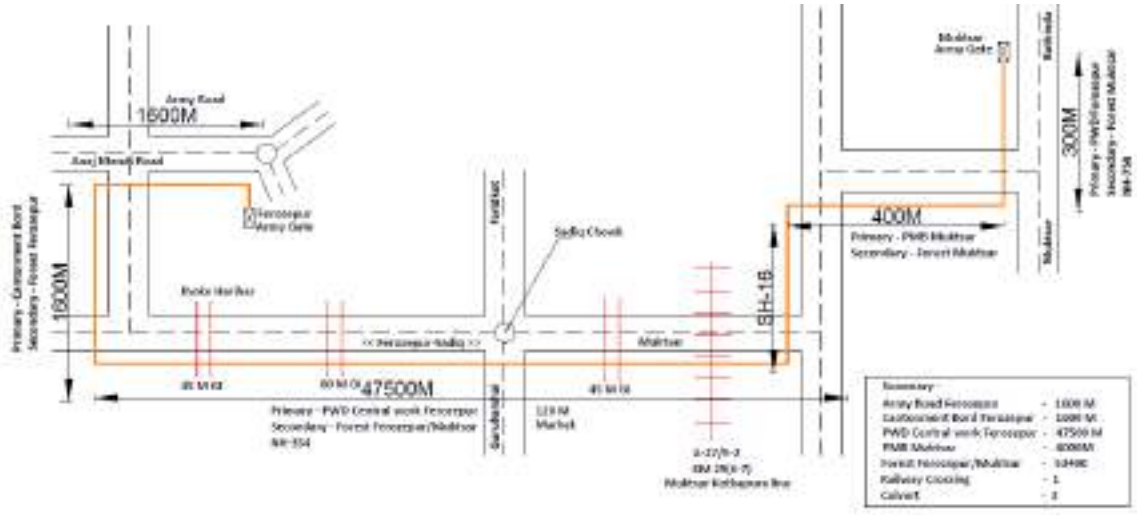
Details of ROW authority

Authority Name	Length in KM
NH	
SH	
Railway	
PWD	
CPWD	
Gas authorities	
Forest	
Any Other as per OFC route	
TOTAL	

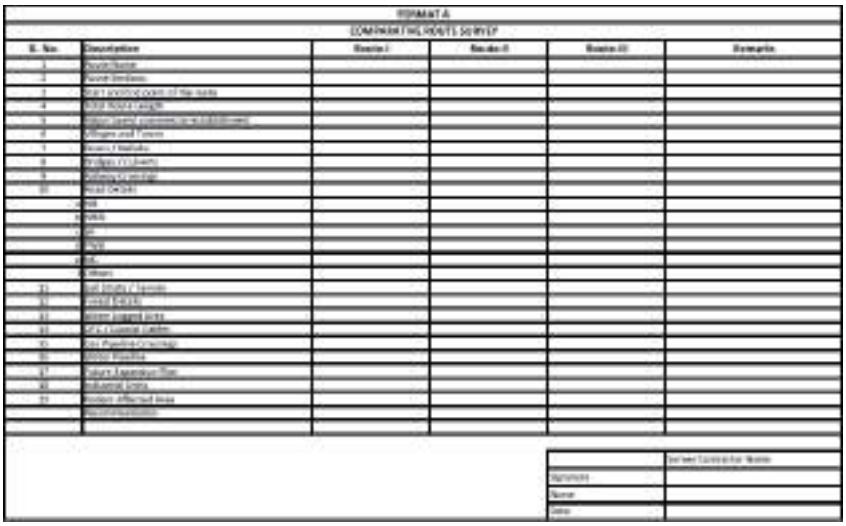
Name of Amplifier Locations

Particular	Location No.1	Location No.2	Location No.3	Any other …
Name				
Distance (KM) (From Start Point to Amplifier location)				

Route Survey: Pre-Construction Map



Comparative Route Survey: Sample Checklist

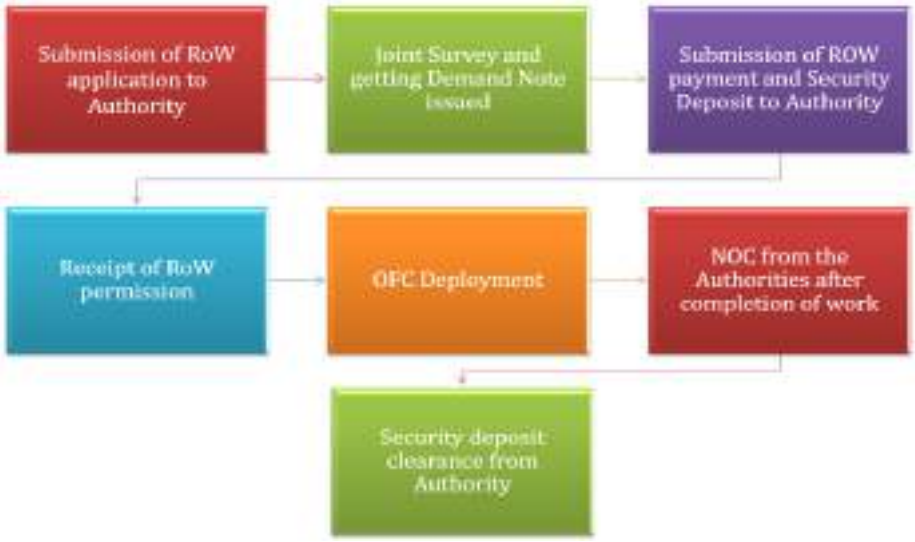


5.3 Right of Way

RoW is to be obtained from central/ state/ local authorities as per the route approved after the survey

- Ø State Highways
- Ø National Highway Authorities
- Ø Forest Department
- Ø Railway Department
- Ø PWD Roads & Buildings Department
- Ø Municipal Corporations
- Ø Panchayat
- Ø Irrigation Department
- Ø Cantonments etc.

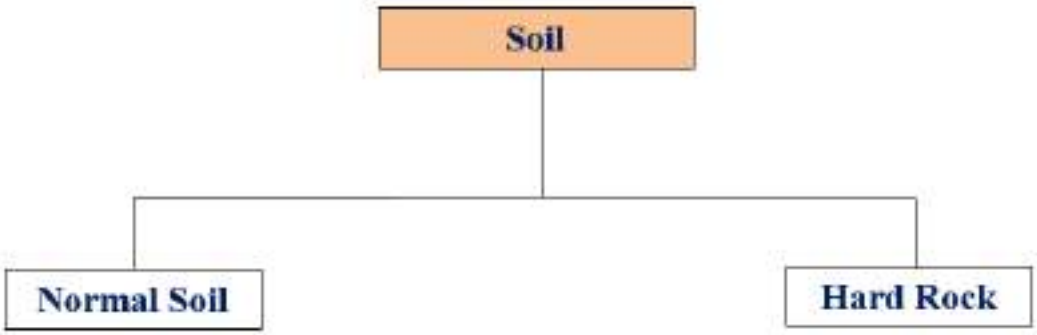
RoW Process



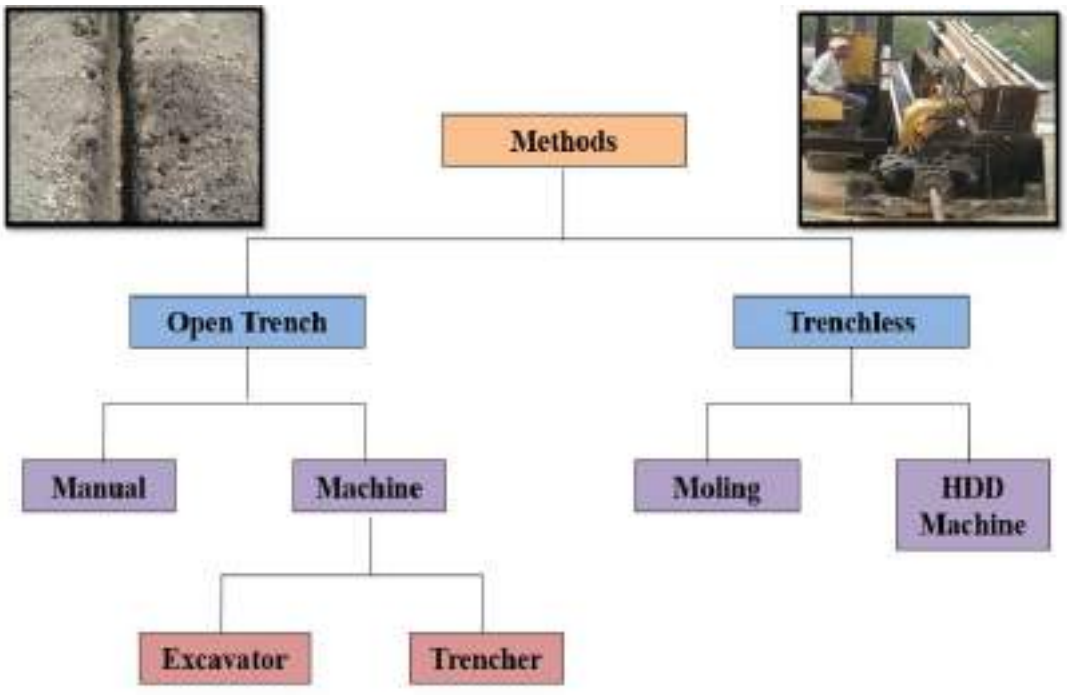
5.4 Open Trenching

Trenching

- Ø The process of continuous digging following a single line with specific dimensions is called Trenching.
- Ø The depth of the trench may vary as per soil strata & specification.



Trenching Methods



Trenching Specifications – General

- Ø Top width 450mm and Bottom width 300mm
- Ø Wherever achieving full depth is not possible due to site constraints such as rocky area, presence of underground utilities like pipelines, power cables etc., less depth may also be resorted with prior permission of user.

STANDARD DEPTH (FROM TOP OF SURFACE)	
Terrain	**Depth (Cms)**
Normal Soil	165
Rocky Terrain	120

PROTECTION FOR LESS DEPTH	
Depth	**Type of Protection**
0 Cm to 30 Cm	Not Permitted
30 Cm to 60 Cm	GI Pipe Dia. 65 mm with Concrete PCC
60 Cm to 120 Cm	DWC Dia. 78 mm
> 120 cm	No Protection

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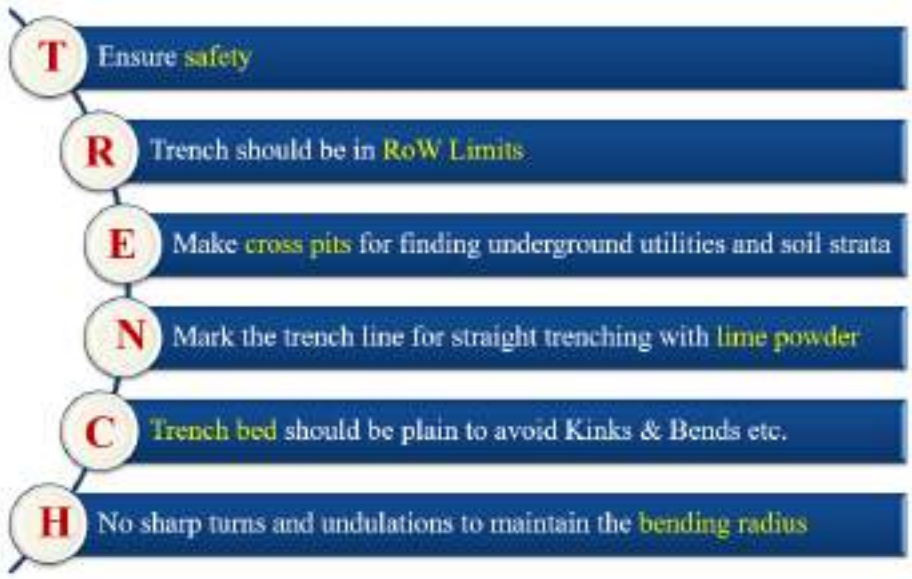
Prerequisite for Trenching



Making of Cross Pit

Cross Pit and Lime Powder Marking

Proper way of Trenching

5.5 Micro-Trenching

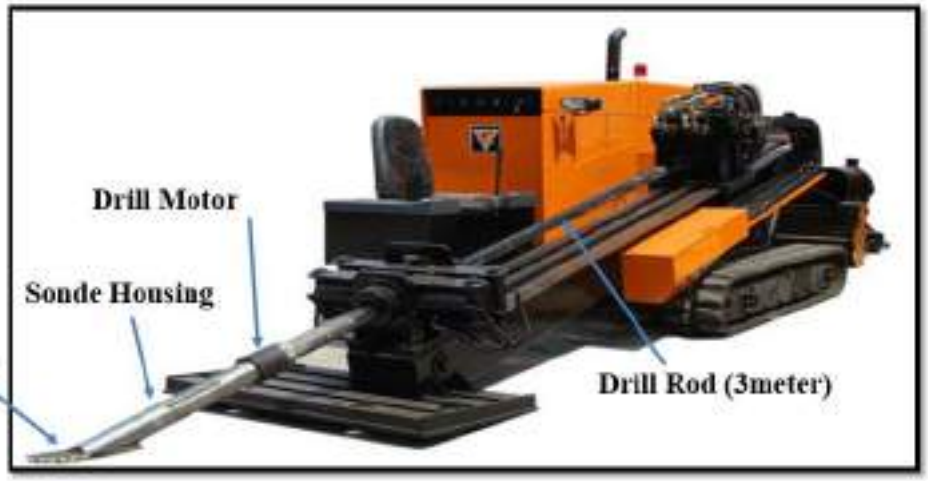
- Ø Micro-trenching is the process of installing HDPE ducts within the edges of the roads to place fiber optic cables.
- Ø A quick, low-impact deployment method, fiber optic cabling is inserted into a small slot-cut trench without damaging or disrupting existing infrastructure and traffic.
- Ø It uses diamond tipped saw blades, which allow efficient cuts through asphalt and concrete.

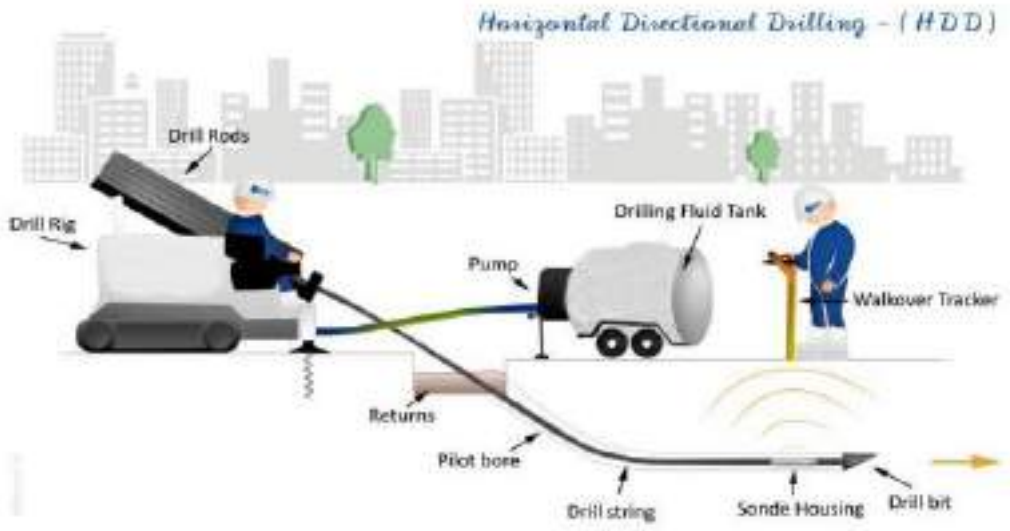
5.6 Horizontal Directional Drilling (HDD)

This is a trenchless method providing limited disturbance, fast & economical installation of duct.

Ø Applicable for drilling of < 250m stretch.

Ø Preferred for Road / River / Culvert /Railway crossing.



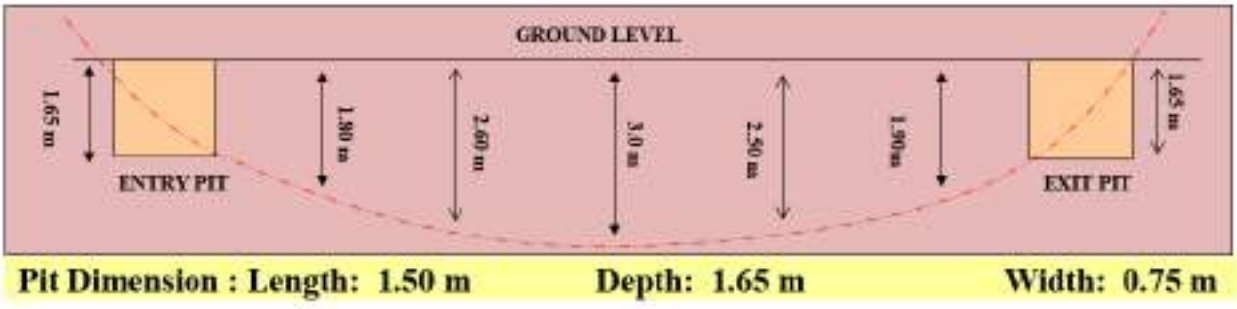


Drilling

Ø Appropriate Entry and Exit Pits are to be made.

Ø During drilling operation, continuous monitoring and plotting of the pilot drill shall be recorded.

Ø The tracking system is used for determining Alignment, Depth and Position of pilot.



Pilot Locating System

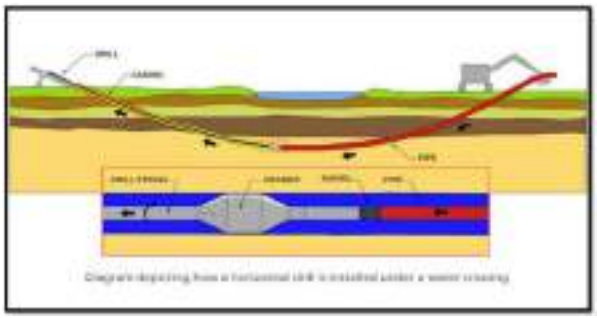
The tracking system shall provide information on:

- Alignment
- Depth
- Position

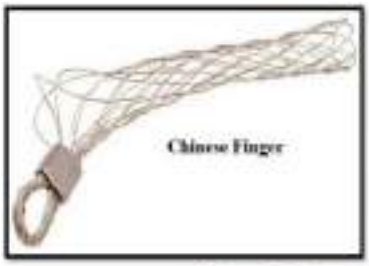
HDD Process

Two stages of HDD:

- Pilot drilling (Tracking system is used to determine Alignment, Depth and Position of pilot)
- Reaming and pulling back the duct



HDD Components



HDD Fluids

- Drilling fluid is a mixture of water and specialized additives used in the drilling process.
- Drilling fluid cools the drill head and transmitter.
- Bentonite is added to drilling fluid to seal the drilled bore from water ingress downwards and at the sides of the bore.

HDD: Do's & Don't

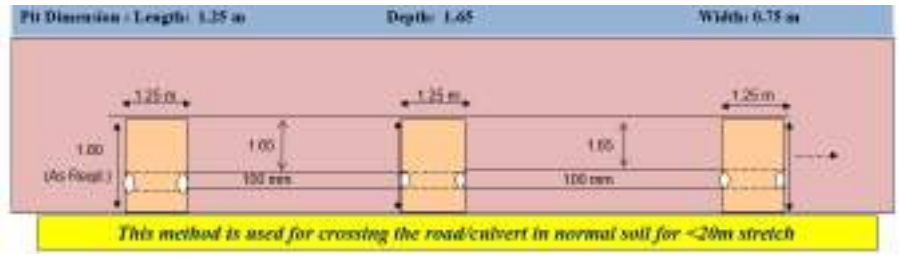
- Entry/Exit pit should have proper depth & size.
- Lime powder marking should be done for drilling in straight line.
- Debris/bushes must be cleared.
- Duct de-coiling should be done using duct de-coiler only.

HDD: General Safety

HDD Operator : PPEs

5.7 Moling

- Moling is a trenchless process in which trenchless operation from pit to pit is done by sectional pipes manually.
- Successful only in places having normal soil strata.
- Unsuccessful/unsuitable for more than 20m patch.
- Moling method is used for crossing under the road.



5.8 Direct Buried Cable Installation

Generally, Armoured type cables are selected for direct burial which offers:

- Higher crush resistance
- Additional protection from ground rodents
- Easy localization

Methods:

- Plowing
- HDD
- Direct Placement in Micro-Trench

While installation take care of:

- Maximum pulling tension of cable
- Minimum bend radius of cable
- Crush resistance of the cable

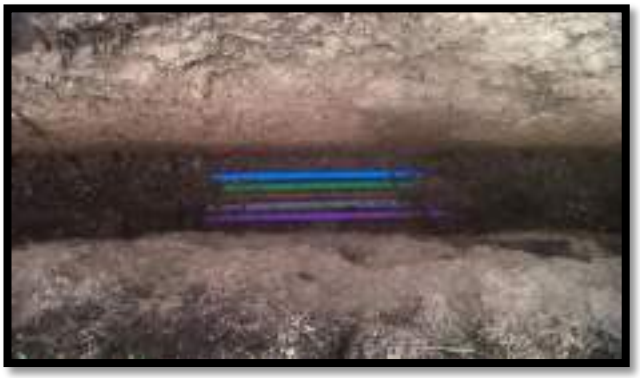
Cautions

- Take care to avoid cable damage during pulling, bending and crushing forces.
- Fiber optic cable should be coiled in a continuous direction in Figure ‘8’.
- Ensure straight and levelled trench bed.
- Potential problems should be identified and resolved in advance.
- Take care of the underground utilities.
- Ensure timely and effective grounding.
- Ensure continuous monitoring of cable during installation.

5.9 Ducting

Ducting is the process of placing duct in the trench

- Ø Check the roll of the duct for any physical damage
- Ø Always decoil the duct using Decoiler
- Ø No Water/Mud should be present in trench while laying the Duct/DWC pipe
- Ø Place the duct in the trench as per guidelines
- Ø The ducts should not overlap to each other
- Ø Ensure coupling before backfilling and cap the end



Ducting Practices: Cautions

Decoiler Not Used

Bending Radius Not Maintained during Laying

5.10 Backfilling

Backfilling Practices

Refilling of excavated area with soil is called Backfilling.

Warning Tape

Warning tape should be placed in the trench at 0.75m depth from the ground level.

Beware of Kinks & Punchers on duct

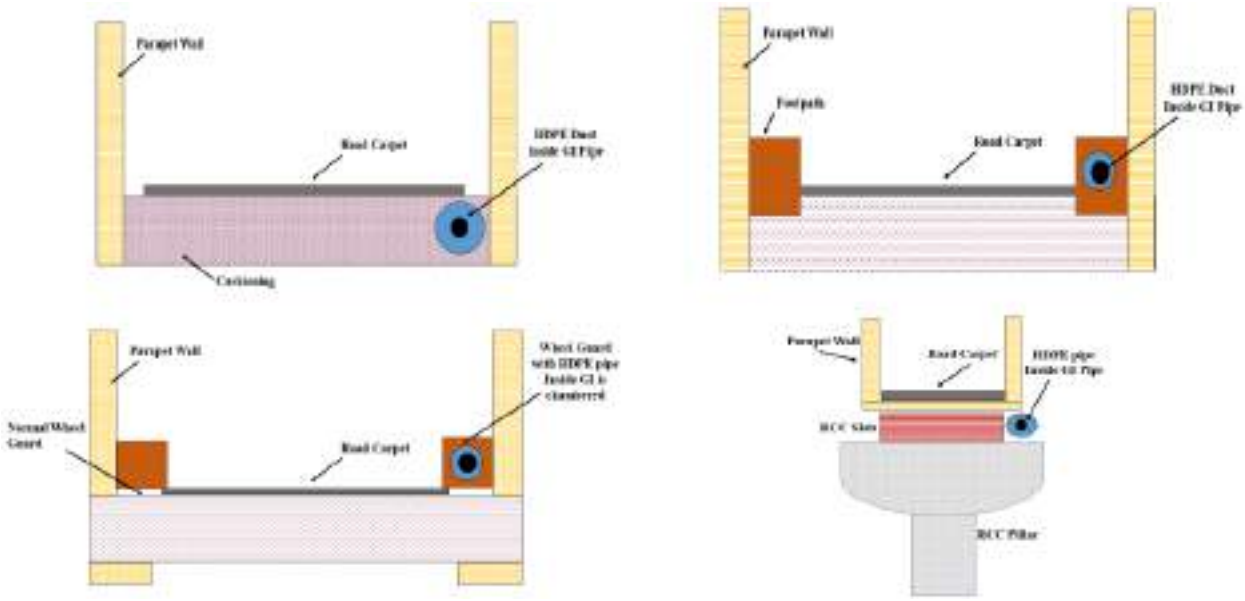
Crowning shall be made over the trench

Every layer of backfill, about 25 to 30 cm, should be compacted with water to achieve adequate compaction

Debris should be removed after completion of work.

Heavy stones should not be put over the duct

5.11 Crossings Protection Guidelines (Bridge/Culvert/Road/Railway)



Guidelines for Bridge / Culverts Crossings

- Ø G.I. pipes should be extended up to depth of 1.55m in case duct running on bridge.
- Ø G.I. pipes to be extended up to 2m length from edges of the bridge/culvert.
- Ø DWC/RCC pipes should be used parallel to dry culvert. For wet culvert G.I. protection and concrete encasement to be provided.
- Ø Outside the railing, G.I. clamps with nuts bolts should be of 12mm diameter.
- Ø On bridge, the G.I. pipe should be encased with M15 concrete (1:2:4 mix) all around the G.I. pipes.

Guidelines for Bridge Crossing

Clamping on Bridges

Bridge Crossing by DWC & PCC

Guidelines for Railway / Road Crossing

G.I./RCC pipes should be extended for 2m on both sides from the end of the road.

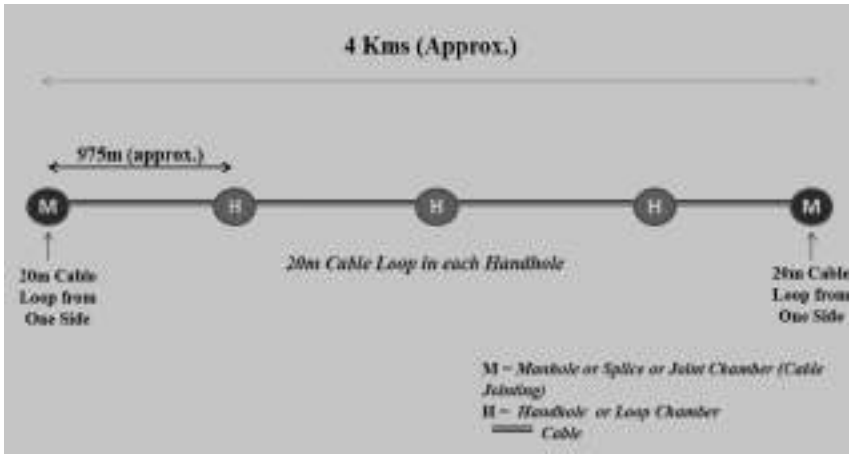
- Ø G.I. or RCC pipes should be joined by using collars.
- Ø HDD or Moling methodology to be used for railway crossing.
- Ø Loop chamber to be provided on one/both side of track.

Road Crossing Through HDD

5.12 Manhole / Handhole Installation

Types of Chambers

Chamber Locations

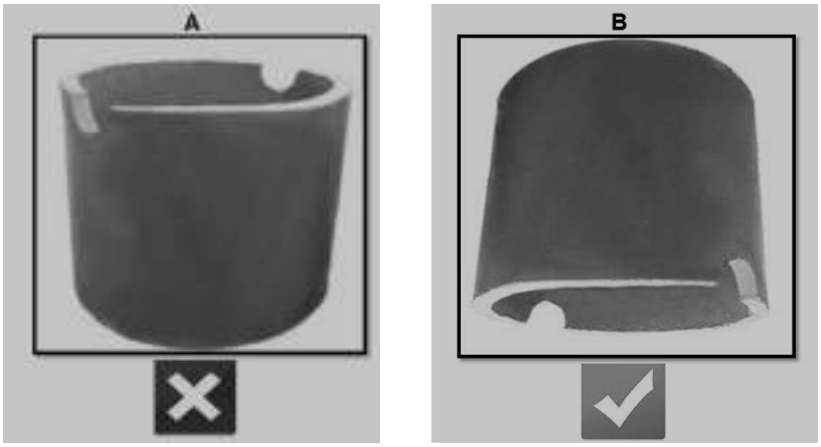


Chamber distances may vary as per ground conditions and requirements

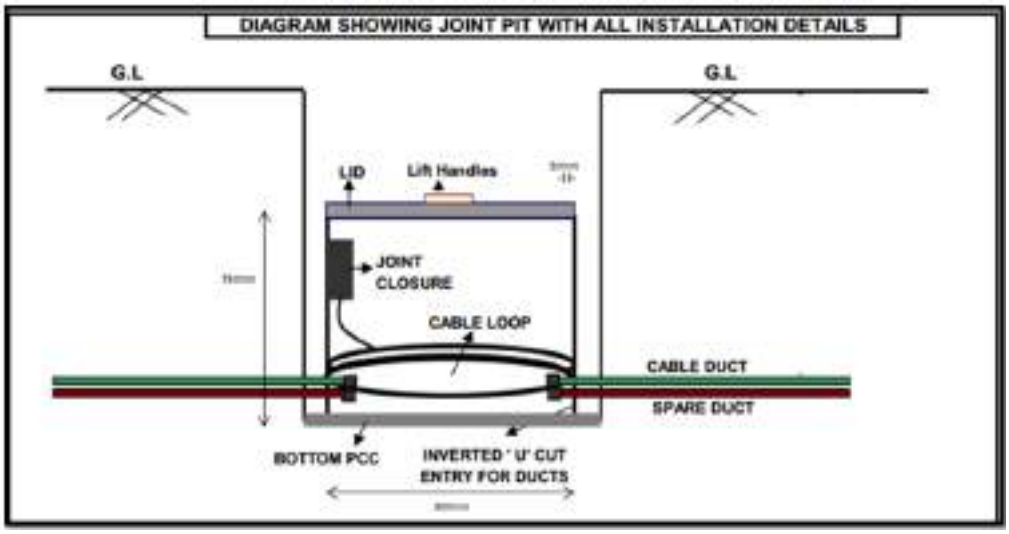
RCC Cylindrical Chamber

- Ø The duct length inside the chamber should be 5-10 cm.
- Ø Duct entry hole should be sealed with cement mortar 1:2.
- Ø Backfilling of joint chamber pit with excavated soil can be carried out.

Chamber Installation Practices

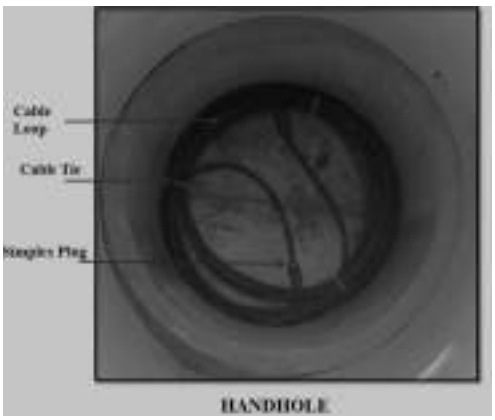


Joint Pit & Loop Pit

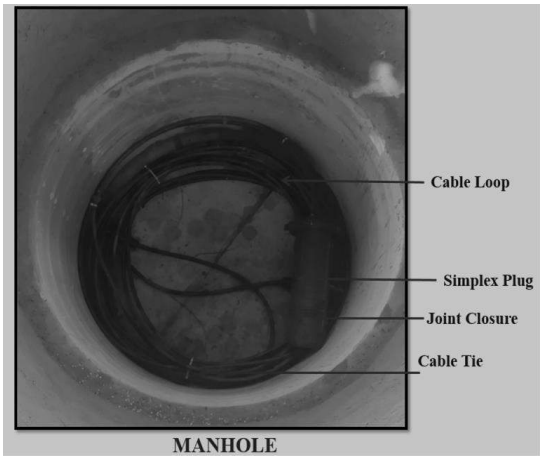


- Ø Manhole (Joint Chamber) location depends on length of cable in a drum and Handhole (loop Chamber) location may as per user's decisions.
- Ø Cable loop in Manhole and Handhole can be between 10 to 30m.

Placement of Cable Loop in Handhole



Placement of Joint Closure in Manhole



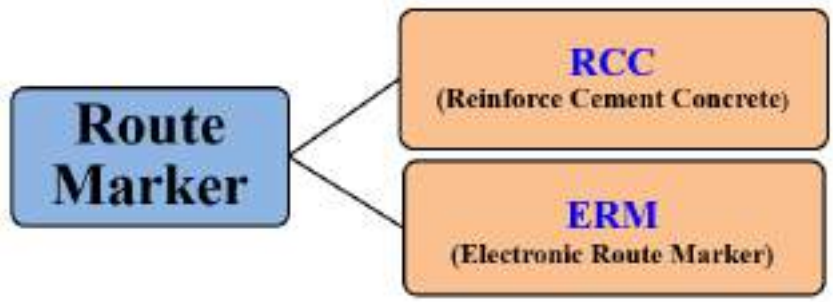
Chamber Installation Documentation

Chamber Documentation:

- Ø Type of Chamber
- Ø Location of Chamber (lat/long details)
- Ø Numbering on Chamber
- Ø Depth of Chamber covers from ground level
- Ø Details of cable slack left at each chamber

5.13 Installation of Route Marker

Route Markers



RCC Route Markers

RCC Route Markers Installation Guidelines

- Ø RCC Route markers are installed at every 200 m along the route.
- Ø Route markers offset should be 1m from the trench away from the road center.
- Ø Route markers should be provided on both sides of bridge/culvert.
- Ø Route markers should be straight and facing the road side.
- Ø Route Indicators are to be placed where OFC changes directions like road crossing, etc.

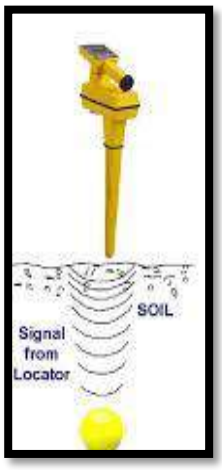
Electronic Route Markers (ERM)

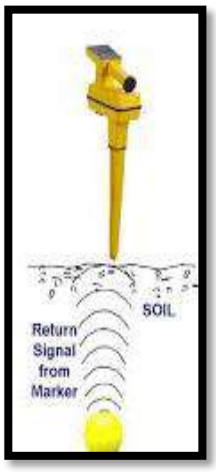
- Ø ERM is used to locate the underground cable.
- Ø It is placed 2 to 3 ft. deep from ground level over the PLB duct or chamber at every 200m.
- Ø It is a ball type ERM with specific operating frequency.
- Ø ERM Locator of specific frequency is used to find the ERM.

Passive ERM

ERM Locator

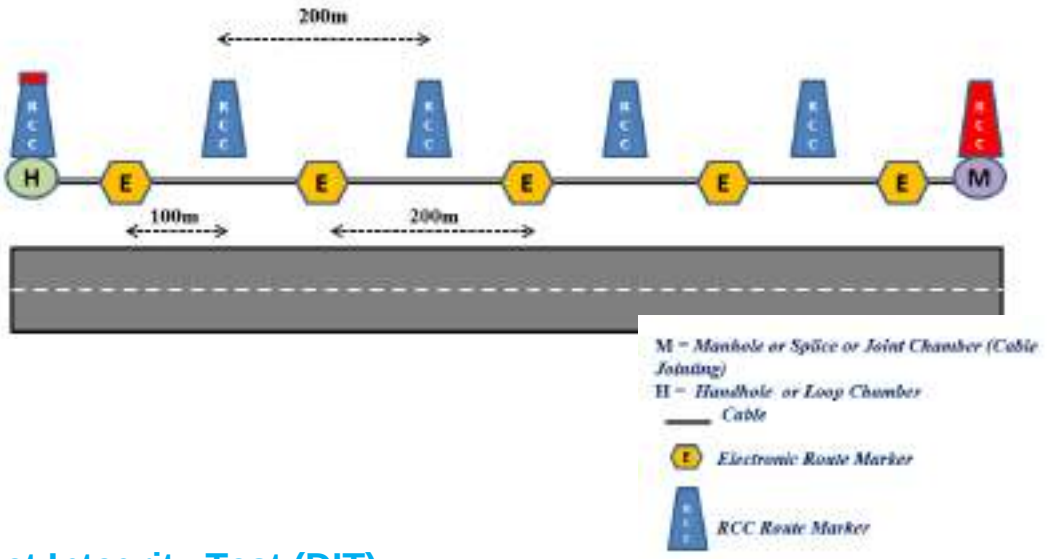
How Electronic Locator System Works?





- Ø The locator transmits a specific frequency signal to buried ERM.
- Ø The ERM, tuned to same frequency, reflects the signal back to locator.
- Ø The locator indicates the signal strength bar graph and depth value of ERM on visual display with audible tone.

Route Marker Placement



5.14 Duct Integrity Test (DIT)

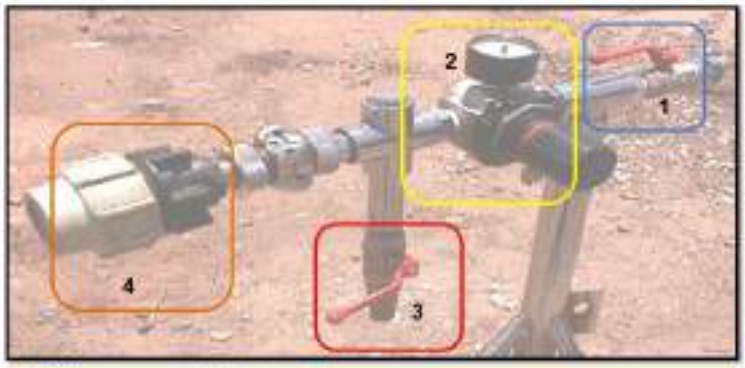
Purpose:

Purpose of Duct Integrity Test is to ascertain and ensure the suitability of duct for optical fiber cable installation through air blowing.

What is DIT?

- DIT is a series of tests performed on the underground duct.
- It is the intermediate step between duct laying and cable blowing.
- Duct Integrity Test is performed to ensure that duct is ready to use for blowing the cable.

Pressure Test Machine



1. Valve to control the flow of air
2. Pressure regulator to regulate the air pressure
3. Drain valve to release pressure
4. End coupler for connecting the system with duct

Duct Integrity Test

The Duct Integrity Test involves:

Air Blowing Test

- Ø Pass the compressed air at 5 to 8Kg/Sq.cm and clean the duct from deposits like mud and small stones.
- Ø Pressure fall should not be >50% in 1 hour……Test Passed.
- Ø No Air flow/Low Air/Back Pressure ……Test Failed.

Reasons for Failure:

- Ø Duct Overlap-Coupler missing
- Ø Blockage (mud, plastic, etc.)

Pressure values and test passing criteria could change as per user standards

Sponge Test

- Ø Insert a medium density sponge into the duct and push it with compressed air of standard pressure.
- Ø The sponge ejected with full force……Test Passed.
- Ø The sponge not ejected at far end……Test Failed.
- Ø If the test fails……. Blow Transmitter

Reasons for Failure:

- Ø Kink or dent

Shuttle Test

- Ø The shuttle is made of hard rubber, polished wood or plastic.
- Ø It should be of cylindrical shape with length of 15 cm and diameter equals 75% of duct diameter.
- Ø At the receiving end, a shuttle catch box must be used.
- Ø The shuttle ejected with full force……Test Passed.
- Ø The shuttle not ejected at far end……Test Failed.

Reasons for Failure:

- Ø Bending radius not maintained

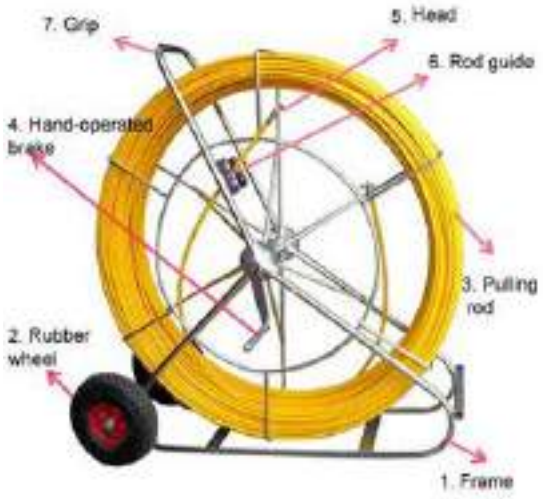
DIT : Safety

- Ø Do not go inside the pit while DIT is being performed.
- Ø Do not open couplers and DIT machine connections before pressure is released completely.
- Ø Use caution tape and traffic cones wherever pits are opened for testing and machinery is placed.
- Ø On completion of test, seal the duct ends with end plugs.

5.15 Cable Pulling and Blowing

Cable Pulling using Duct Rodder

Duct Rodder is used to pull the cable in duct for distances upto 300m. It is made of Fiber Reinforce Plastic (FRP).



Step 1 : Unlock the duct rodder hand brake and position the duct rodder

Step 2 : Insert the duct rodder Bullet into the duct until it reaches the other end

Step 3 : Attach the cable with Bullet and pull duct rodder Bullet to install OFC cable inside duct

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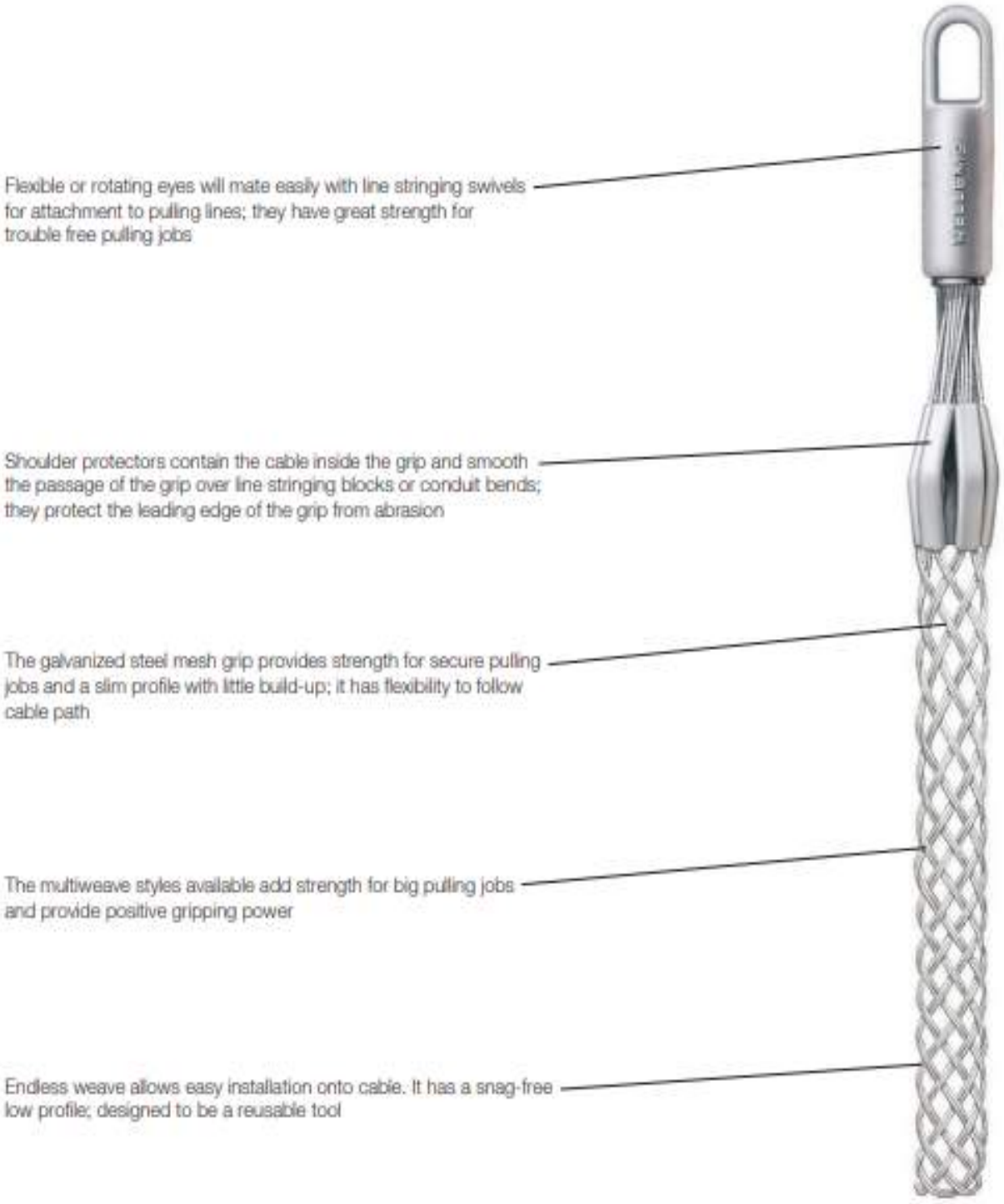
Use of Kellems Grip

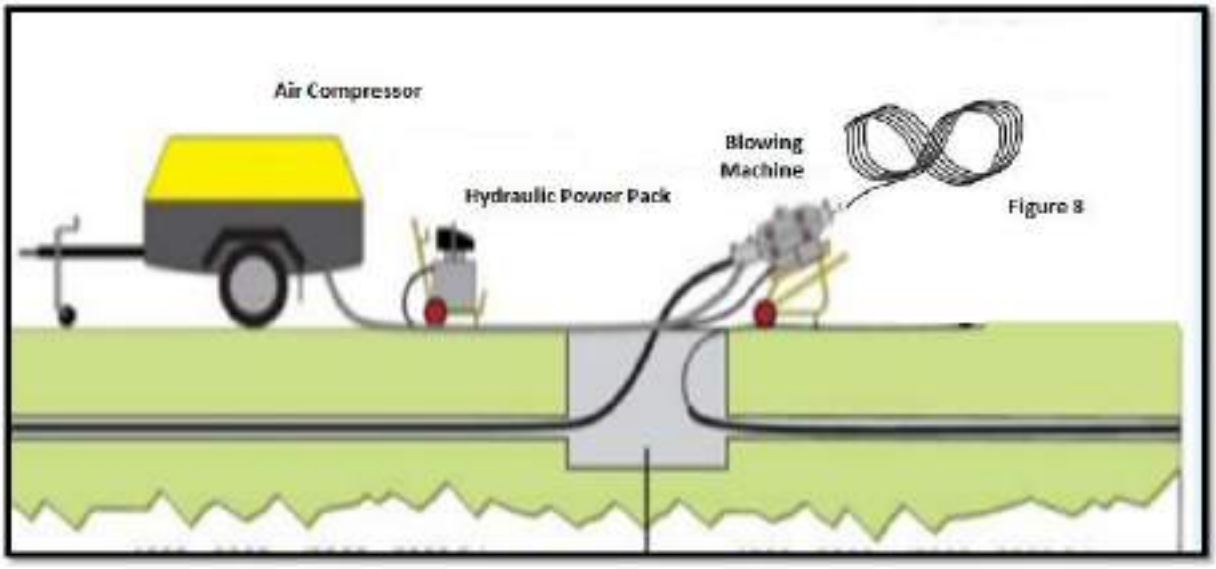
- Kellems Pulling Grips are reusable tools for pulling fiber cable, especially having dual jackets.
- They are easy and fast to install, providing the user with a smooth, slim profile that allows for easy passage through ducts and conduit.



Cable Blowing

Blowing is the process of installing the OFC cable in underground duct with the help of air pressure

- Ø Cable blowing is done with the help of Air Compressor, Hydraulic Power Pack, Cable Blowing Machine (Super Jet Machine)
- Ø Drum should be kept approximately at the center of two adjacent manholes.



Drum Test and Figure 8

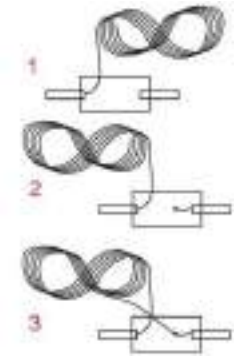
- Ø Each fiber in the cable is tested using OTDR before blowing.
- Ø Cable drum should be mounted on jack, kept on a plain surface with cable stored in figure of “8”.

Cable Blowing Process

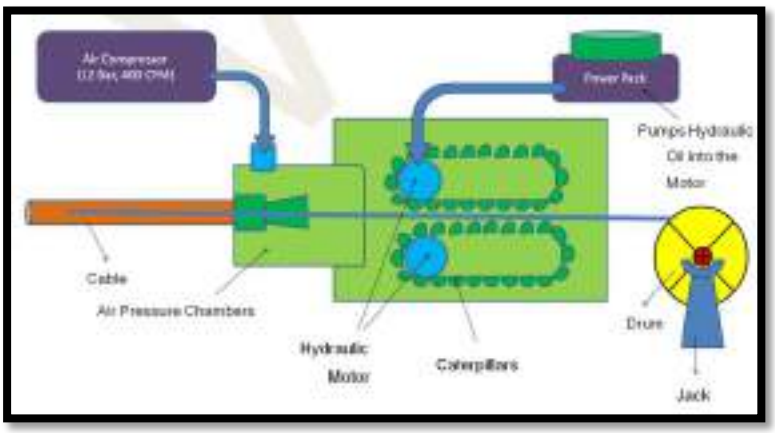
- Ø Cable blowing is done with the help of compressor, hydraulic power pack, blowing machine (Super Jet Machine).
- Ø Ensure the OFC drum tested using OTDR.
- Ø Drum should be kept approximately at the center of two adjacent manholes.

- Ø Divide long pulls into several shorter pulls, using the figure 8 technique for storing cable at the intermediate locations.

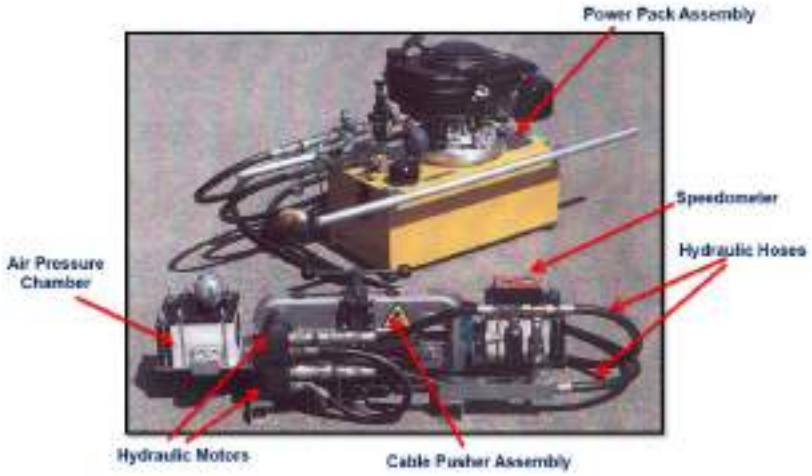
Blowing Technique : Super Jet Machine



- Ø Hydraulic Super-jet Machine is driven by two hydraulic motors. Power is supplied by a hydraulic power pack, which is driven by Petrol Engine.
- Ø Hydraulic Super-jet Machine can blow the cable of Dia 14mm to 32mm at the speed upto 60m/min upto 2km length (cable) at a time.
- Ø Cable blowing compressor should deliver pressure equal to or less than pressure deployed for DIT.



Super Jet Blowing Machine



Ø Never exceed the maximum pulling load rating.

Ø Never exceed the cable bend radius.

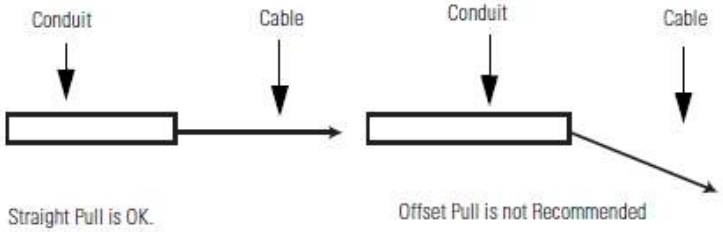
Ø Never twist the fiber cable. Putting a twist in the cable can stress the fibers too.

Ø Pull, do not push cables.

Ø When installing long runs, communicate and monitor along the path of the installation.

Ø Use fiber optic cable lubricant. Lubricate the cable when installing in conduits. Lubrication reduces the pulling load and the chance of breakage.

Ø The lubricant has to be compatible with the cable jacket material.



Ø Use the figure 8 technique.

Ø Install a cable in locations in which the temperature range imposed is within the temperature operating range.

Ø Avoid placing cable reels on their sides or subjecting them to shock from dropping.
Ø Fiber optic cables should be placed in their own dedicated ducts or trays.

Ø Do make every effort to pull cables from a conduit in as straight an angle as possible. Pulling on an angle can cause damage to the cable.
Ø Follow the blowing equipment suppliers blowing distance recommendations; 3000 to 6000 feet is a typical blowing length.

5.16 Splicing

Splicing of Fibers

- Ø The cable ends shall be prepared after the cable entry into the closure at every 2/4 Kms or as per cable drum length.
- Ø The strength member shall be fixed to its fixing mechanism provided in the joint closure.

Sealing of Joint Closure

- Ø After completion of splicing, the base and the dome of the closure and the cable entry shall be air sealed.
- Ø It shall be ensured that the splice closures are air tight and water proof.

Re-instatement of Pit

- Ø After completion of splicing arrangements, the pit is to be filled with sand/soil incorporating warning bricks/stone etc. as per standard procedures.

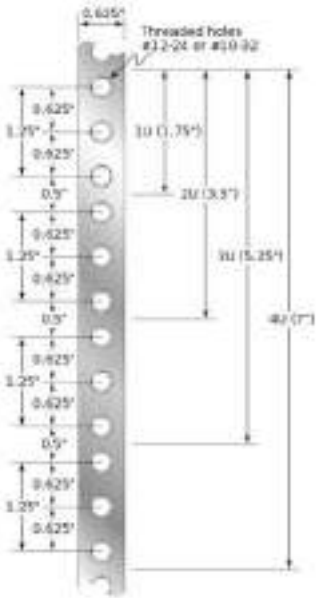
5.17 Fiber Termination

Fiber Distribution Management System (FDMS)

OFC is entered in FDMS and terminated in Fiber Management System (FMS).

Concept of 'U'

- Ø One Rack Unit (U) is equal to 1.75 inches or three threaded, square or circle holes.
- Ø These holes are placed in a vertical orientation and are used to secure mounting equipment to the rack.
- Ø Spacing between holes within a rack unit are the same at 0.625 inches, but that on its own would only make up 1.35 inches of height. The remaining 0.5 inches comes from the distance from the bottom hole to the top hole of the rack unit below it.
- Ø Generally, server racks are available anywhere from 1U to 70U (sometimes even 90u).



Floor Mount

FDMS Installation Practices

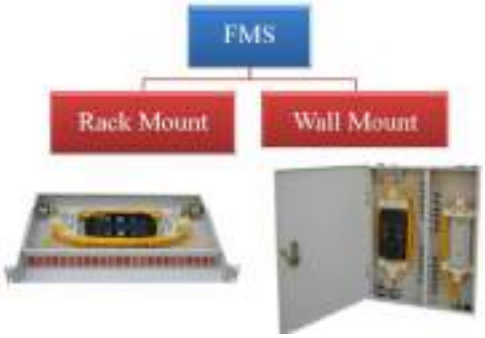
Use of Cable Ties

Use of Transport Tubes

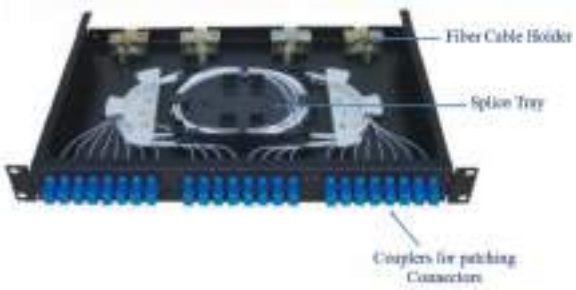
Fiber Management System (FMS)

- A Fiber Management System (FMS) manages optical fiber connections from outside of fiber rack to the active equipment.
- Fiber-optic cable duct containing many fibers comes from far end sites and terminates on the FMS using splicing technology.
- FMS has FIBER IN and FIBER OUT ports.
- FMS is also known as:
  - Line Interface Unit (LIU)
  - Fiber Distribution Management System (FDMS)
  - Fiber Distribution Frame (FDF)
  - Fiber Optic Interconnect Unit (FOIU)
  - Fiber Patch Panel (FPP) etc.

Type of Fiber Management System (FMS)



Rack Mount



Wall Mount

Fiber Termination: Best Practices

Ø End to end testing can be carried out from the FDMS to FDMS after cleaning the connectors.
Ø Fibers shall be neatly arranged in fiber tray.
Ø Cable shall be brought into the building/container/shelter or cabinets through duct/GI pipe.
Ø Tagging of Fiber optic cable should be properly done for identification.
Ø Proper Racking and Clamping is to be ensured.

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Section 3: Exercises

Exercise 1: Word Search Puzzle.

Find the answer of the following questions in the word search puzzle.

a) Answer words can go in any direction.

b) Answer words can share letters as they cross over each other.

	Question	Answer Hint
1.	Component used to join ducts	7 Letters Word
2.	Name of cable blowing machine	8 Letters Word
3.	A component that is used to join HDD drill bit and duct	6 Letters Word that starts with ‘S’
4.	A type of trenchless method	6 Letters Word that ends with ‘G’
5.	Method of making hump on backfilled trench	8 Letters Word that starts with ‘C’
6.	Name of the chamber used for placing fiber cable joints	7 Letters Word that starts with ‘M’
7.	A type of Route Marker	10 Letters Word that ends with ‘C’
8.	A type of Duct Integrity Test	7 Letters Word that starts with ‘S’
9.	Process of making a small slot-cut trench	14 Letters Word that starts with ‘M’
10.	Device used to blow air in the duct	10 Letters Word that ends with ‘R’

Z A R R Z J W N L M Z N C N D
N N U G O P S Z Y G H O I G C
Y R U G I K O N R Y U K N R O
P S U P E R J E T M B D O A M
P F E O Q G B H B O Q W R S P
V W E P M U R S P L N J T H R
G Y W D P E W F C I M K C M E
N D F I L V L L N N V R E G S
S V D P U R Z G V G F L L D S
I W U E L O H N A M T X E Q O
A O I P E B I N A T Y A P Q R
C O X V F R J R U U K N Y Y F
P K N X E C Z H T Z C L O D Z
C D Y V L L S G T G D U P M S
M I C R O T R E N C H I N G N

Exercise 2: Make a flow chart of Right of Way (RoW) process.

Exercise 3: Draw a flow chart of cable blowing process.

Exercise 4: While surveying you are faced with such type of situation as shown below. What type of trenching / OFC laying practice would you suggest to adopt?

Exercise 5: Choose the appropriate path for crossing the bridge?

Exercise 6: What type of situation is shown in below image and how would you overcome the issue while laying the cable?

Exercise 7: Participate in group discussion on following topics:

a) Types of Route Markers and its Placement Procedure
b) Duct Integrity Tests (DIT)

Section 4: Assessment Questionnaire

1. What details do we capture in route survey?
2. What are some problems encountered during RoW process?
3. The process of continuous digging following a single line with specific dimensions is called:
4. What are various methods of trenching?
5. Why cross pits are made during trenching?
6. During micro-trenching, what can be used which allow efficient cuts through asphalt and concrete.
7. What is full form of HDD?
8. What is the typical shot distance of HDD method?
9. What information is provided on Pilot Locating System?
10. What is used to connect the duct with HDD machine pilot?
11. Name some components used in HDD operations.
12. _____is a mixture of water and specialized additives used in the drilling process.
13. What is use of drilling fluid?
14. Why bentonite is added in drilling fluid?
15. The trenchless process in which trenchless operation from pit to pit is done by sectional pipes manually is called:

16. Which type of cables can be used in Direct Buried Cable Installation?
17. What precautions are taken during Direct Burring Cable Installation?
18. The process of placing duct in the trench is called:
19. Refilling of excavated area with soil is called:
20. At what depth warning tape is generally placed?
21. Which pipe is used while crossing the wet culvert?
22. Where we should not install DWC Pipe?
23. G.I. or RCC pipes should be joined by using:
24. Identify the type of chamber.

25. What are various types of Chambers?
26. Duct entry hole should be sealed with cement mortar of mix ratio:
27. What should be the duct length inside the chamber?
28. Cable loop in Manhole and Handhole can be between:
29. What is used to fill-in the Manhole chambers?
30. What are two types of Route Markers?
31. RCC Route markers are installed at every _____along the route.
32. Why do we use ERM?
33. RCC route marker should be straight up and facing road side. True or False?
34. What is purpose of DIT?
35. What equipment and accessories do we need for DIT?
36. At what rate air is pressured in Air blowing test?
37. What may be reasons of failure of Shuttle Test?
38. In what test sponge is inserted in duct?
39. Air pressure during DIT is less than the cable blowing pressure. True or False?
40. What material can be used to make shuttle for shuttle test?
41. What should be the shape of shuttle used in DIT?
42. What should be diameter of shuttle for shuttle test?
43. Use of water is essential to perform DIT. True or False?
44. What are precautions to keep in mind while conducting DIT?
45. _____is used to pull the cable in duct for distances upto 300m.
46. What material is used to make rod of Duct Rodder?
47. _____is the process of installing the OFC cable in underground duct with the help of air pressure.
48. Name the machine used for cable blowing process?
49. What is speed of Hydraulic Super-jet Machine used commonly?
50. Cable blowing compressor should deliver pressure equal to or ____than pressure deployed for DIT.
51. The process of jointing two fibers is called:
52. What material is required for earthing of Joint Enclosure?
53. Unarmoured cable should be earthed /grounded at every 8 Kms. True or False?

54. Arrange following activities of obtaining ROW in correct order:
    a) Collect the DD / BG for submitting to the ROW authority
    b) Obtaining ROW permission for the entire Route
    c) Submission of ROW applications authority wise
    d) Follow-up with the ROW authority for obtaining Demand Note
55. In normal soil condition, open trench depth is generally:
56. Arrange the following lengths in ascending order for a link:
    Duct Length, Cable Length, Fiber Length, Surface Length
57. Purpose of cable loop in loop chamber is to:
58. Which factor will determine the distance between manhole?
59. Why crowing is done over the backfilled trench?
60. What information is depicted in pre-construction route survey report and map?
61. What is full form of FDMS?
62. 1 Rack Unit = ____ inches?
63. Generally, server racks are available anywhere from _____U to _____ U.
64. What are other names of FMS?
65. What are two types of FMS, based on mounting?

----------End of the Module----------

MODULE 6
AERIAL OFC INSTALLATION PRACTICES

Section 1: Learning Outcomes

After completing this module, you will be able to:

- State the need of Aerial Cabling and various Customer Serving Areas
- Install the Aerial Cable using various installation methods
- Differentiate between various Types of Aerial Assemblies
- Install the Figure 8 cables on poles
- Install Aerial Cable using Anchoring Clamps (Wedge Clamps) Assembly
- Install Aerial Cable Suspension and Tension Assembly
- Adhere safety guidelines while installing Aerial Assemblies

Section 2: Relevant Knowledge

6.1 Introduction to Aerial Cabling

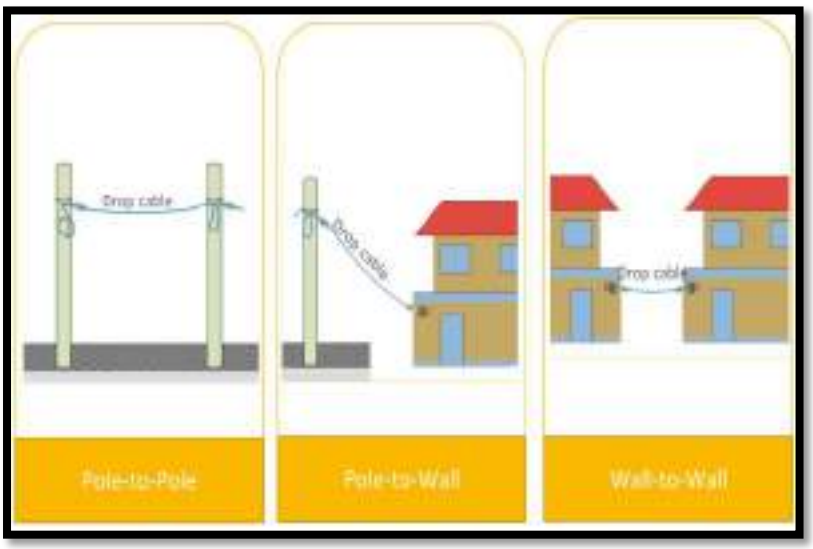
Aerial Installation

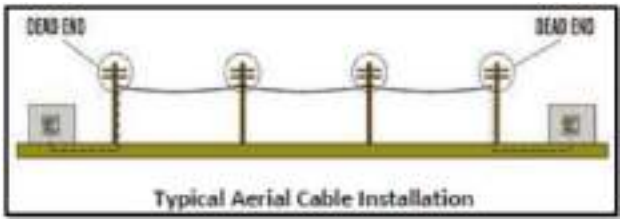
Ø Alternative solution to underground OFC installation.

Ø Optical Fiber Cable can be hanged from:

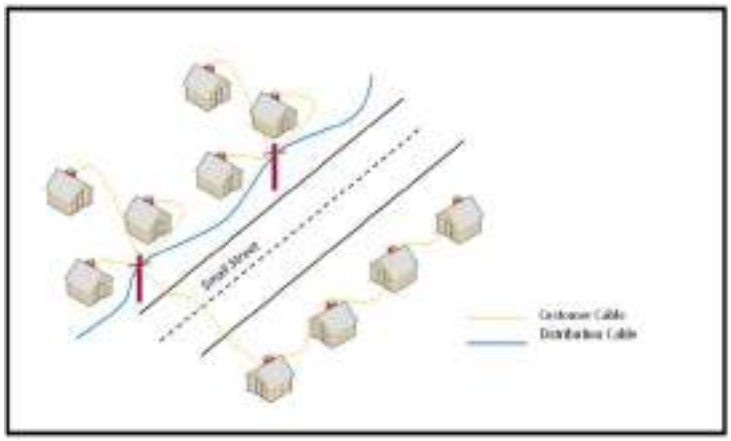
- Pole to Pole
- Pole to Building/Wall
- Building to Building (Wall to Wall)

Ø All Dielectric Self Supporting (ADSS) Optical Fiber cable is installed.

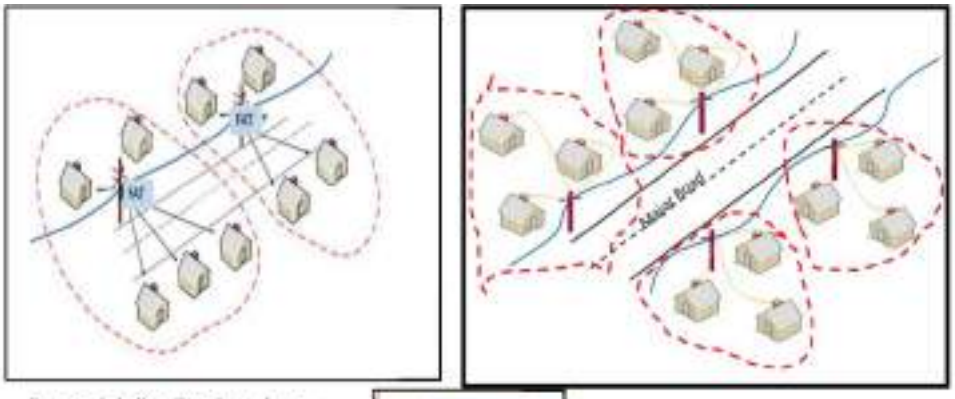




Customer Serving Area – Road Crossing Pole to Building



Customer Serving Area – Aerial Distribution



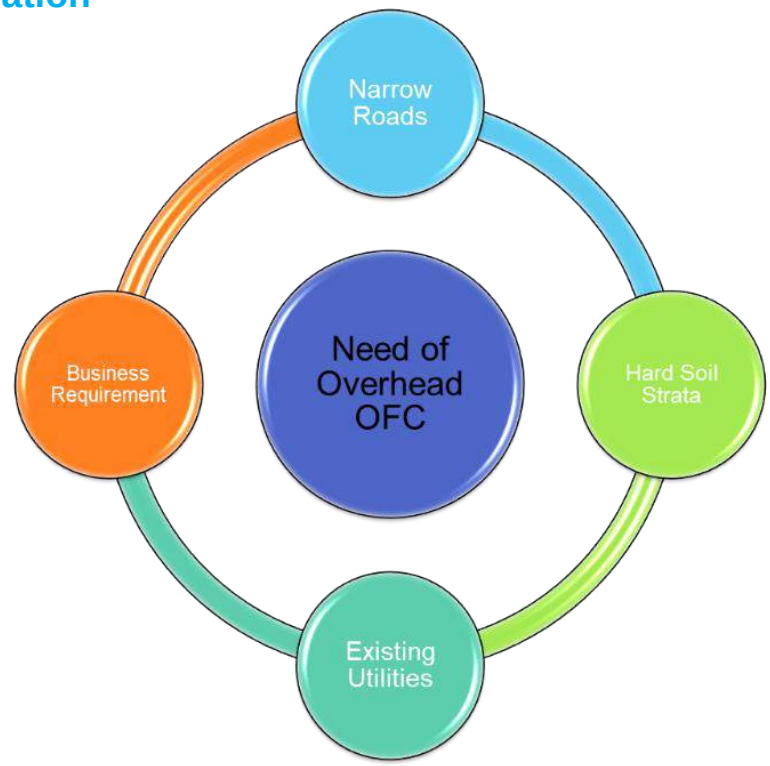
For aerial distribution along small streets, FAT or OTB at pole serve the buildings or customers on both sides.

For aerial distribution along major public roads, FAT or OTB at pole serve buildings or customers on same side of the pole.

Customer Serving Area – Road Crossing & Building to Building

Have a building to building distribution on the same side of road. This scenario is applicable for the buildings that are located in the same compound. In this scenario, underground road crossing is done and aerial cabling is done to connect buildings buildings on the is done on same side of road.

Need of Aerial Installation

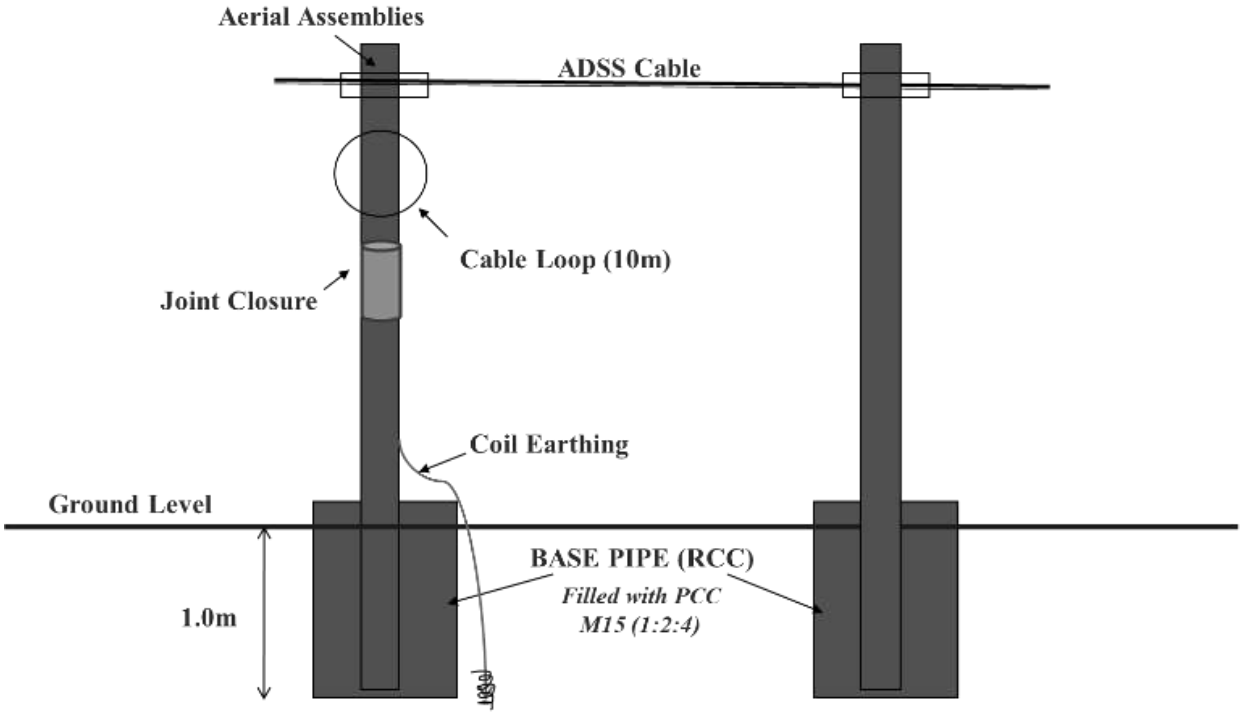


Aerial Installation is Non- feasible in Stormy or Heavy Wind Area and Ice Land

Aerial vs Underground Cabling

Execution Method	Underground Installation	Aerial Installation
Fiber Protection	More	Less
Supervision & Maintenance	Difficult	Easy
Installation Speed	Low	High
Material Cost	More	Less

Aerial Cabling Practices



- Survey of the aerial route should be carried out pole to pole.
- The span length must not exceed above recommendations as per cable.
- Ground clearance of 12 to 15 feet in a section should be kept.
- Cable loop of atleast 10m is recommended at splice location.
- The splice box can be stored aerially or buried underground.
- The cable should be brought down through a GI pipe clamped on the pole.
- Earthing of each pole is recommended.

Pole to Pole Deployment

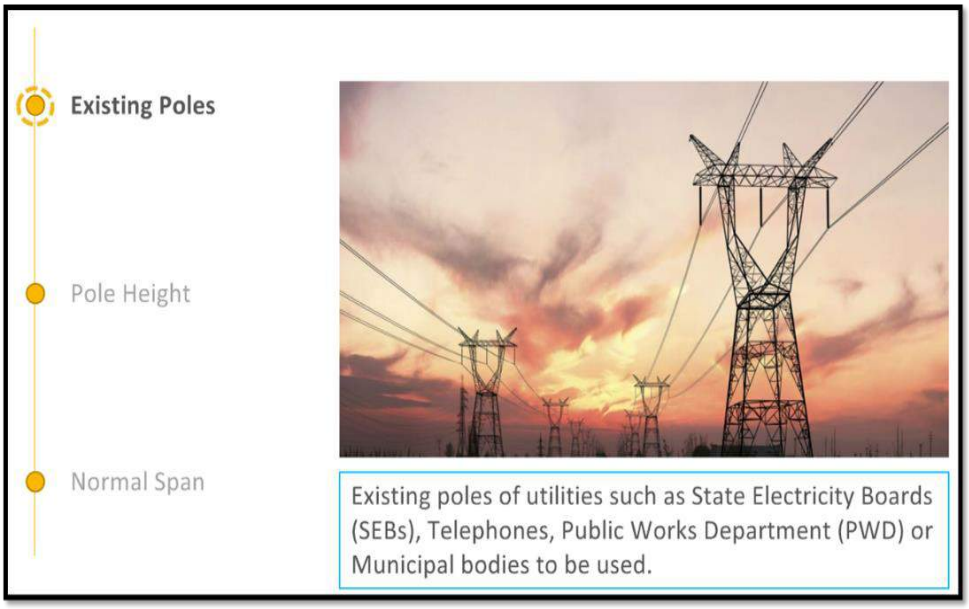
Existing poles of utilities such as SEBs, Telephones, PWD or Municipal bodies to be used. If required and subject to permission Poles can be owned and installed.

Existing Pole Deployment

Ø When using existing pole, it shall be ensured that Optical Fiber Cable is installed below existing/ future power lines running on such poles.

Ø Minimum separation between electrical cable/ fittings and Aerial Optical Fiber Cable shall be ensured:

a) From insulated electrical cable : **600mm**
b) From non-insulated electrical cables/ wires : **1500mm**
c) From light-fittings/ conduits and stay fittings : **100mm**
d) At crossing of Low Voltage power lines : **1000mm**
e) At crossing of High Voltage power lines : **3000mm**



6.2 Aerial Cable Installation Methods

- Ø Figure 8 cables feature a built-in support wire for tensile strength and stability.
- Ø The support wire is typically a ¼ inch 7-strand, Extra High Strength (EHS) galvanized steel messenger, flooded to inhibit corrosion.
- Ø There are two methods of Aerial cable installation:

The Moving Reel (or "Drive Off") Method:

It is used when the entire route is accessible by support vehicles. The route must be free of trees, limbs, and guy wires to allow full vehicle access. Support vehicles are used to pay off and raise the fiber cable to temporary support hardware. Once the cable is in position, it is transferred to the permanent support hardware.

The Stationary Reel Method:

It is typically used when the route is not fully accessible by support vehicles. The cable is pulled into place from a stationary reel located at one end of the section run, and supported by temporary hardware. Once the cable is in position, it is transferred to the permanent support hardware.

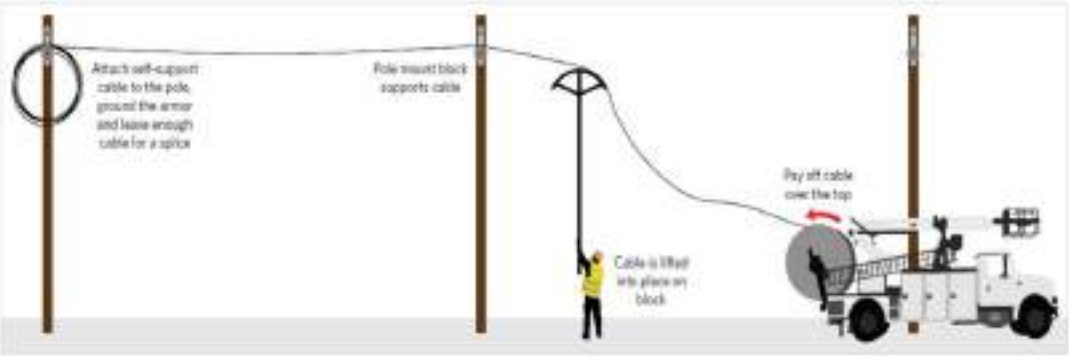
Limitations and Precautions

- Ø Installation crews must be sensitive to the limitations of the fiber cable regarding maximum tension, minimum bend radius, and crush resistance, and take action throughout the installation process to prevent exceeding these limits.
- Ø Leave the lagging or other protective wrap on the cable reel until the reel is delivered to the installation site to prevent handling damage.
- Ø Ensure the curvature of the support device is greater than the minimum bend radius of the cable to prevent damaging the cable.
- Ø Avoid surges in cable tension during reel payout.
- Ø To avoid damage to the cable jacket, do not drag the cable over fixed surfaces.
- Ø Slack coils may be assembled in a continuous direction loop configuration or a "figure eight" (not to be confused with figure 8, the cross-section of the cable).

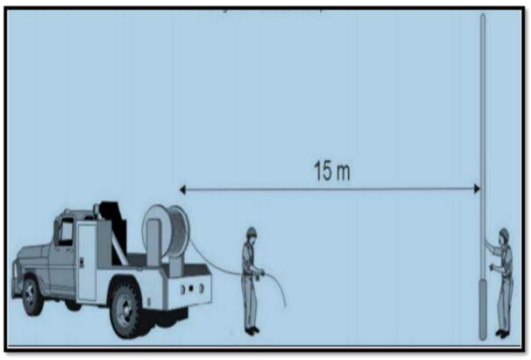
Construction Planning

- Ø Perform a detailed site survey of the aerial cable route to identify potential issues, determine accessibility, and create an installation plan. Site survey should include analysis of the following:
  - Route accessibility
  - Right of way/permitting issues
  - Determination of installation technique
  - Condition of poles and guying support
  - Location of fiber cable splice points
  - Locations for equipment setup
  - Clearances to existing power lines and other cables
- Ø Cable splice locations must be selected with consideration of splice vehicle accessibility.
- Ø For fiber cable(s), slack must be added to both cable ends at each splice location to allow for splicing.
- Ø Cable slack must allow the cables to reach ground level and into a splice truck plus 30 feet (9 meters) minimum.

Moving Reel Method



- Ø Cable pulled directly from drum mounted on moving vehicle
- Ø Vehicles selected for use using this method must provide full accessibility on the placement side of the poles along the entire section run.
- Ø Radio communication must be established between the cable reel payoff unit and the ground crew.
- Ø Cable Drum mounted with proper support for easy Cable pay-off.
- Ø Cable raised and placed on J-hook or block fitting for temporary support.
- Ø Procedure continued till dead end pole where Cable is terminated using Termination assembly sets and tensioned using turnbuckles to maintain cable slag.
- Ø In most cases, the moving drum method is the fastest and less expensive method of installing aerial cable.
- Ø Pole mounted hooks are the only temporary support devices required. Manpower required is less than by other methods.
- Ø This method requires vehicular access to the placement side of the pole line and a right-of-way clear of tree limbs, guy wires, and other obstructions.
- Ø To being installation, park the vehicle with the cable drum approx. 15 meters away from the pole facing away from it down the pole line.

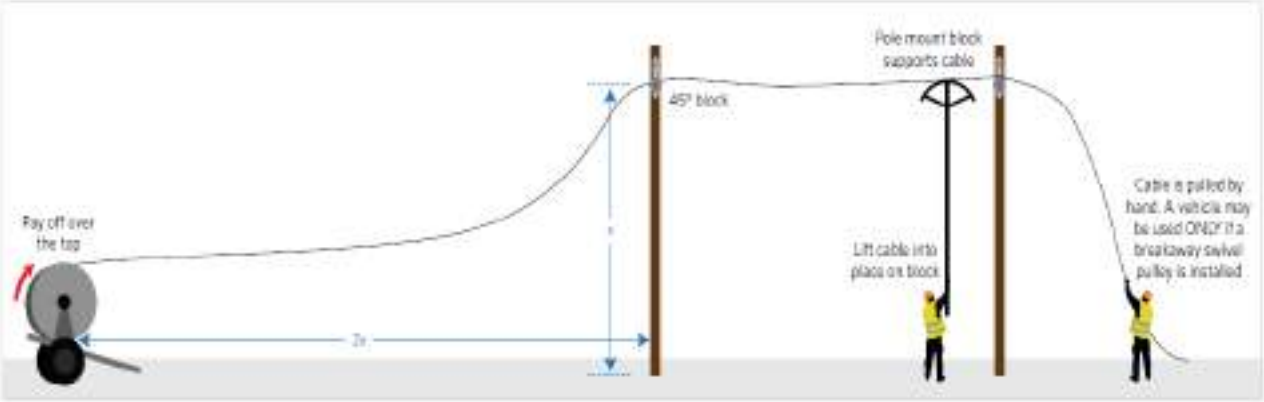


- Ø The cable must pay off from top of the drum towards the rear of the vehicle.
- Ø Install the termination supports and temporary J-hooks on the poles at the starting point and subsequent poles as per plan.
- Ø Pull off the necessary amount of slack, lift the dead-end to the top of the pole and mount on the termination assembly.
- Ø Pay out additional length of cable as it is lifted to the fixing location.
- Ø Start driving the drum-carrying vehicle down the placement side of the pole line, paying out cable off the back of the truck.

- Ø Once the drum is approx. 15 meters past each pole, lift the cable up the pole and place it on J-hook till the vehicle reaches end of the span with another termination assembly set.
- Ø Once the cable is fixed at both ends with at the terminating assemblies, carry out tensioning.
- Ø After the cable section is properly tensioned and secured at both ends lift the cable out of the J-hooks at each of the intermediate pole and support it with the suspension set assemblies.
- Ø Repeat the process for each of the span between two terminating assemblies.

Stationary Drum Method

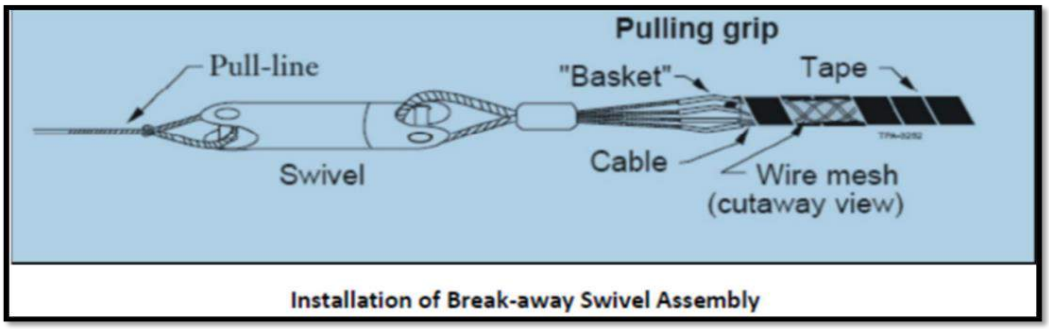
- In the stationary drum method of aerial cable installation, the cable is pulled along the cable route through temporary support hardware installed for this purpose.
- The Stationary Drum installation method is more time consuming than the Moving Drum Method.
- This method can be useful when the cable is to be installed where vehicular access may be limited or unobstructed Right-of-Way is not available.



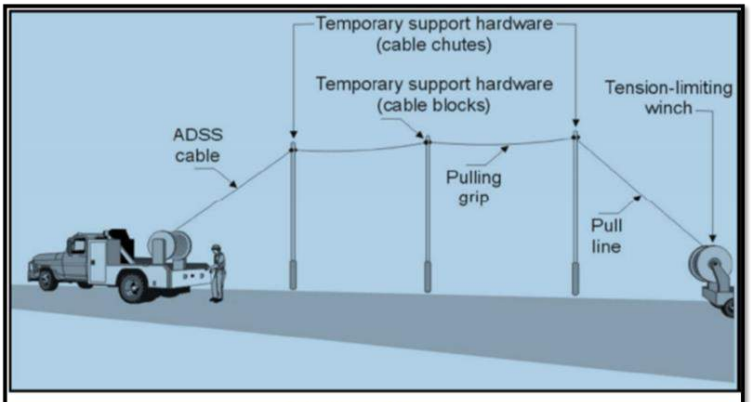
- Stationery drum installation method requires installation of temporary support hardware such as pulley blocks and cable chutes for stringing the cable by pulling through such block.
- The first step in the installation by this method is to install the temporary hardware described above at each of the pole within a span of terminating ends at desired height.
- These supports are to be hung at the same height as final position of the cable after installation. Permanent pole clamps can be used for hanging these temporary supports.
- The hardware shall ensure minimum bending radius (normally 20D where D is diameter of the cable) is not exceeded.
- A rope wound on the tension limiting winch is passed through each of string blocks and chutes and connected to the cable on the drum installed on a stand which allows free rotation of the drum.
- Where tension limiting winch is not available, as an alternative, beakaway swivels of appropriate rating shall be installed between pulling rope and cable.

Swivel

Pulling Grip



Installation of Break-away Swivel Assembly



Cable Pulling Operation

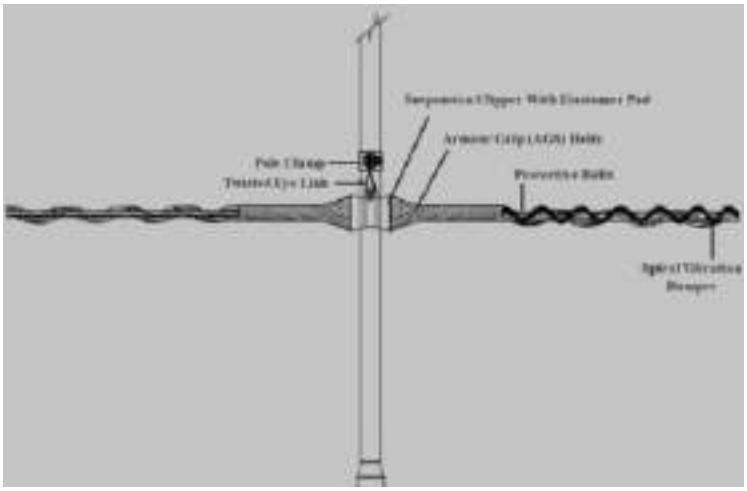
- Ø Once the system is ready for pulling, the winch start pulling the rope thus pulling the cable through the temporary stringing hardware.
- Ø This method requires a very careful monitoring of the pull force during cable pulling operations and sophisticated pulling winch or use of break-away swivel joints.
- Ø Length of cable that can be pulled in one go depends on the cable characteristics and quality of temporary support hardware.
- Ø The pulling load should normally not exceed 60% of the maximum permissible cable tension recommended by cable supplier.
- Ø A careful planning of location for the cable drum and pulling winches is a must. The cable drum and winch locations must have vehicular access.
- Ø It is always better to pull downhill if there are significant elevation differences along the route.
- Ø The cable drum should always be placed on leveled ground so that its flanges are vertical thus avoiding rubbing of cable against flanges.
- Ø The orientation should be such that the cable pay-off is directly in the direction of pull. Always pay-out the cable from top of the drum and not from bottom.
- Ø Cable pay-out needs to be controlled (by hand or by breaks) to prevent free running or jerking.
- Ø It is important to have a two-way communication between the cable pay-out area and pulling area for proper coordination and safety of pulling operations.
- Ø Sufficient number of personnel needs to be deployed to monitor entire operation.
- Ø At the end of the pull i.e. when the cable has reached the winch, it should not be wound onto winch drum unless winch drum radius is more than bend radius permissible for the cable.
- Ø Once the cable is completely pulled end to end, it is then ready for installation of permanent supporting system of terminating and suspension set assemblies at required locations and tensioning for sag control.
- Ø A low-elasticity pull line, such as an aramid yarn or wire rope, is recommended to minimize elastic-induced surges during the pulling process.

6.3 Aerial Cable Installation Assemblies

Suspension and Tension Assembly

Suspension Assembly

The Suspension Assembly is installed on the pole when cable is to be installed straight on OFC path



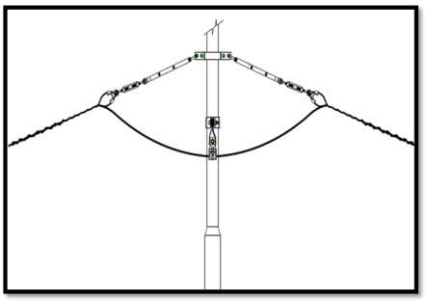
Tension Assembly

Ø This assembly is installed where:

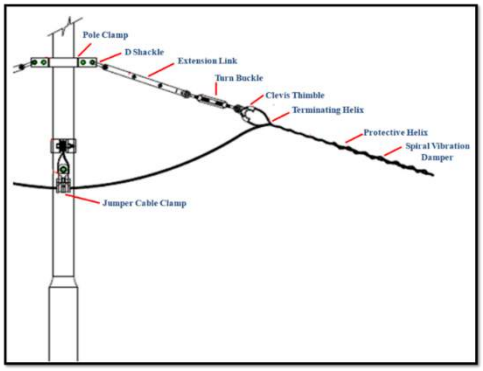
- Cable route direction is changed
- Cable needs to be terminated (Start/Dead End)
- Cable is routed Underground to Overhead and vice versa
- Splice and Cable Loop is required in OFC path

Ø Every fifth pole is planned be a tension pole in straight alignment with 10m cable loop.

Single Sided Tension Assembly



Double Sided Tension Assembly



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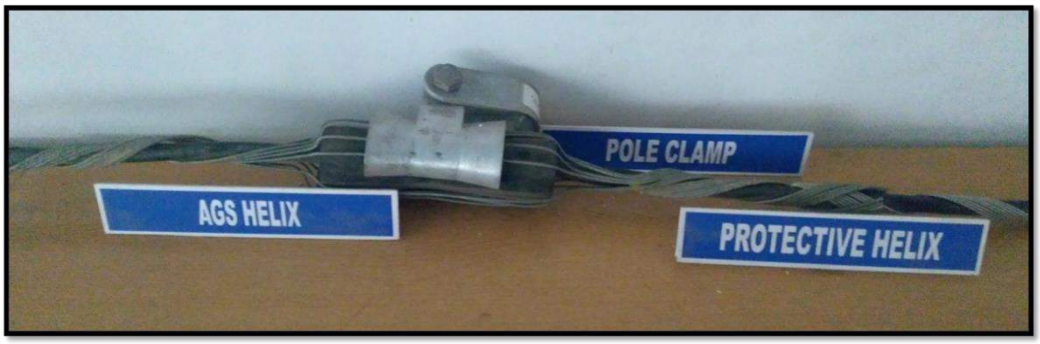
Components of Aerial Assemblies

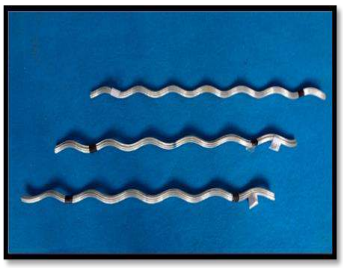


Suspension Assembly

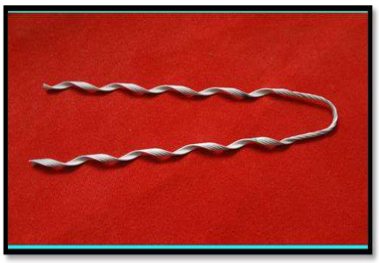
Tension Assembly

Hume Pipe

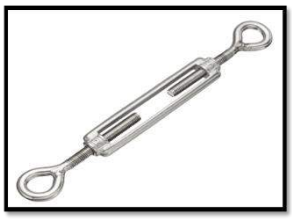
Protective Helix



Termination Helix



Turn Buckle



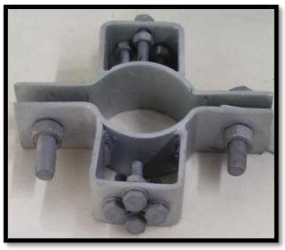
D Shackle

Clevis Thimble

Suspension Set

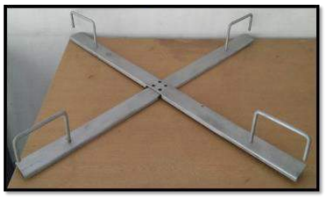
Twisted Link

Pole Clamp



Jumper Clamp

Loop Frame



6.4 Anchoring Clamp (Wedge Clamp) Assembly

Stainless Steel Strap

- Ø Stainless Steel Straps with high corrosion resistance and tensile strength
- Ø Can be mounted on poles of any geometry
- Ø Easy and safe Installation
- Ø Supplied in a plastic case for easy handling with indication of strap length

Stainless Steel Strap Lock Buckle

Wedge Clamp/Dead End/Anchoring Clamp

- Ø Used to grip the cable
- Ø Specially designed teeth for clamping the steel core of Fig-8 cable
- Ø Aluminum alloy body and thermoplastic wedges climate resistant
- Ø Flexible wire rope to take care of the vibration on spans

PCL Ratchet Type Strap Binding Tool

Fitting tool for Stainless Steel Strap

Universal Bracket

- Ø Pole bracket for anchoring, suspension and stay wires
- Ø Made of high strength aluminum alloy
- Ø Mountable on poles with steel straps or bolts

Suspension Clamp

- Ø Fully Insulated plastic body for protection
- Ø Heat & UV resistant, Anti corrosive parts
- Ø No tools or bolt tightening required for Installation

Adjustable Loop Frame
Pulling and Lifting Machine

Installation Steps

Step 1

Estimate the necessary strap length according to pole width and cut it

Step 2

Mark on the Steel Strap

Step 3

Insert the buckle inside the Steel Strap

Step 4

Bend the Strap end and the buckle ears

Step 5

Insert the buckle universal bracket in strap

Step 6

Tight the strap on pole adjusting the universal bracket

Step 7

Insert the wedge clamp in universal bracket

Step 8

Tight the wedge clamp appropriately

Step 9

Step 10

Tight the strap having suspension clamp on pole

Step 11

Install the loop frame wherever required

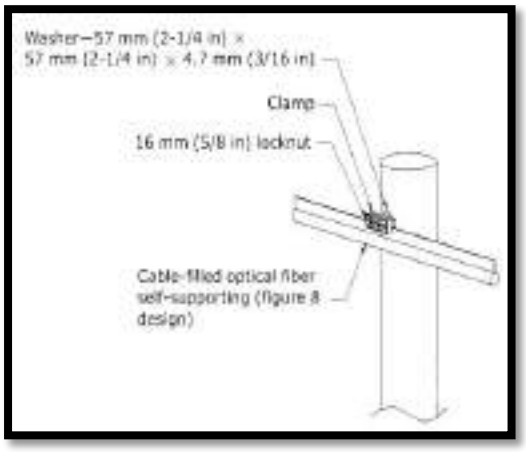
Step 12

Step 13

Provide suggested tension to the cable to get desired sag

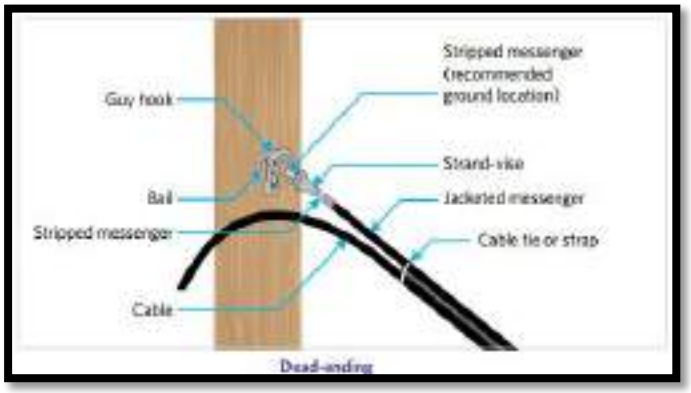
Step 14

Anchoring & Tension Clamps



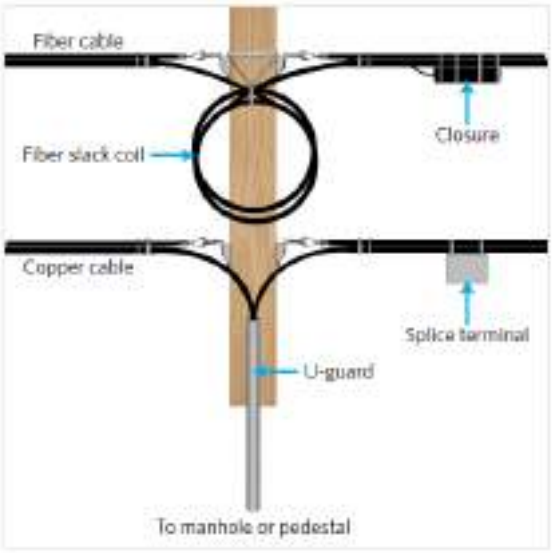
Features

- Ø For both figure-8 and concentric ducts
- Ø Wedge clamp type, easy and quick installation
- Ø Installation span 40–70 m



Slack Storage and Splice Locations

- Location of splice closures and terminals are best located at or very near a pole location for easier access and workman safety.
- By dead-ending the cableat the pole and removing the messenger, the cable will be lighter and easier to route for slack storage and into a splice closure.



Grounding of Messenger

- The messenger is required to have electrical continuity throughout the cable run.
- At dead-end poles where the messenger is attached to pole fixtures, install a bonding clamp and follow appropriate safety standard or code.
- At intermediate poles where bonding to the power ground neutral is required, follow appropriate safety standard or code.

6.5 Aerial Installation Safety

Precautions for Aerial Cabling

Near Electrical Lines

The minimum separation between optical fibre cable and other elements:

- Uninsulated power main conductor—1500 mm (4.92 ft)
- Light fittings, conduits and stay fittings—100 mm (0.33 ft)
- Insulated power main conductors or service leads—1000 mm below (3.28 ft)

Any power earth wires to be insulated between ground and 1000 mm (3.28 ft) above the uppermost optical fibre attachment or fitting.

Crossing Electrical Lines

During aerial cabling, when crossing electrical power lines:

- Ensure that optic fibre cables do not cross above aerial power lines
- Ensure that there is a minimum vertical separation of 1 metre (3 ft) where aerial cables cross under LV lines in span
- Avoid using shared poles in a parallel route with power lines except if the owner of the pole has authorised the joint-use arrangement in writing
- Maintain a minimum separation of 600 mm between the optic fibre cable and any insulated mains power conductor or service lead

Ground Clearance

Minimum ground clearance that aerial cables should maintain is:

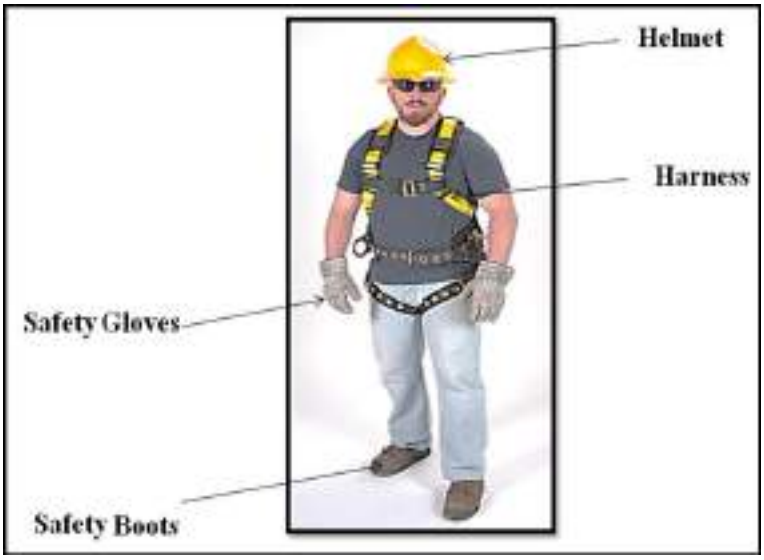
- 2.5 metres (8.2 ft) for customer premises land (if vehicles cannot enter)
- 4.0 metres (13.1 ft) for residential driveway
- 4.9 metres (16.1 ft) for commercial/industrial driveway or private roadway
- 6.5 metres (21.3 ft) or as per directive of the local bodies, corporations, etc. for public footpath or roadway

Dos

- Test and ensure that all cables, tools and installation equipment are in proper condition
- Use proper Personal Protective Equipment
- Use a wooden ladder for Pole-to-Pole aerial cabling
- Ensure adequate supervision
- Maintain safe distance while working near Low Tension (LT)/High Tension (HT) lines and cables
- Strictly follow your supervisor's instructions
- Strictly follow safe operating procedure guidelines

Don'ts

- Don't ignore Lock Out/Tag Out signage and warnings
- Do not work during high winds and heavy rains
- Do not ignore safety instructions
- Do not work alone
- Use buddy system for high-risk jobs
- Do not indulge in horse play (Fighting/unnecessary stoppage) during work



Section 3: Exercise

Exercise 1: Enlist components of suspension and tension assembly.

Exercise 2: Enlist components of wedge clamp assembly.

Exercise 3: Participate in a group discussion on following topics:

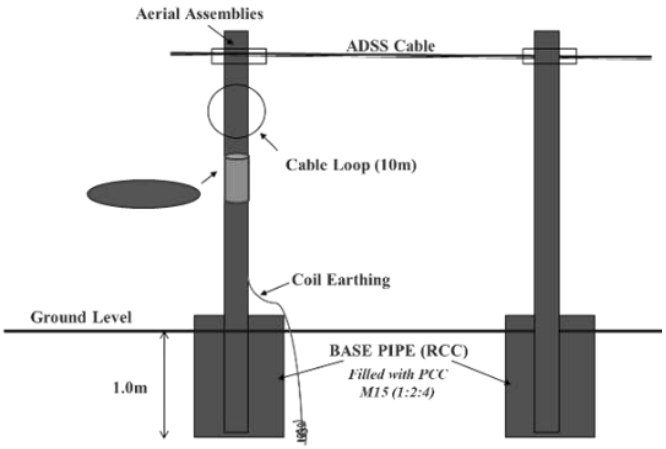
a) Moving Reel Method
b) Stationary Drum Method
c) Aerial Installation Safety

Section 4: Assessment Questionnaire

1. Is it possible to install OFC on Poles?
2. In how many ways optical Fiber Cable can be installed?
3. Which type of OFC is used in Aerial Installation?
4. Which passive device is Installed on Poles to serve the buildings or customers on both sides?
5. When Aerial Installation is preferred over Underground installation?
6. Aerial Installation is non-feasible in:
7. Fill the blank column:

Execution Method	Underground Installation	Aerial Installation
Fiber Protection	More	
Supervision & Maintenance	Difficult	
Installation Speed	Low	
Material Cost	More	

8. Identify the item in below picture.



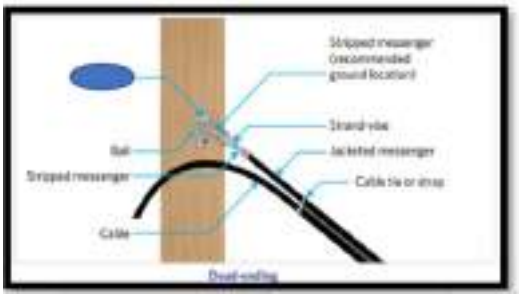
9. Ground clearance of _____feet in a section should be kept.

10. Cable loop of atleast _____is recommended at splice location.
11. The cable should be brought down through a ___clamped on the pole.
12. Earthing is not recommended for poles. True/False?
13. What should be the minimum separation between insulated electrical cable and Aerial Optical Fiber cable?
14.What should be the normal span of poles?
15. What are two methods of Aerial cable installation?
16. The curvature of the support device should be _____than the minimum bend radius of the cable to prevent damaging the cable.
17. _____may be assembled in a continuous direction loop configuration.
18. Cable slack must allow the cables to reach ground level and into a splice truck plus _____minimum in construction planning.
19. Which type of communication must be established between the cable reel payoff unit and the ground crew?
20. In moving reel method, cable is raised and placed on _____for temporary support.
21. _____assembly is installed on the pole when cable is to be installed straight on OFC path.
22. Every fifth pole is planned be a tension pole in straight alignment with _____ cable loop.
23. Which component of aerial assembly is installed over protective helix to control cable vibrations?
24. Identify the item.

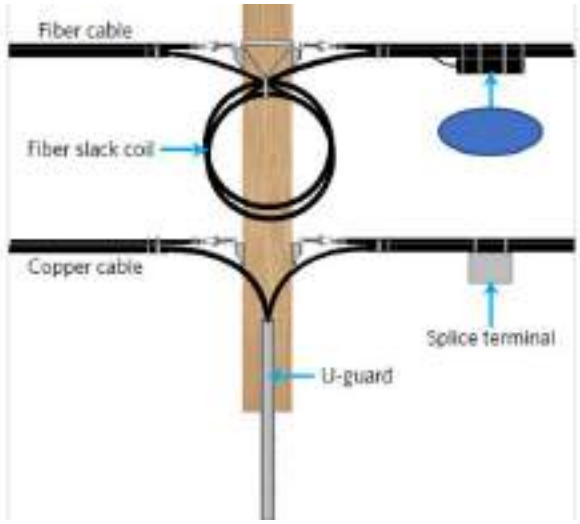
25. Why do we use wedge clamp?
26. What materials are used for body of wedge clamp?
27. Identify the below item?

28.Can we mount Universal Bracket on poles?
29. Where do we use Anchoring & Tension Clamps?
30. What should be installation span in case of using anchoring and tension clamps?

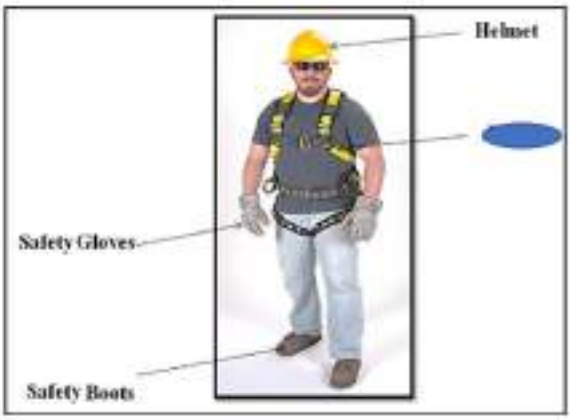
31. Name the missing item in below picture?



32. Identify the encircled item in below picture?



33. The messenger is required to be grounded? True or False.
34.Should we use wooden ladder for pole to pole aerial cabling?
35. Name the missing item.



----------End of the Module----------

MODULE 7
FIBER SPLICING TECHNIQUES

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Differentiate between various Types of Splicing Techniques
- Prepare Loose Tube Optical Fiber Cable
- Distinguish between various types of Splicing Machines
- Perform Fiber Stripping, Cleaning and Cleaving
- Splice the Single and Ribbon Fibers
- Protect the Splices
- Follow Splicing Safety Guidelines
- Maintain the Splicing Machine
- Prepare checklist for Performing Fiber Splicing

Section 2: Relevant Knowledge

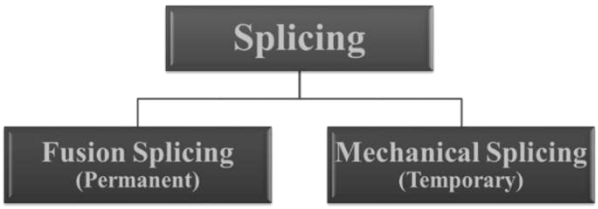
7.1 Introduction to Splicing

Splicing is the act of joining two optical fibers end-to-end.

Need of Splicing

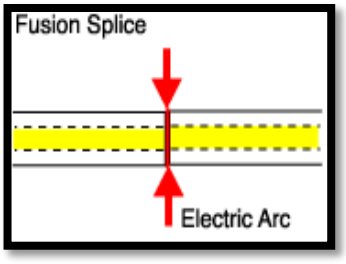
Ø Fiber optic cable that is available is not sufficiently long for the required run.
Ø Optical fibers may be connected to each other by connectors or by splicing to form a continuous optical media.
Ø The OFC drums are of approx. 2/4 kms in length, hence optical fiber need to be joint at approx. every 2/4 kms.

7.2 Types of Splicing



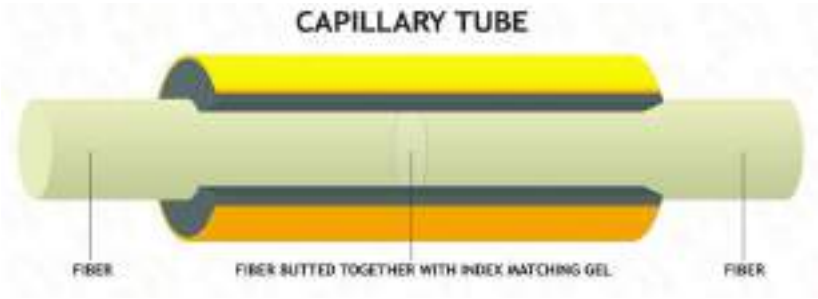
Fusion Splicing

Ø This splice is made by fusing or melting the two ends of fiber together.
Ø It uses an electric arc to weld two optical fibers using specialized equipment.

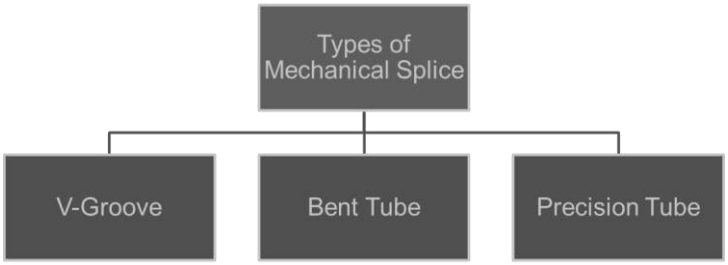


Mechanical Splicing

- A mechanical splice is a small fiber connector that precisely aligns two bare fibers, securing them mechanically.
- Used when splices need to be made quickly and easily.
- Insertion Loss is Approx. 0.5dB.

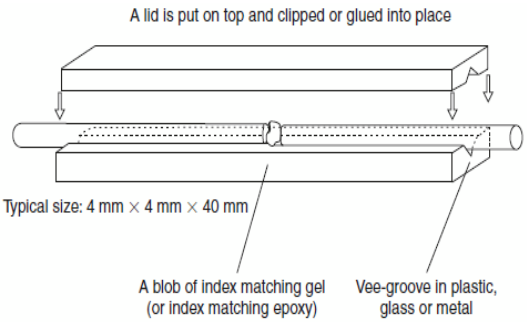


Types of Mechanical Splice



V-Groove Type Mechanical Splice

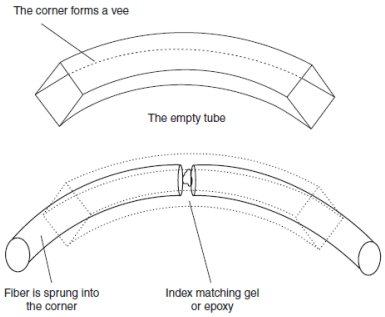
- V-groove is the most commonly used alignment mechanism for mechanical fiber splices. It consists of a base plate in which a precise V-groove is etched.
- Cleaved fibers are placed into the groove and their ends are butt-coupled into contact.
- Index matching gel is used to bridge the gap between the two ends to prevent gap loss thereby reducing attenuation.
- A locking mechanism then holds the fibers in position and provides mechanical protection for the fibers.



- Index matching epoxy can be used in place of index matching gel.
- The epoxy is usually cured with ultraviolet light, the epoxy can hold the fibers in place.
- Mechanical splices are then placed in a tray.

Bent Tube Type Mechanical Splice

- In Bent tube design a length of fiber is pushed into a tube which is curved, the springiness of the fiber forces itself to follow the outside of the curve.
- If the tube is of square cross-section, the fiber will follow the far corner.
- The fiber is now positioned by a V-shaped wall of the tube.
- In some designs, the cross-section of the bent tube is circular instead of square.



Precision Tube Type Mechanical Splice

- In precision tube method, a precise hole with a slightly larger diameter than the fiber OD is formed through a piece of ceramic or other material.
- When a piece of bare fiber is inserted from each end, the two fibers are aligned when they contact.
- It has insertion loss higher than other types. This is caused by the hard to control tolerance of the hole diameter.

Advantages of Mechanical Splicing

There are some significant advantages of using a mechanical fiber splice rather than fusion splices. Here are a few of them:

- Mechanical splices require no power supplies.
- Many mechanical fiber splice designs require no extra tools beyond a fiber stripper and fiber cleaver.
- They can be used in situations where fusion splicing is not practical or impossible.
- Mechanical splices can be made within a couple of minutes, this makes it ideal for temporary connections.

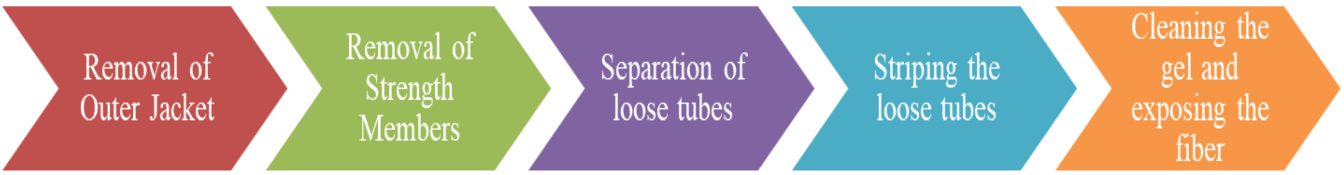
Disadvantages of Mechanical Splicing

- The typical insertion loss for a mechanical splice is about 0.3dB to 0.5 dB which is significantly higher than the 0.02dB loss for a typical fusion splice.
- Mechanical splices are typically used for multimode fibers. The tough alignment tolerance for single mode fibers makes it hard for mechanical splices to meet the required power in an optical link.
- Due to variation in refractive index of index matching compounds with temperature, the performance of a mechanical splice can be sensitive to ambient temperature.
- Mechanical splices are not thought to be as reliable as fusion splices over long periods of time.
- Mechanical splices can be used only in relatively benign environments such as inside an office building.

Fusion vs Mechanical Splicing

Fusion Splicing	Mechanical Splicing
Fibers are Fused/Welded	Fibers are only Aligned
Permanent Connection	Temporary Connection
Typical loss: 0.02 dB	Typical loss: <0.5 dB

7.3 Cable Preparation: Loose Tube



Using a sample of loose tube OSP cable:

- Remove the outside jacket
- Separate the buffer tubes
- Cut strength members
- Strip the tube for which fibers are to be spliced
- Expose the fibers. If the cable is gel-filled, use cleaner to remove the gel

Cable Preparation Tools

- Cable Cutter is used to cut the cable, if required.
- Round cutter is used to make circular and lateral cuts in the cable.
- The cable is stripped of their outer and inner sheath using cable sheath stripper.

Cable Cutter

Round Cutter

Cable Sheath Stripper

Cable Preparation Steps

Step 1: Removal of outer jacket

a) Using Round cutter make circular cut in the cable at about 3 meters distance from end of the cable.

b) Use cable sheath stripper to make lateral cut in the cable jacket.

c) Use cable rip cord to cut through the fiber jacket

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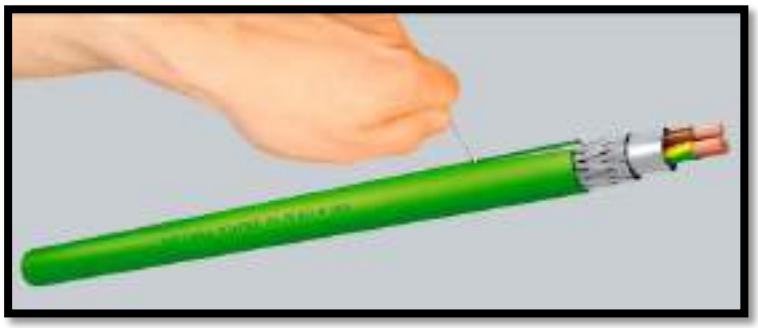


d) Carefully peel back the jacket and expose the strength members such as armour or yarns.

Step 2: Removal of strength members

Cut away exposed yarn and sheath using scissor. Leave enough of the strength member to properly secure the cable in the joint closure.

Step 3: Separation of loose tubes

Separate the fiber loose tubes carefully.

Step 4: Stripping the loose tubes

Cut the central strength member (metal or plastic). Strip away about 2 meters of fiber tube using a buffer tube stripper and expose the individual fibers.

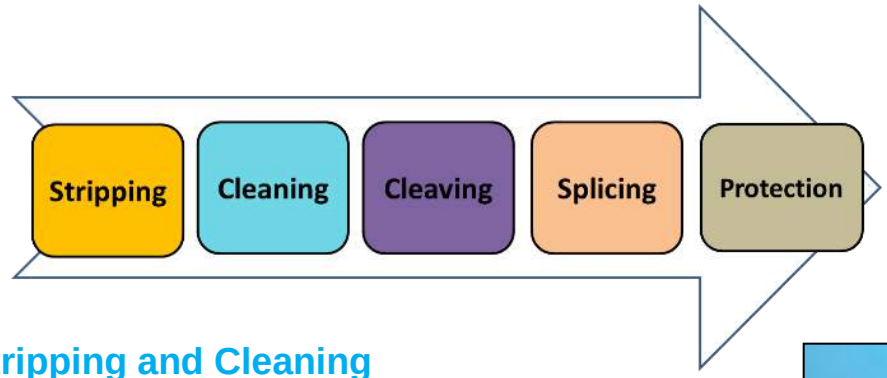
Step 5: Cleaning the gel and exposing the fiber

Carefully clean all fibers in the loose tube of any filling gel with cable gel remover or lint free tissue.

7.4 Fusion Splicing Process: Single Fiber

Single Fiber Splicing Process

Before Stripping, take the Splice Protection Sleeve and slide over one of the ends of fiber.



7.5 Fiber Stripping and Cleaning

Placement of Protection Sleeve in Single Fiber

Before starting the splicing operation, place the protection sleeve in any one of the fiber to be spliced.

Fiber Stripping Tool

Stripping tool provides a quick, easy, and reliable way to cut and remove the buffer from an optical fiber.

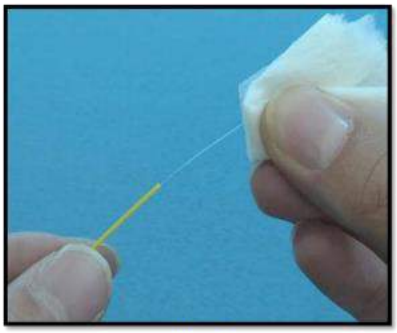
Tri-Hole Fiber Optic Stripper

- The First hole strips the 2~3mm jacket to expose 600~900µm buffer.
- The Second hole strips the 600~900µm buffer to expose 250µm coating.
- The Third hole strips the 250µm coating to expose 125µm cladding.

Stripping and Cleaning Fiber

- Strip the fiber using stripper to remove 250 micron coating to reach down to the 125 micron glass fiber/clad.
- Clean the fiber with Isopropyl Alcohol moistened gauze or lint-free tissue thoroughly.

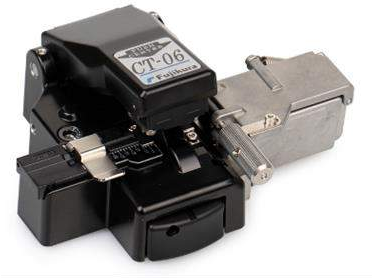
Stripping



Cleaning

7.6 Cleaving

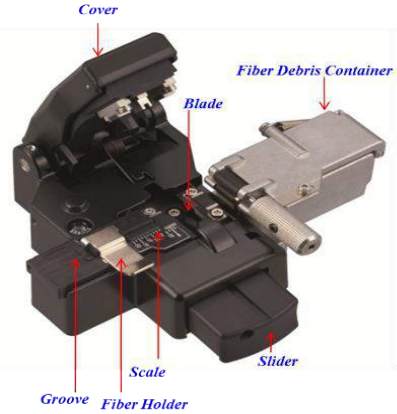
- Cleaving is the process of cutting Optical Fiber perpendicular using cleaver.
- It is intended to create a perfectly flat endface precisely for splicing.



Fiber Cleaver

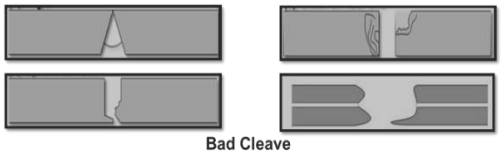
Fiber Cleaving Process

- **Step 1:** Close the slider.
- **Step 2:** Place the fiber into the groove and close the fiber holder. *(For 40mm sleeve, end of stripped fiber coating should be placed at 15mm marking on scale, whereas, for 60mm sleeve, end of stripped fiber coating should be placed at 20mm marking on scale.)*
- **Step 3:** Press down the cutting lever.
- **Step 4:** Release the pressure on the cutting lever. A spring force will bring it to its open position.
- **Step 5:** Open the fiber holder and remove the fiber from the cleaver.

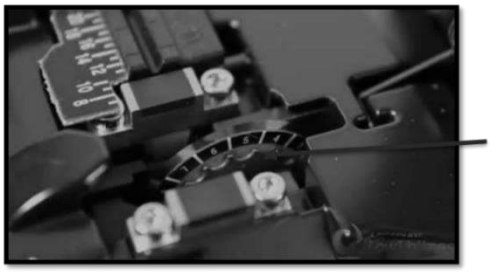


Cleaving Quality

Good Cleave



Bad Cleave

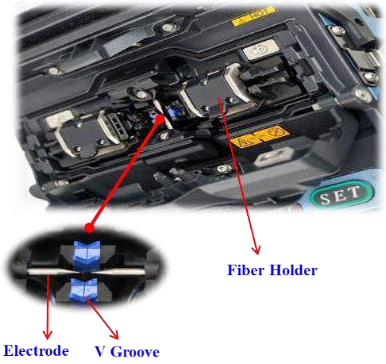


Rotate the blade periodically for maintaining good cleaving quality

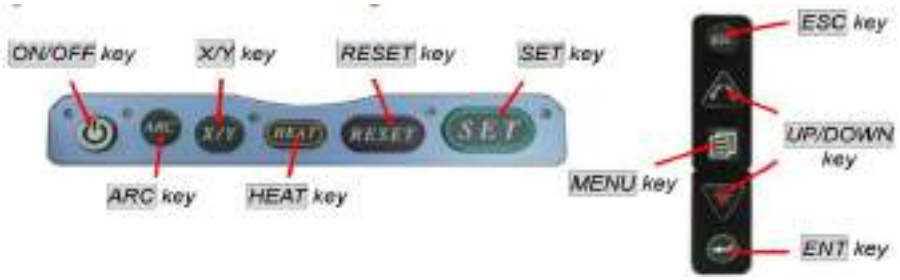
7.7 Introduction to Splicing Machine

Single Fiber Fusion Splicing Machine

Ø Fusion splicing machine is a device that generate electric arc to melt endface of optical fiber.



Operation of Keys



Key	Key Function
ON/OFF	To turn ON/OFF the power
ARC	Arc discharge manually
X/Y	Change the X/Y images
HEAT	To start the heating process by the tube heater
RESET	To quit from any state except the heating process
SET	To start/pause the splicing operation and move the cursor direction of arrow at menu state
ESC	To display the data at the "Ready", "Pause", "Finish" state. and to escape from any menu.
Up/Down	Brightness adjustment, wind protector automation and Cursor Movement
MENU	Open Main menu and go to next page
ENT	To open the menu at the "Ready" state. To select any parameter.

Accessories

A standard package of splicing machine may contain following accessories:

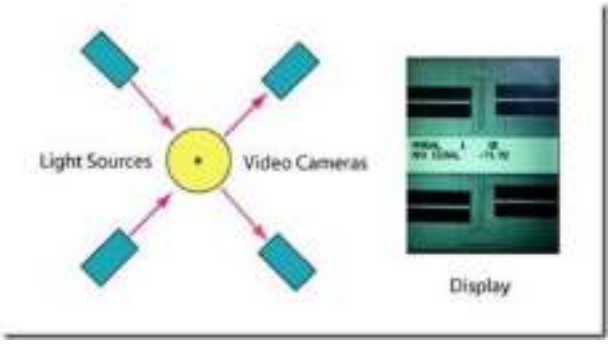
Fusion Splicer	USB cable
AC adaptor/battery charger	Quick reference guide
AC power cord	Cooling Tray
Spare Electrodes	Fiber Stripper
Fiber Cleaver	Protection Sleeves
Battery Pack	Car Battery Cable
Battery Charging Cord	Carrying Case

7.8 Types of Splicing Machine

Below given is different fiber alignment technologies in several types of fusion splicers:

Core Alignment Machine

- Ø Optical fiber core fusion splicers use multiple cameras to inspect the two cleaved fibers before fusing and allow for multiple axis movement of the fibers.
- Ø The two fibers are illuminated from two directions, 90 degrees apart.
- Ø From the multiple video cameras, the machine recognizes the core of the fibers and aligns them automatically using movable stages.
- Ø Light injection technology and imaging software line up the fiber cores so maximum light passes from one fiber to the other, ensuring minimal splice loss.
- Ø This provides for precise fiber alignment, resulting in a typical splice loss of only 0.02dB.
- Ø Ribbon splicers typically use core alignment.



Clad Alignment Machine

- Ø In clad alignment machines, the fibers sit in a holder or V-groove and are lined up “physically”, based on the outer diameter of the fiber’s cladding.
- Ø Just because the outer diameters are aligned, doesn’t mean the cores will be perfectly aligned.
- Ø Such units typically produce higher loss splices and lack the features and flexibility of higher end splicers.
- Ø Clad alignment splicers also have multiple cameras but only allow for single axis movement of the fiber.
- Ø Alignment is aided by a fixed v-groove.
- Ø The typical loss for this type of splice is 0.05dB. Clad alignment splicers are best suited for multimode applications.

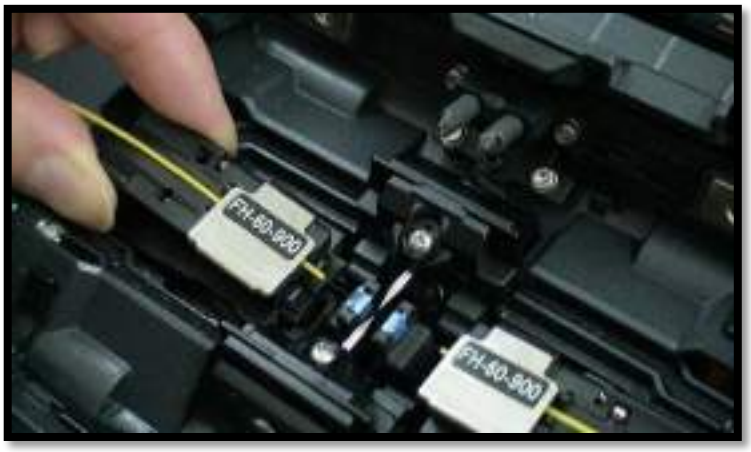
Handheld Machine

- Ø A revolution in splicing came about with the introduction of battery powered handheld fusion splicers.
- Ø These popular devices are compact and portable, yet offer performance on a par with bench top models.
- Ø The handheld fusion splicer features a 14 second splice (high speed mode), built in shrink oven, and other desirable features.
- Ø Handheld splicers are great for working in confined spaces and aerial applications.
- Ø They are ideal for FTTx, LAN, backbone and long-haul installations.

7.9 Single Fiber Splicing Procedure

Loading the Fiber

- Ø Open the wind-protector and fiber holder.
- Ø Once the fiber ends are prepared, they are placed in V- groove of fusion splicer.
- Ø Be careful not to contact the fiber tips to maintain fiber end-face quality.
- Ø Place the fiber holders into guide-pins.
- Ø Prepare and load left and right fibers into the splicer.
- Ø Close the wind-protector.



Cleave and Endface Check

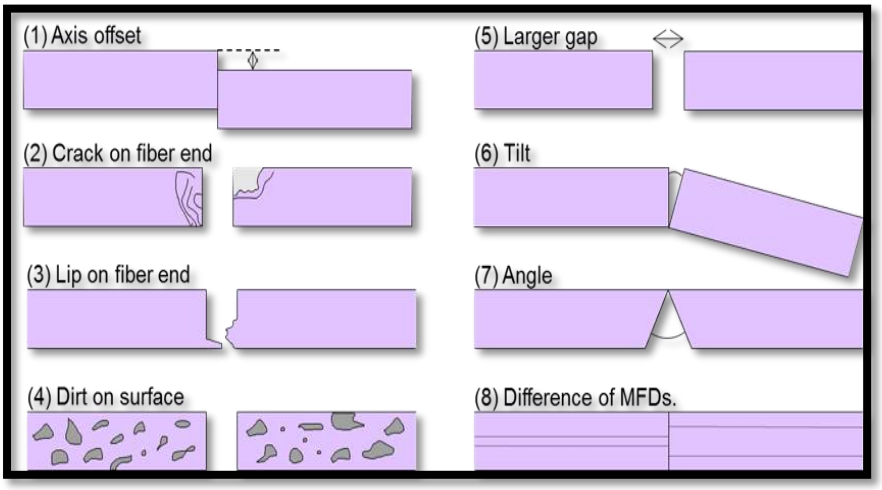
- Ø Press the “SET” key, splicer starts the splice procedure automatically.
- Ø Fibers loaded in the splicer move forward toward each other.
- Ø Cleave angle and end-face quality are checked.
- Ø If Cleave angle is not ok or greater than set threshold or fiber chipping is detected, the buzzer will sound an error message.

Splice Loss

- Ø After fiber inspection, the fibers are aligned core-to-core or cladding-to-cladding and then arc discharge is performed to splice the fibers.
- Ø Estimated splice loss is displayed upon completion of splicing.
- Ø "OK" beeps to remove the splice from the machine.
- Ø It is ensured to achieve individual splice loss less than 0.2 dB.

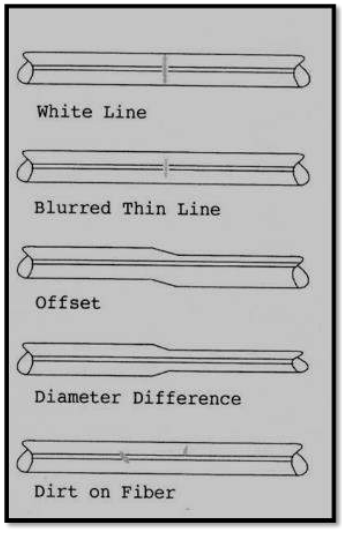
Loss in Fusion Splice

Factors that influence the loss in a Fusion Splice

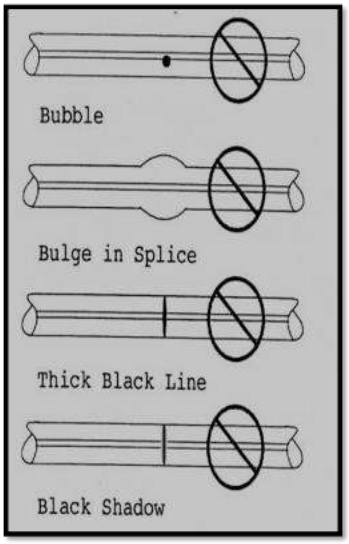


Evaluating Splices

Acceptable (if loss in under limit)



Not Acceptable at any Circumstances

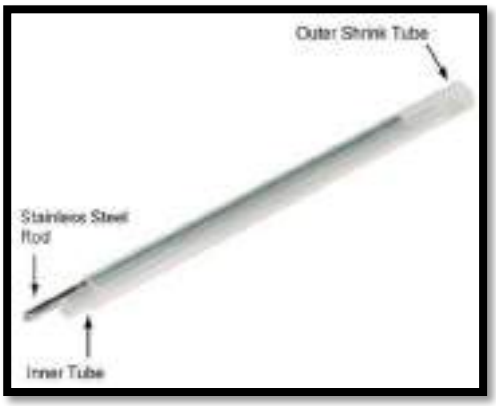


Removal of Spliced Fiber from Machine

Ø Open wind protector and fiber holders to remove the splice carefully

7.10 Splice Protection

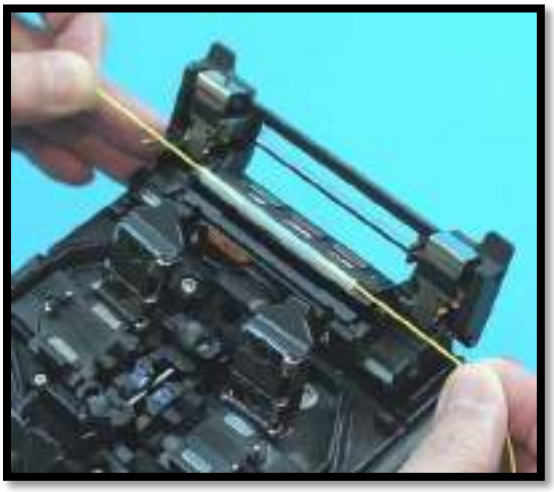
Protection Sleeve

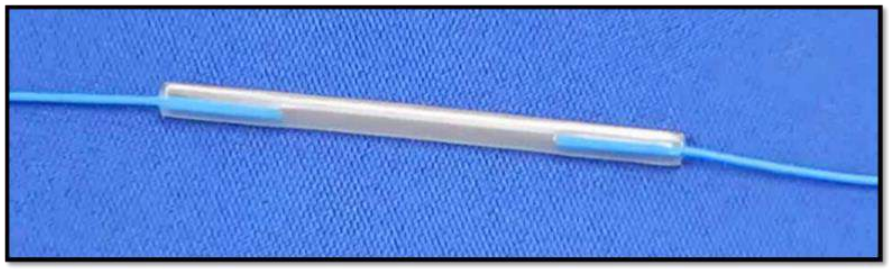


- Ø Placing the Protective Sleeve gives physical protection to the splice.
- Ø Protection Sleeves are composed of an outer and inner sleeve reinforced by an internal member made of stainless steel or ceramics.
- Ø Protection sleeves of 40mm and 60mm sizes are generally used in field.
- Ø Varieties of protection sleeves are available to accommodate single and ribbon fiber.
- Ø It is ensured that splice point is located at the center of the protection sleeve.

Splice Protection

- Ø Place the sleeve in heater unit (Tube heater lids automatically get closed).
- Ø Press the 'HEAT' key to start sleeve heating.
- Ø On completion of heating process, buzzer sounds and heater lid gets open automatically.





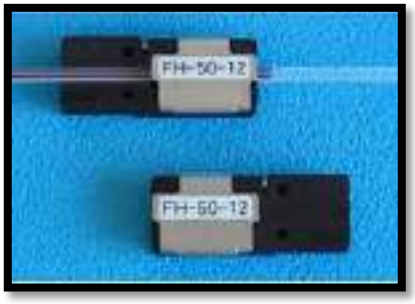
Single Fiber Splice

7.11 Ribbon Fiber Splicing Procedure

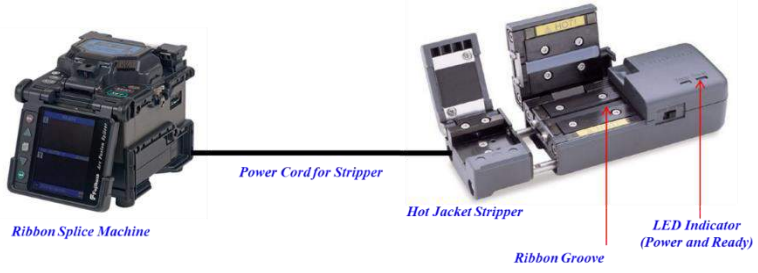
Ribbon Fiber Splicing Procedure

Step 1: Protection Sleeve Insertion in Ribbon

Step 2: Placement of Ribbon in Holder



Step 3: The holder is inserted in an Auto Stripper (Hot Jacket Stripper) that uses heat to make stripping easier.



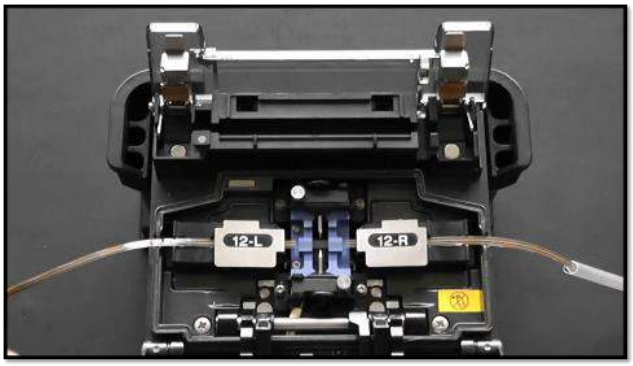
Power LED: *Green when auto stripper is ON*
Ready LED: *Orange: Fiber Ribbon heating in progress*
Green: Signal for performing stripping operatio

Ribbon Fiber Cleaver

Step 4: Cleaving of all 12 fibers together using ribbon cleaver.

Placing the Ribbon in Machine

Step 5: The fixture with all the cleaved fibers is placed in the splicing machine.



Ribbon Fiber Display

Step 6: All 12 fibers are displayed on magnifying screen on machine.

Step 7: On pressing the 'SET' Key, splicer aligns all the fibers and starts the splice procedure automatically.

Spliced Ribbon Fiber

Step 8: Spliced ribbon is protected using 40mm protection sleeve using heater mode of the machine. Before providing protection to spliced fibers, splice loss is ensured to be within the permissible range.

7.12 Housekeeping of Splice Machine

Check Points : Fusion Splicer

- Ø Alignment check - Verifies that fiber are correctly aligned
- Ø End face check - Verifies that both fibers are cleaved to the tolerance required by splicer
- Ø Electrode check - Automatic reminder to clean electrodes after a certain number of splice
- Ø Arc check - Tests the current conditions to warn if arc current need to be adjusted
- Ø Battery Warning - Warns of impending low battery to give user time to change batteries

Not every splicing machine performs all these checks

Fusion Splicer Calibration

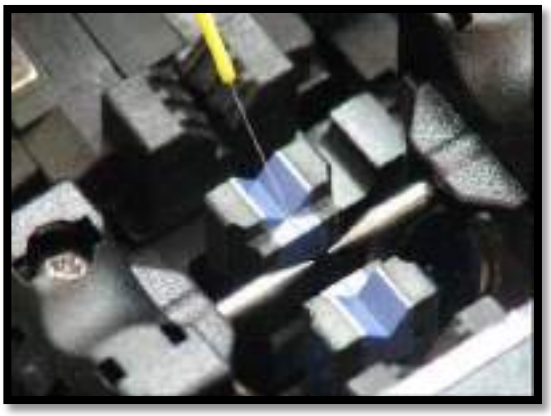
- Ø Arc Calibration
- Ø Electrode Stabilization and Replacement
- Ø Diagnostic Test:
  - LED Check
  - Dust Check
  - I/O Port Check
  - Memory Check
- Ø Motor Calibration

Fusion Splicer Cleaning Practices

- Ø Clean Mirrors - Microscope lenses
- Ø V-grooves
- Ø Fiber holders
- Ø Dust Check - Stuff Check - LED Check - Motor Check
- Ø Optical adapter and head cleaning
- Ø Battery reconditioning and replacement
- Ø Dirty mirrors
- Ø Cleaver cleaning

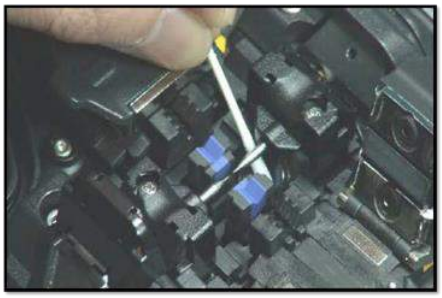
Cleaning V- Grooves

- Ø Clean and Check the V-grooves before Splicing



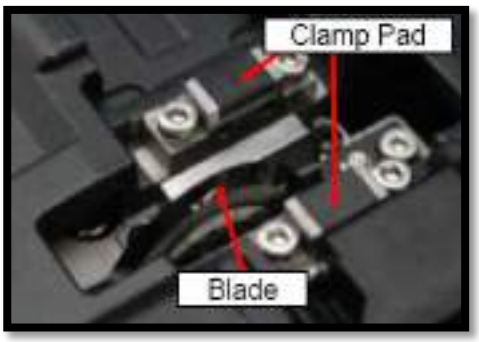
Cleaning of Lens

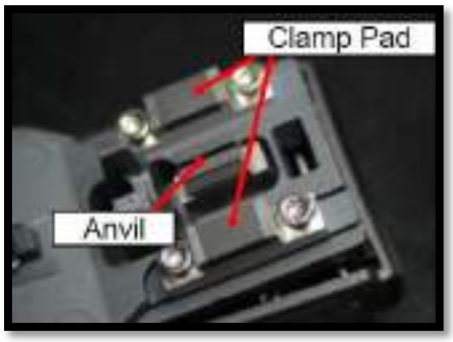
- Ø Clean the Microscope Lens.
- Ø Electrodes need not to be removed from the machine for cleaning microscope lens.



Cleaning Fiber Cleaver

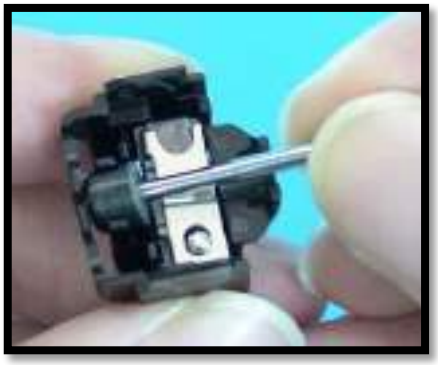
- Ø Cleaning the circular blade or clamp pads with cotton swab moistened with Iso-Propyl Alcohol (IPA).





Replacement of Electrodes

- Ø The message prompting to replace the electrodes is displayed after turning on the power.
- Ø Electrodes are replaced after approx. 3,000 arc discharges.
- Ø Electrode can be removed and clean to get additional arcs. However, electrode replacement is better practice.



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Splicing Safety Practices

- **S** Try to work in clean area.
- **A** Wear Apron and Safety Gears.
- **F** Perform splicing work on Black Safety Mat to easily identify fiber debris.
- **E** Always keep dust caps on Connectors.
- **T** Always use Isopropyl Alcohol to clean the fiber with Lint Free Tissues.
- **Y** Dispose the fiber ends at designated area.

Factor Affecting Splice Loss

7.13 Checklist for Performing Fiber Splicing

Fusion Splicing Machine	Cable Sheath Stripper
Mechanical Splices	Plier Set
Cleaver	Screw Driver Set
Battery Charger	Loose Tube Cutter (Rolling Knife)
Additional Battery for Splice Machine	Nipper Cutter
Splice Protection Sleeves	Duct Cutter
Iso-propyl Alcohol	Chamfering Tool for Duct
Lint Free Tissues	Coupler Spanner
Cotton Buds	Joint Closure
Fiber Stripper	Heath Shrink Sleeve
Knife	Aluminum Foil
Tweezers	Branching Clips
Scissor	LPG Butane Cylinder
Allen Key Set	Tape Line
Cable Cutter	Marker Pen
Round Cutter	Carry Bag

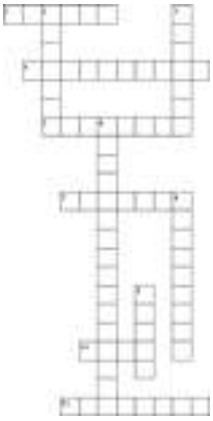
Section 3: Exercises

Exercise 1: Participate in group discussion on following topics:

a) Types of Fiber Splicing
b) Splicing Safety Guidelines
c) Types of Splicing Machine
d) Housekeeping of Splicing Machine

Exercise 2: Solve the Crossword Puzzle given below.

Across (Left to Right)		Down (Up to Down)
1. Splice that uses arc to join the fibers **4.** A temporary splicing technique **5.** It is used to remove the fiber coatings to reach upto 125 microns **7.** Cleaved fiber is placed on it to perform fusion splicing; a part of splice machine **10.** Part of joint closure **11.** Process of joining two fibers		**2.** It provides protection to splice **3.** It is used to cut the fiber perpendicularly **6.** Liquid used to clean the fiber **8.** It generates arc in a splice machine **9.** Colour of LED on hot jacket stripper when it is ready for stripping



Exercise 3: Enlist the tools required to perform fiber splicing and manage fiber in joint closure.

Exercise 4: Analyse the below image and tell what do you infer?

Section 4: Assessment Questionnaire

1. _____ is the act of joining two optical fibers end-to-end.
2. What are two types of splicing?
3. In which splicing fiber is melted?
4. Which part of splicing machine produces electric arc?
5. Which type of splicing method has higher loss?
6. Arrange in correct order of splicing process:
   Cleaving, Striping, Cleaning, Splicing, Protection
7. Which method make permanent splicing?
8. Fiber Cleaver is used to:
9. What are advantages of Mechanical Splicing?
10. What are disadvantages of Mechanical Splicing?
11. Which tool is used to cut cable in circular and lateral direction?
12. _____provides a quick, easy, and reliable way to cut and remove the buffer from an optical fiber.
13. Which solution is used for cleaning the fiber?
14. The individual splice loss shall be less than:
15. Fusion splicing machine is a device that generate _____to melt end face of optical fiber.
16. What is the use of SET key in splicing machine?
17. What are the various types of splicing machines?
18. Auto stripper gets the power from:
19. What do we use for protection of spliced fiber?
20. Which size of protection sleeve is generally used in ribbon splicing?
21. What are some diagnostic tests carried out on Fusion Splicing Machine?
22. What are some Fusion Splicer Cleaning Practices?
23. Electrodes are generally replaced after _____arc discharges.
24. What are some splicing safety practices?
25. Why black safety mat is used in splicing process?
26. Joint closure is supplied in configuration of _____ in a cable.
27. What are the factors that influence the loss in a Fusion Splice?
28. What accessories are contained in a standard package of splicing machine?
29. For 40mm sleeve, end of stripped fiber coating should be placed at 15mm marking on scale, whereas, for 60mm sleeve, end of stripped fiber coating should be placed at 20mm marking on scale. True or False?
30. In a three-hole fiber stripper:
    a. The First hole strips the _____
    b. The Second hole strips the _____ buffer
    c. The Third hole strips the _____
31. Before Stripping, take the _____and slide over one of the ends of fiber.
32. What are the cable preparation steps of loose tube cable?
33. In fusion splice fibers are _____ and in mechanical splice fibers are _____.
34. It is ensured that splice point is located at the _____of the protection sleeve.
35. Can 12 fiber ribbon fiber machine splice single fiber?
36. What are the three types of mechanical splices?
37. In _____design of mechanical splice a length of fiber is pushed into a tube which is curved.
38. In which method of mechanical splice, a hole with a slightly larger diameter than the fiber OD is formed through a piece of ceramic or other material?

----------End of the Module----------

MODULE 8
JOINT CLOSURE

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Identify different parts of Joint Closure
- Manage the fiber in Joint Closure
- Install Pole Mount Joint Closure
- Perform Earthing of Joint Closure

Section 2: Relevant Knowledge

8.1 Introduction to Joint Closure

Ø Physical protection to the splice is provided by placing the splice in splice tray.

Ø The cover is a cylindrical plastic enclosure with corrosion resistant metal hardware.

Ø The splice tray is used for storing optical fibers and the splice holders are used for securing fusion splices.

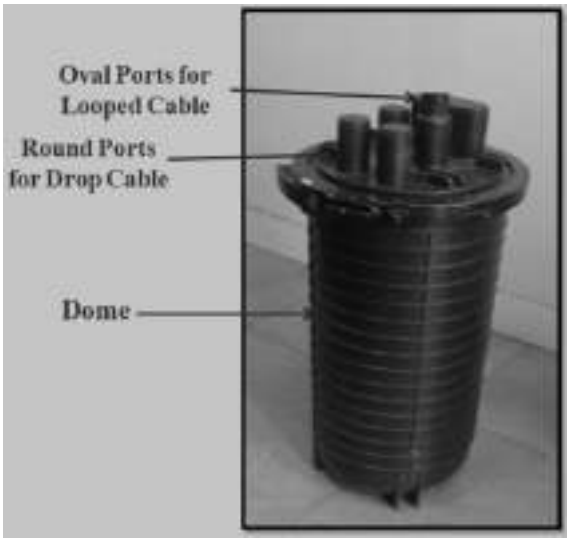
Ø Carefully place the finished splice into the splice tray and loop excess fiber around its guides.

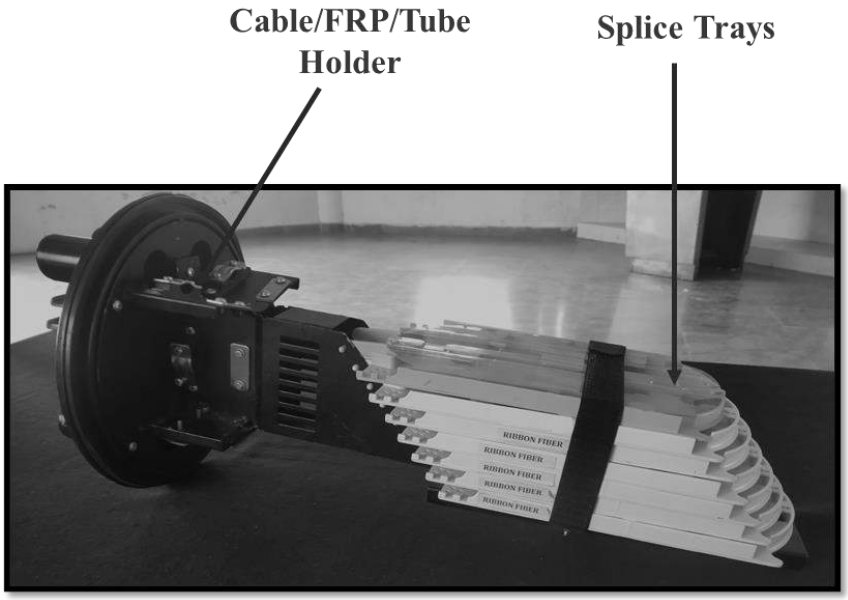
Ø Ensure that the fiber's minimum bending radius is not compromised.

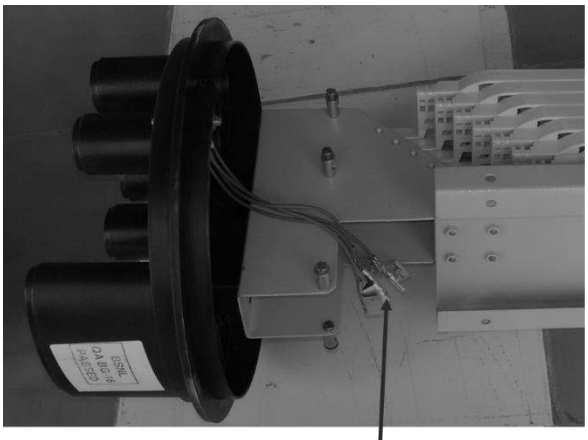
Ø Joint closure is supplied in configuration of fiber counts in a cable, i.e., 24 / 48 / 96 fiber etc.

Ø It is waterproof and dust proof and suitable for outdoor aerial hanged, pole mounted, wall mounted, duct, buried application.

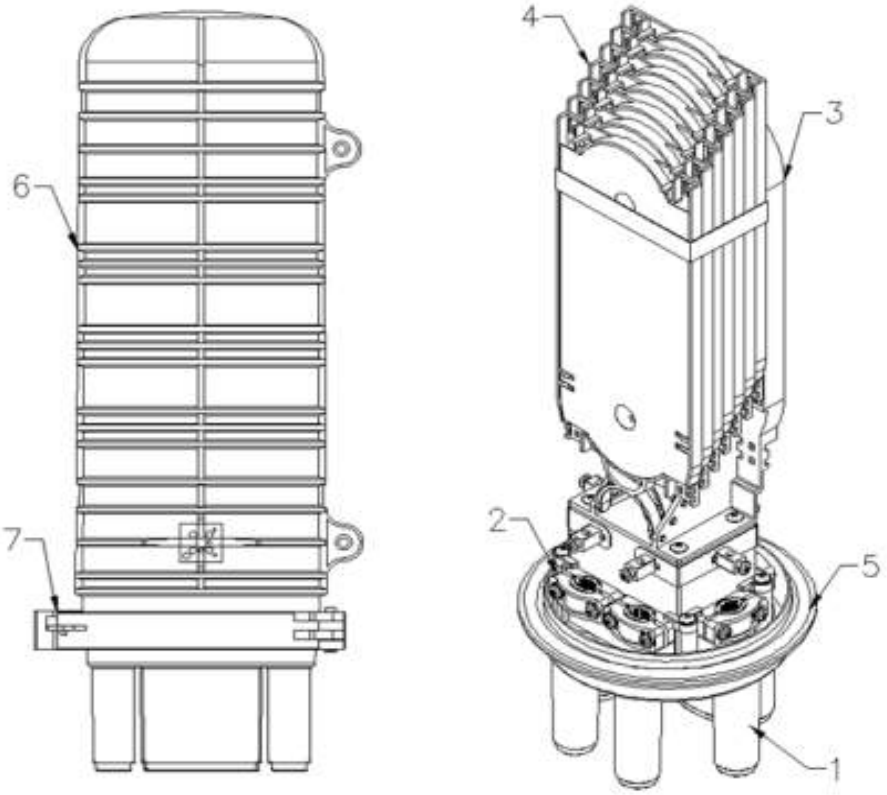
Ø It can be opened after sealing and can be reused without changing sealing material.





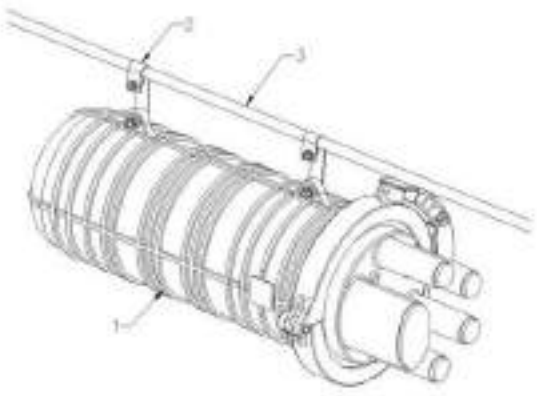


Structure Composition



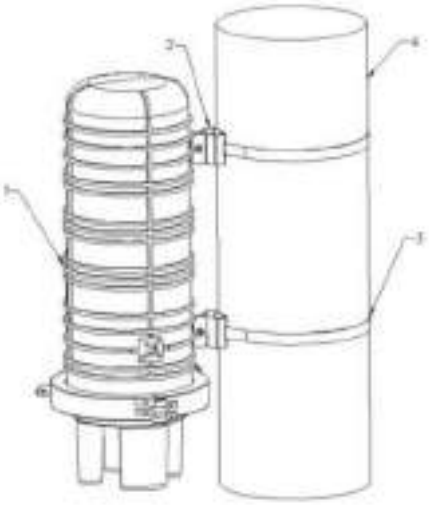
1-- bottom base 2-- cable fixing part 3-- cable storage tray 4-- fiber splice tray
5-- sealing gasket 6-- closure housing 7-- hoop

Aerial Hanged

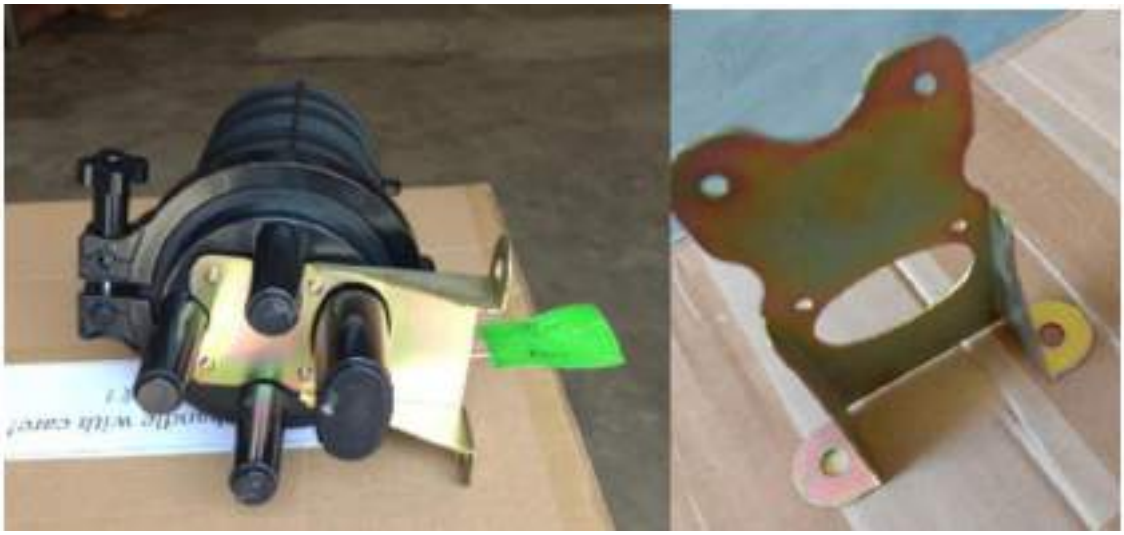


1-- closure 2-- Aerial hanged accessory 3-- steel wire

Pole Mounted



1– Splice closure 2– Fixing part 3— Stainless tape 4— Pole

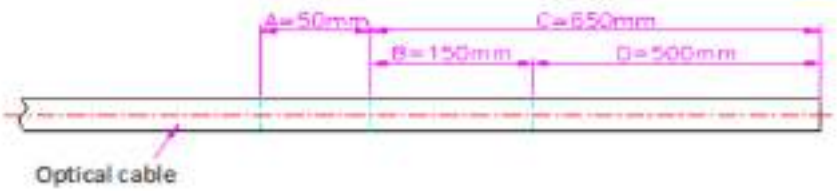


Features of Joint Closure

IP 68 Sealing
Fully mechanical
Compact size
UV stable
Can accommodate desired numbers of trays Loop Storage basket
Air Valve for pressure testing

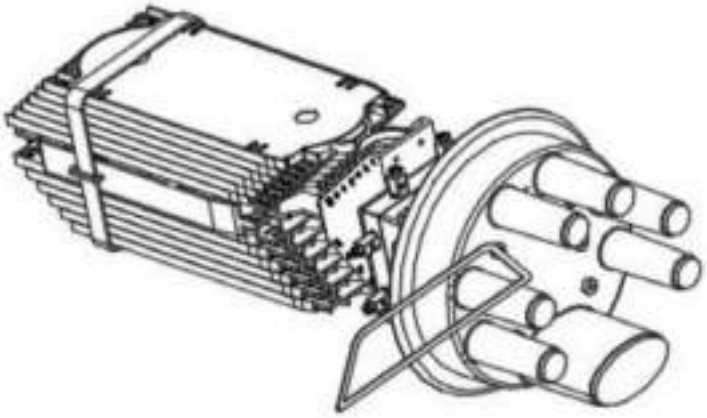
8.2 Fiber Management in Joint Closure

Make sure the optical fiber cable length in enclosure and break out length are enough.

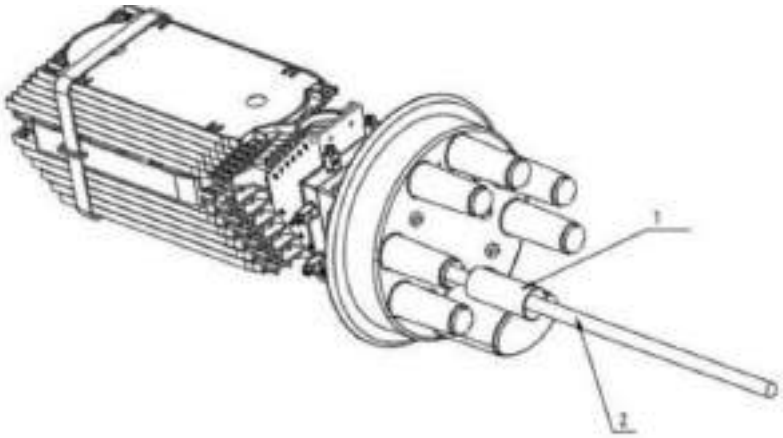


A— cable fixing length B-- Cable with jacket length inside closure

C— Cable mini. length inside closure D— Break out cable length

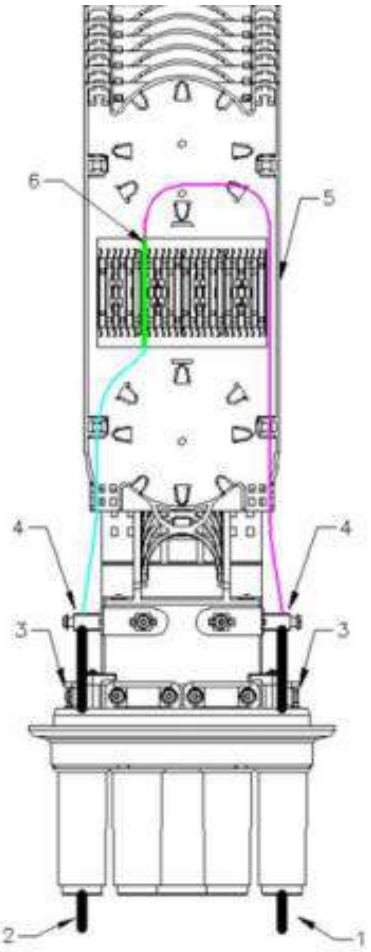


- Ø Strip out cable outside jacket by pipe cutter and longitudinal stripper.
- Ø Cut off the cable port by hacksaw (recommended hacksaw cut position: approximately 10.0mm to 20.0mm hacksaw cut from tip of cable port), then open the cable port
- Ø Put the stripped optical cable get through the heat shrinkable tube, closure cable port.



1. Heat shrinkable tube 2. Fiber optic cable

Ø Fix the cable strengthen core by cable fixing column.



1. cable port 2. cable port 3. cable fixing part
4. Cable fixing column 5. Splice tray 6. Heat shrinkable protection sleeve

Ø Put the stripped optical fiber into fiber splice tray, do splicing and storage.

Ø Single fiber splice placed in the splice tray

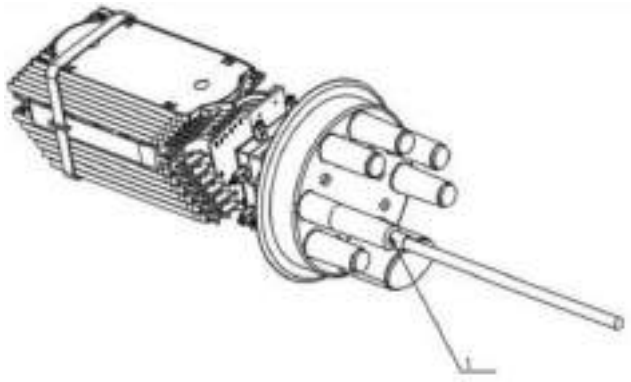
Ø Ribbon fiber splice placed in the splice tray

Optical Cable Heat Shrink Sealing

Ø Wrapping aluminium foil paper on the optical cable, then put the heat shrink tube on cable port and junction of cable.

Ø Heat the shrinkable tube by air gun or alcohol burner, then the heat shrink tube fix the cable-on-cable port tightly.

Ø If two cables entry one cable port, put the branch kit between the two cable, let the metal part of branch kit fixed outside the heat shrink tube, then heat it.



1.Heat shrinkable tube

Optical Cable Heat Shrink Sealing

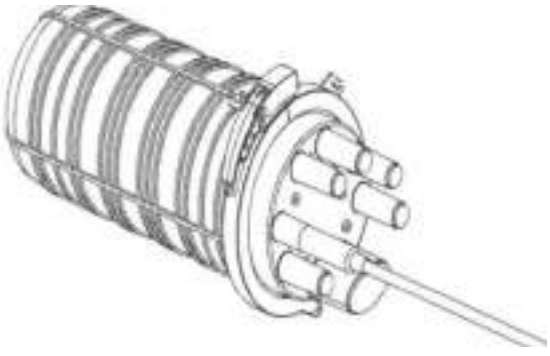
It is ensured that the splice closures are air tight and waterproof.

Heat Shrink Sleeve

Heat Shrink Sleeve and Aluminum foil is used to seal the joint closure

Closure Sealing & Housing

- Ø The cable with jacket should be fixed by cable tie in the entry of splice tray.
- Ø Check the splice tray if close tray cover.
- Ø Check the inside fixing part if they are fixed tightly.
- Ø Check the sealing parts are in good condition.
- Ø Check the heat shrinkable tube sealing if tightly and completely.
- Ø Put the closure housing close the splice tray and connect the closure base.
- Ø Fixed the closure housing and closure base by hoop.



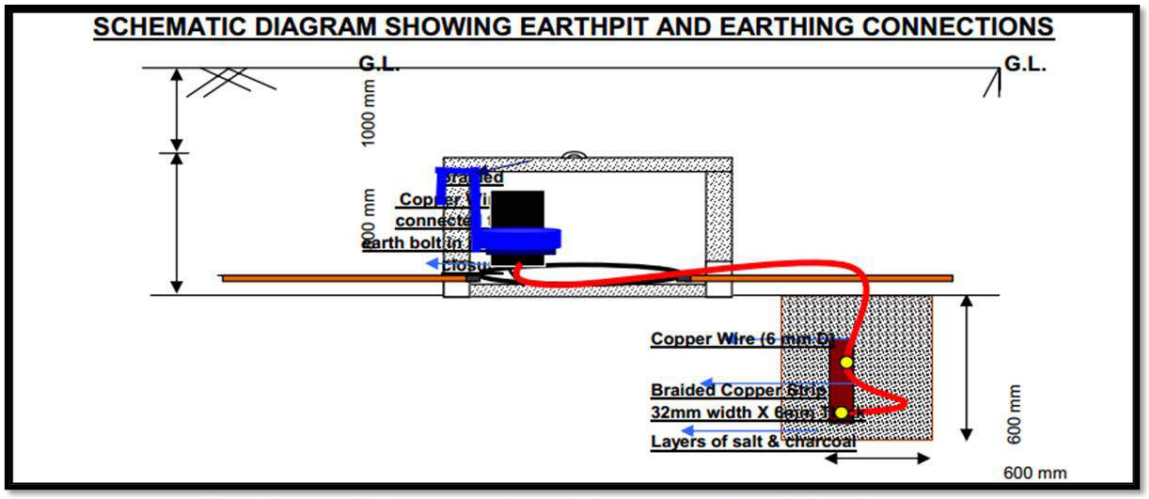
8.3 Installation of Pole Mount Joint Closure

- Ø It has pole bandings, or worm type stainless steel ties.
- Ø No need to cut the bracket to take the Dome closure off the pole. One may release the dome by holder, and take the closure down the pole.
- Ø Quick and easy attachment with fiber cable slack storage bracket.
- Ø Simple installation with aerial FTTH drop cables.

8.4 Earthing of Joint Closure

Joint Closure Earthing Practices

Item		Specs
Earthing Interval (Common Practice)		8km (Long Route Route)
		At Every Joint (City Area)
Material Required	Copper Rod	20mm dia, 0.5m length
	Copper Plate	300 x 300 x 3mm
	Copper Strip	32mm wide and 6mm thick
	Charcoal	At Min 2.5m depth and 600mm dia
	Salt	



Earth resistance should not exceed 2 ohms

Section 3: Exercises

Exercise 1: Make a diagram of joint closure and its parts.
Exercise 2: Draw a schematic diagram showing earth pit and earthing connection**.**
Exercise 3: Participate in group discussion on following topics:

a) Fiber management in Joint Closure
b) Sealing of Joint Closure

Section 4: Assessment Questionnaire

1. Physical protection to the splice is provided by placing the splice in _____.
2. What is the use of Splice holders?
3. Can we reuse Joint Enclosure?
4. Identify the hidden item.

5. Identify the hidden item.

6. What are some features of Joint Enclosure?
7. How can we seal joint closure?
8. Is bending radius for fiber is maintained in Joint closure?
9. What are qualities of Joint closure?
10. Where can we use Joint closure?
11. The splice tray is used for _____
12. Why do we use crocodile clip in Joint closure?
13. Name the item no 3 in below picture.

14. Why joint enclosure is used in field?
15. _____ is used for connecting cable earthing in joint closure.
16. _____is used for pressure testing of joint closure.
17. Joint closure cannot be installed on pole. True or False?
18. Ovel ports of joint closure is used for placing _____ cables.
19. Number of spliced trays may vary in every joint closure. True or False?
20. In IP 68 standard of joint closure sealing. What does IP stand for?

----------End of the Module----------

MODULE 9
OPTICAL LINK TESTING PROCEDURES

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Differentiate between various types of optical link testing equipment
- Explain functions and working principle of OTDR
- Configure the OTDR for link testing
- Read and understand the information on OTDR trace and test results
- Describe OTDR performance parameters
- State OTDR undesirable properties
- Perform bi-directional analysis using OTDR
- Perform Light Source-Power Meter (LSPM) test (1,2 and 3 Cable Reference Methods)
- Perform fiber test using Visual Fault Locator (VFL)
- Use fiber detection meter
- Distinguish between various optical attenuators
- Test the OFC Drum
- Housekeep the OTDR

Section 2: Relevant Knowledge

9.1 Link Testing Equipment

Link Test shall be carried out on OFC section terminated at both ends.

S. No.	Test Instrument	Test Parameter
1	**Optical Time Domain Reflectometer (OTDR)**	▪ **Continuity** ▪ **Length** ▪ **Location Identification** ▪ **Fiber Faults** ▪ **Splice Loss** ▪ **Overall Loss**
2	**Optical Power Loss measuring Equipment (Light source & Power meter)**	▪ **Continuity** ▪ **Overall Loss** ▪ **Fiber Identification (Swap)**
3	**Visual Fault Locator (VFL)**	▪ **Continuity** ▪ **Fiber Identification (Swap)**

Fiber Swap takes place when two fibers of different numbers are spliced or connected

9.2 Optical Link Budget Calculation for Long Distance Links

Insertion Loss

- Insertion loss is the amount of light that a signal loses as it travels along a fiber cable link.
- Insertion loss is measured in decibels (dB)
- It can be called as attenuation as well.
- Each component in a fiber link has its own insertion loss. Typical insertion loss of few components of fiber link is tabulated below:

Fiber Link Component	Typical Insertion Loss
G. 652D Fiber at 1310 / 1550 /1625 nm	0.36 / 0.22 / 0.25 dB
Optical Connector	0.5 dB
Fusion Splice	0.1 dB

dBm

- The units dB and dBm stand for decibel and decibel milliwatt, respectively.
- dBm is a unit of power used to indicate an Output power, Input power and Receiver Sensitivity in optical systems.
- Power injected or power received in the fiber optic cables is expressed in dBm.
- It is the power level with reference to one milliwatt (mW).

$$x = 10 \log_{10} \frac{P}{1mW}$$

- A measurement of 0 dBm using an optical power meter indicates 1 milliWatt of power.
- It is used in radio, microwave and fiber-optical communication networks as a convenient measure of absolute power because of its capability to express both very large and very small values in a short form.

Optical Link Budget Calculation

- The optical link budget is the amount of loss that a cable link should have if it is installed properly.
- It is just a theoretical calculation and may differ from actual link loss given by testing instruments.
- It is calculated by adding the estimated average losses of all the components used in the cable link to get the estimated total loss of the link.

Link Loss
=
[Fiber Length (km) X Fiber Attenuation per km]
+
[Splice Loss X no. of OFC Joints]
+
[Connector Loss X no. of Connectors]

1	Standard for connector loss	0.5 dB
2	Typical cable attenuation at 1310 nm	0.36 dB/km
3	Typical cable attenuation at 1550 nm	0.22 dB/km
4	Typical cable attenuation at 1625 nm	0.25 dB/km
5	Typical splice attenuation	0.1 dB/km
6	Typical safety margin	3 dB

Theoretical link loss is calculated using following formula:

Value in dB at 1310 or 1550 or 1625nm
=
No. of connector pairs X 0.5
+
No. of splices X 0.1
+
Distance in Km X 0.36 or 0.22 or 0.25

Example 1:
Assume a 10 km single mode fiber link at 1310nm with 2 connector pairs and 4 splices.
Link Budget = [10km × 0.36dB/km]
+
[0.5dB × 2]
+
[0.1dB × 4]
=
5 dB

Example 2:
Assume a 60 km single mode fiber link at 1550nm with cable drum length of 4 Kms installed in the link.

Link Budget = [60km × 0.22dB/km]…..loss at 1550nm is 0.22dB/km
+
[0.5dB × 2]……..2 connectors at each end
+
[0.1dB × 16]……16 splices (15 drums + 1 splice behind FMS)
=
15.8 dB

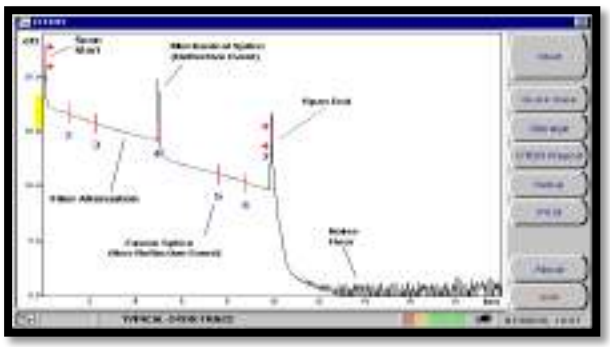
9.3 Introduction to OTDR (Optical Time Domain Reflectometer)

The Optical Time Domain Reflectometer (OTDR) is a test equipment used for measuring fiber length, attenuation in optical fiber cable (OFC) and event loss (reflective and non- reflective).

- Ø Generates a baseline trace: A “visual” of the link.
- Ø Can identify and evaluate specific events in the link.
- Ø Cable acceptance tool
- Ø Fault localization tool
- Ø Excellent documentation

Purpose of using OTDR

- Ø To have a visual representation of the fiber link (Loss vs Distance Graph).
- Ø To detect and locate the cut in fiber, attenuation, splice, connector and bending loss in the fiber link.
- Ø To perform optical network testing and troubleshooting.



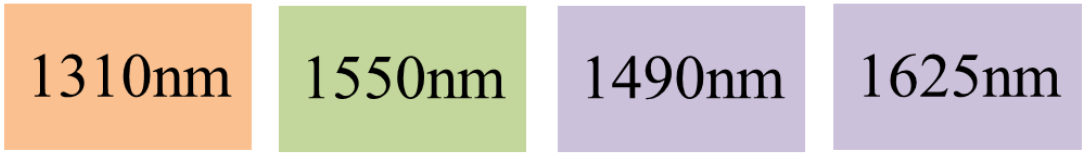
Functions of OTDR

A typical OTDR can locate and determine optical fiber's:

- Ø Attenuation characteristics along length of fiber
- Ø Splice Loss
- Ø Connector Loss
- Ø Bending Loss
- Ø Section Loss
- Ø Total Loss in the fiber
- Ø Fiber Cut Distance

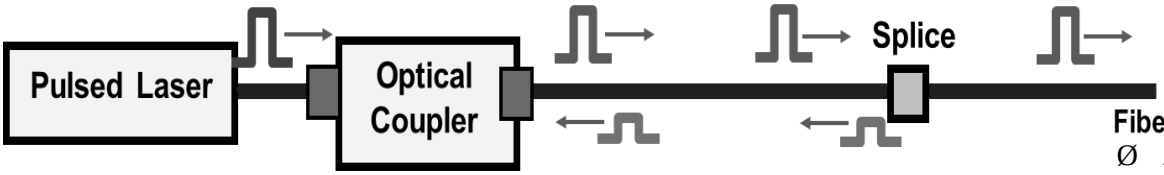
OTDR Wavelengths

OTDRs commonly operate at following spectral bands.



- Ø 1310, 1550, and 1625 nm is required for DWDM testing.
- Ø The wavelength 1490 nm is used for FTTx network.
- Ø 1625nm wavelength gives better display of the fiber bends in the link and used for testing purpose only, not communications.

Working Principle of OTDR



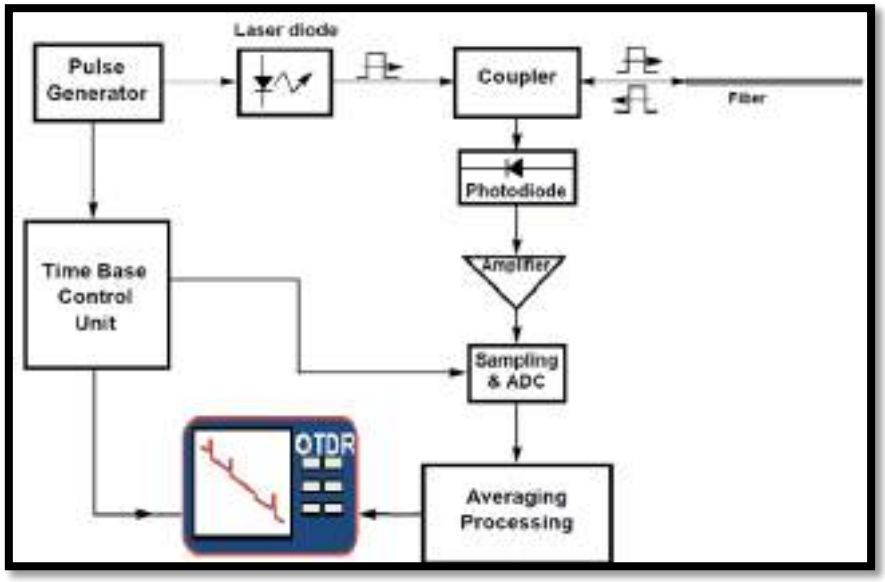
- Ø An OTDR sends light pulses into the fiber.
- Ø The light pulses reflect back to OTDR due to discontinuities such as:
  - Change in Refractive Index of fiber
  - Change in Medium (Connector, Mechanical Splice)
  - Events like splices, bends and fiber cut
- Ø OTDR then calculates the travel time and power of reflected pulses to determine event distance using following formula.

$$\text{Fault Distance} = \text{Speed of Light in Optical Fiber} \times \frac{\text{Travel Time of Reflected Pulse}}{2}$$

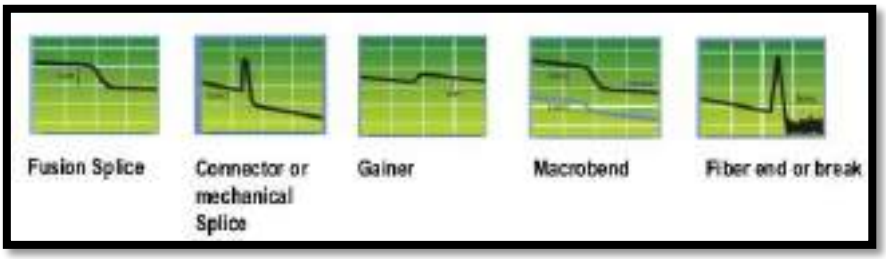
Speed of Light in Optical Fiber (approx.) = 2 x 10^5 Km/Sec

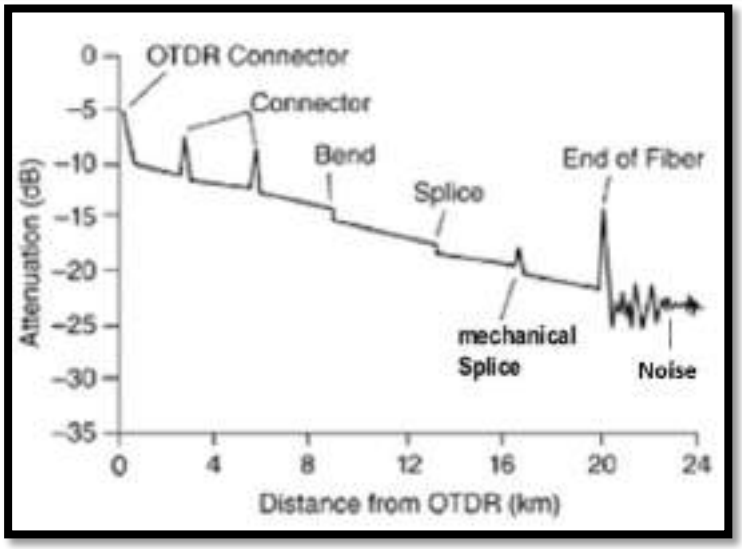
Inside the OTDR

- Ø The laser diode injects the light pulses of selected pulse width into the fiber.
- Ø The returning light pulses due to discontinuities in fiber is fed to the photodiode by the coupler to convert optical signal into electrical signal.
- Ø The electrical signal is then amplified and sampled.
- Ø OTDR processes the resulting data to display trace on the screen.

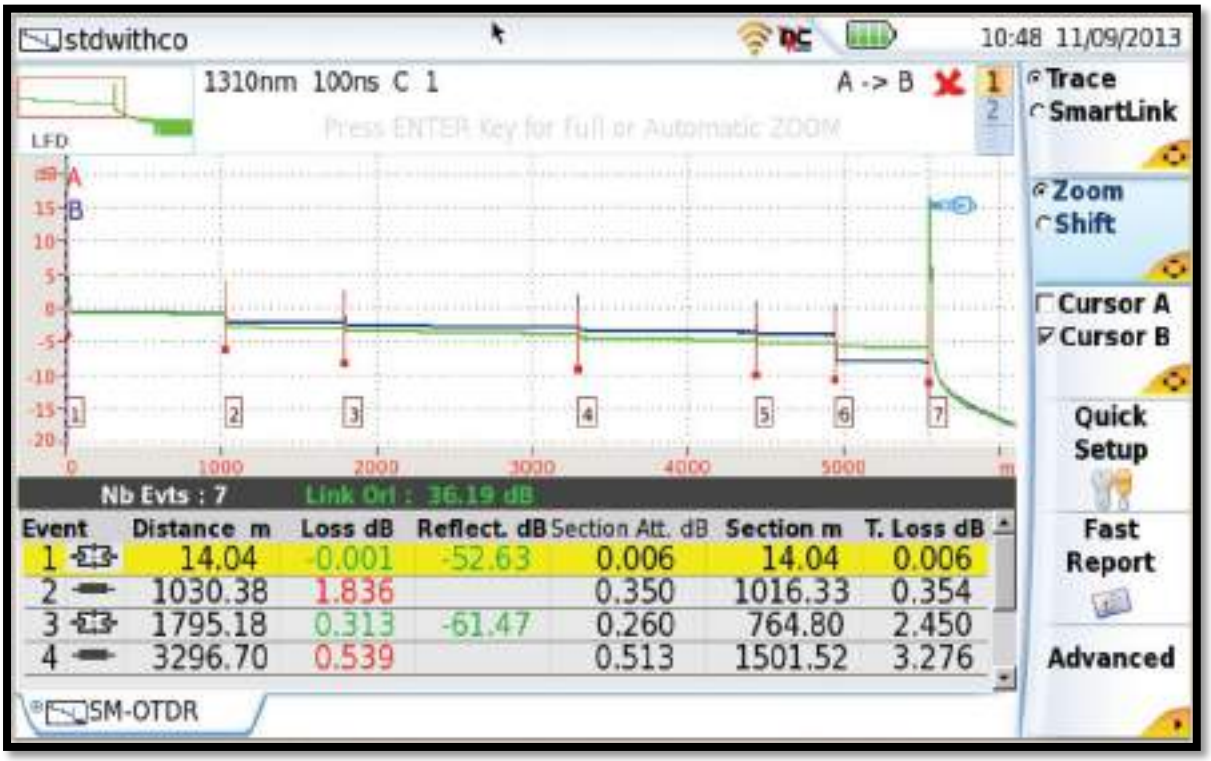


Information on OTDR Display



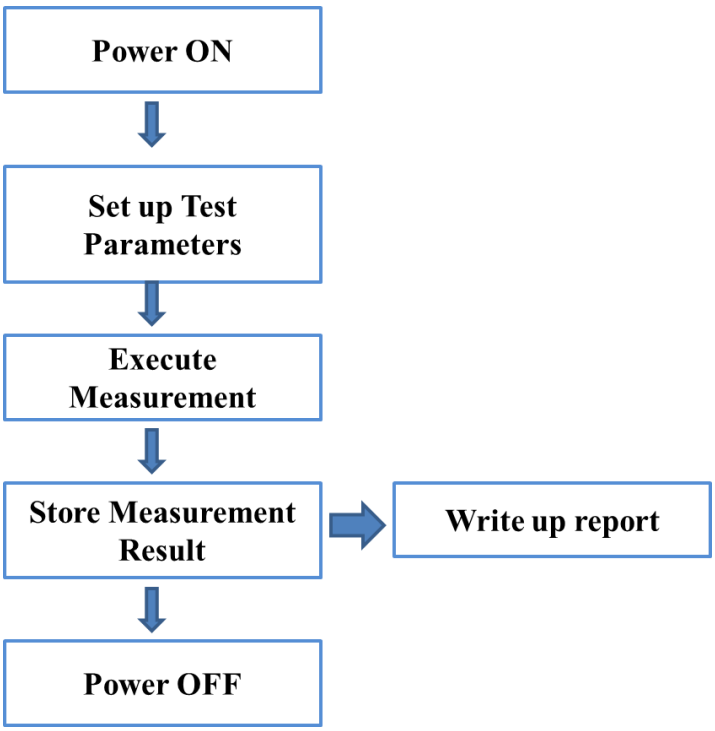


OTDR Trace with Summary



9.4 OTDR Test Parameters Configuration

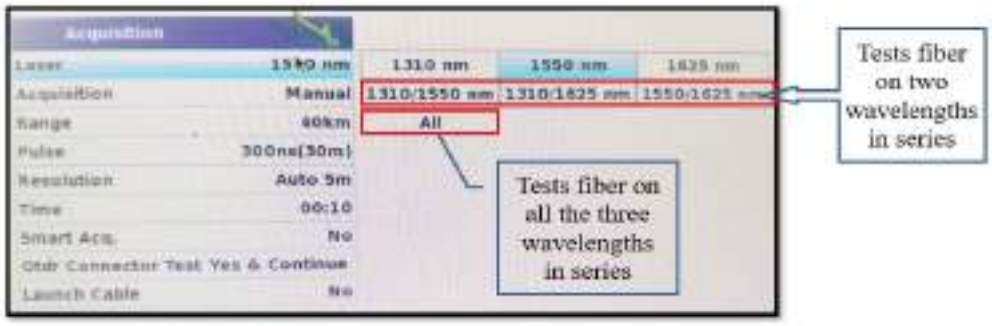
OTDR Measurement Flow Chart



OTDR Test Parameters Configuration

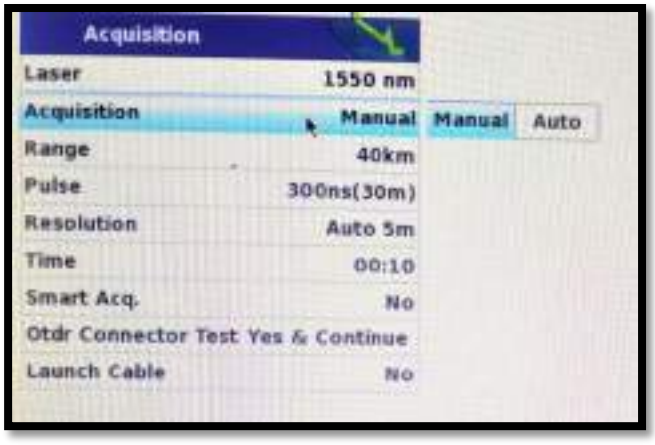
Wavelength Settings

- The desired test wavelength should be selected in OTDR.
- Higher wavelengths are more sensitive to bends.
- Fiber bend is identified by testing the fiber on two wavelengths.



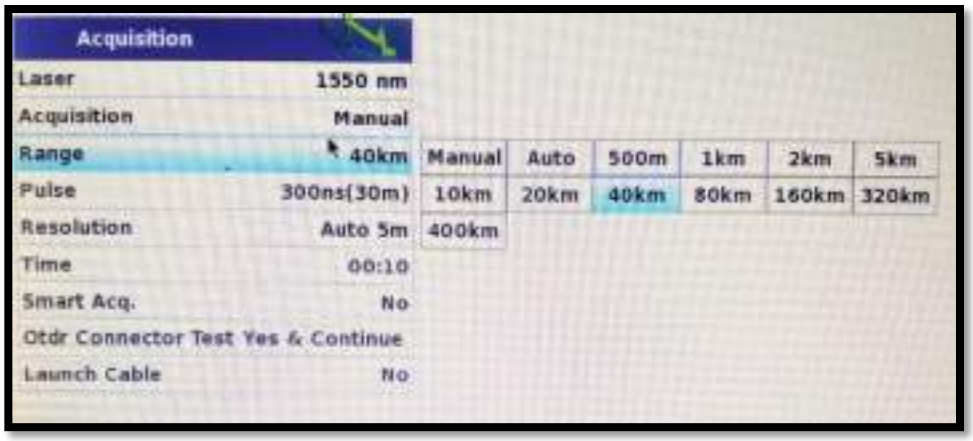
Acquisition Mode

- 'Manual' Mode - OTDR setup can be done manually.
- 'Auto' Mode - OTDR automatically sets the test parameters



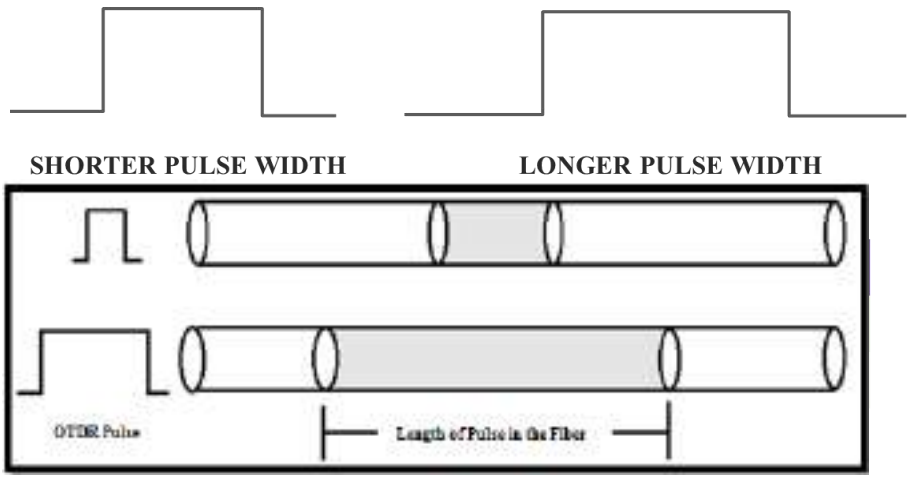
Distance Range

- Ø ‘Manual’ - Fiber length can be entered manually.
- Ø ‘Auto’ - OTDR automatically sets the fiber length and corresponding pulse width.
- Ø User may select other available distances, if fiber length is known.



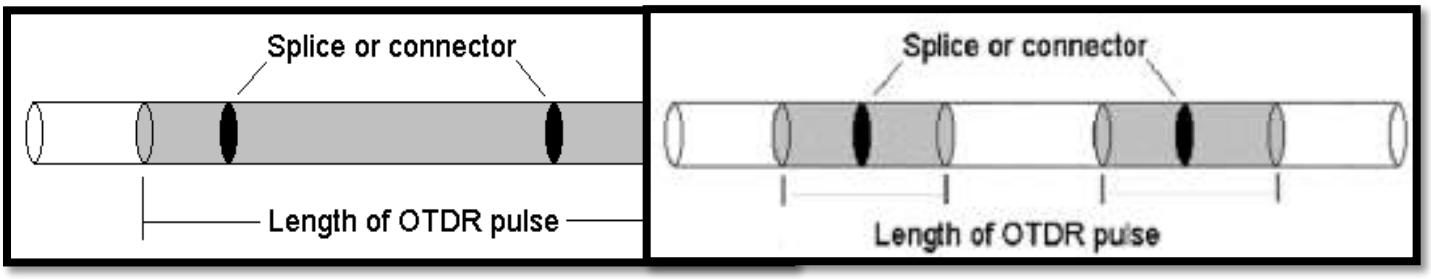
Pulse Width

Pulse Width is the time duration of Pulse that is launched into the fiber. In OTDR, it is mentioned in microseconds and nanoseconds.

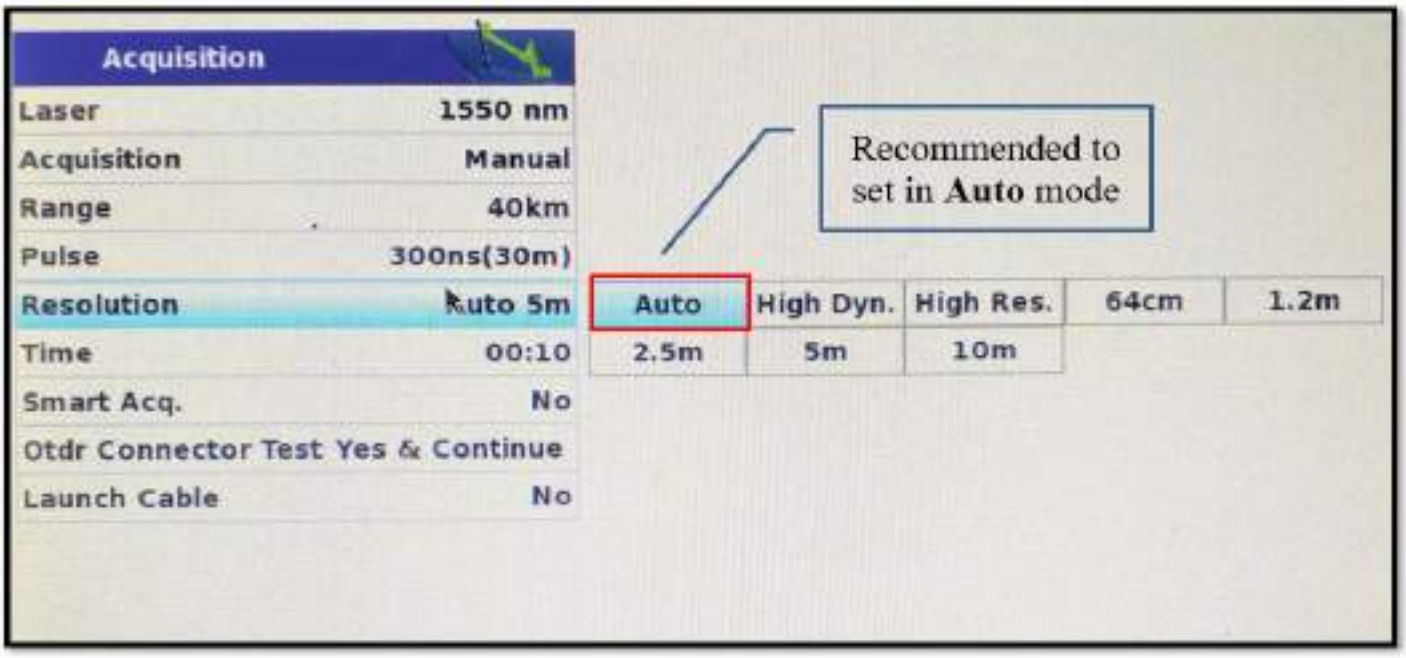


Resolution

Resolution is the ability of OTDR to distinguish between two events in the fiber.



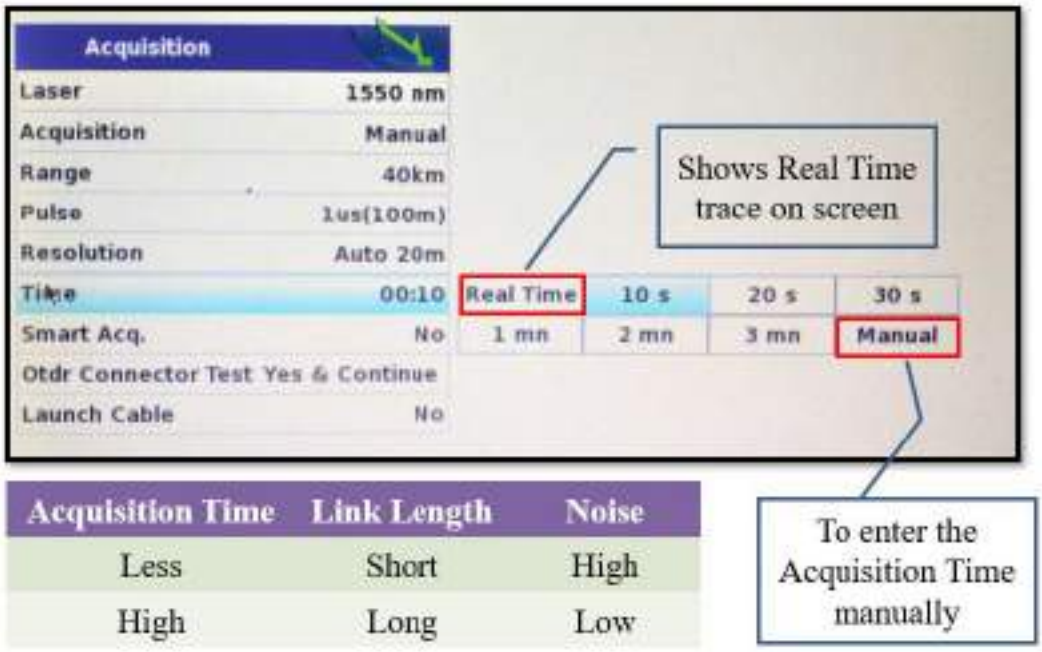
Pulse Width	Resolution	Outcome
Shorter	High	Closer events may appear as separate events
Longer	Low	Closer events may appear as single event



Acquisition Time

Acquisition time is the time taken by OTDR to calculate the results and show trace on the screen.

Acquisition Time	Link Length	Noise
Less	Short	High
High	Long	Low



Acquisition Time	Link Length	Noise
Less	Short	High
High	Long	Low

Link Description

Link parameters can be saved in OTDR to track the trace in future and fill the link information in export file.

9.5 OTDR Performance Parameters

Dynamic Range

- Ø Dynamic Range is the parameter that signifies the maximum optical loss an OTDR can measure in a fiber link.
- Ø Typical Dynamic Range of OTDR is 20 to 45 dB.
- Ø Bigger the dynamic range (in dB), the longer the distance reached.
- Ø Larger pulse width provides larger Dynamic Range.

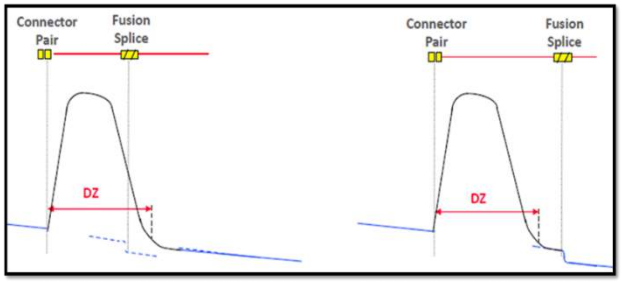
Accuracy

- Ø Accuracy of OTDR represents the correctness of the measured value with respect to the true value of Loss and Distance measurements.
- Ø The Distance Accuracy depends on:
  - Fiber Refractive Index setting in OTDR
  - OTDR Calibration

Dead Zone

When there is a strong reflection, the power received by the OTDR can saturate the photodiode. In such times, it will not detect the backscattered signal accurately. The length of fiber, within which, fiber is not able to detect any event and losses is termed as Dead Zone.

Dead Zone = Pulse Width + Receiver Recovery Time

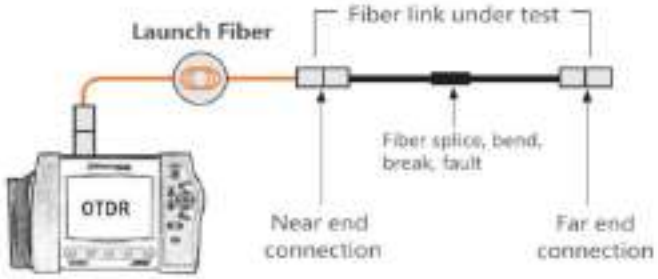


The OTDR cannot detect the splice *The OTDR can detect the splice*

Countering the effect of Dead Zone

Dead Zones can be reduced by:

- Ø Configuring Lower Pulse Width
- Ø Inserting a Launch Cable of known fiber length between the OTDR and the link under test



Spool length must be longer than the pulse width setting used for the OTDR test

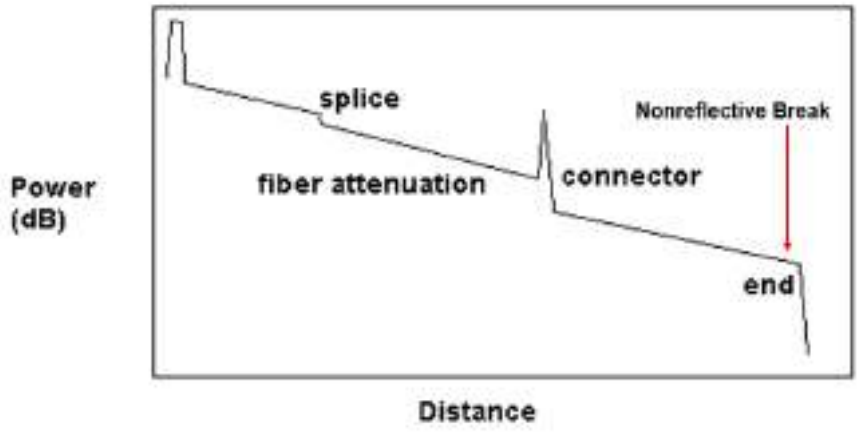
9.6 OTDR Undesirable Properties

Non-reflective Break

This occurs when:

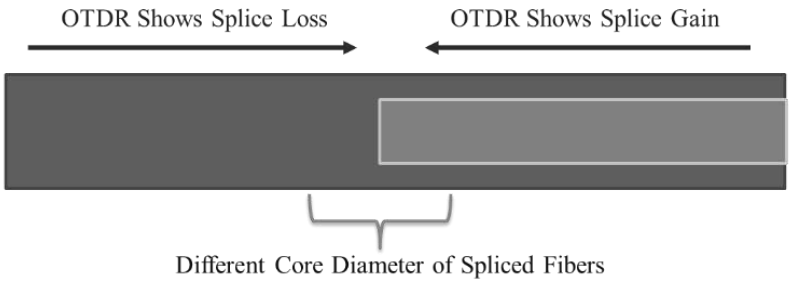
Ø Fiber is cut and fiber end is bent excessively

Ø Fiber is cut and immersed in liquid

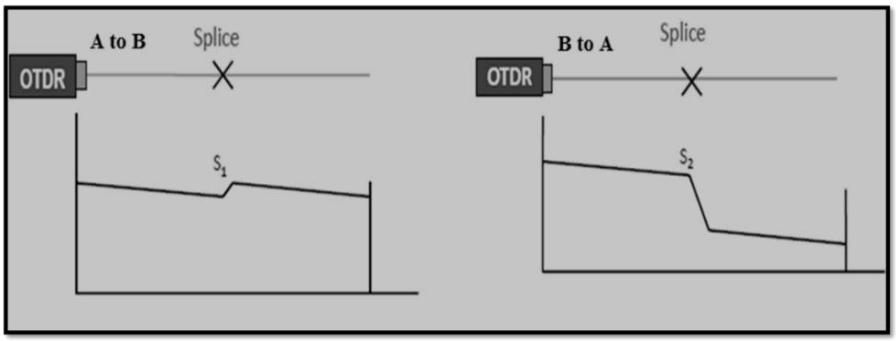


OTDR Undesirable Properties Gainer

Ø When two fibres with different core diameter are spliced and measured with OTDR, splice shows gain from one direction and loss from opposite direction.



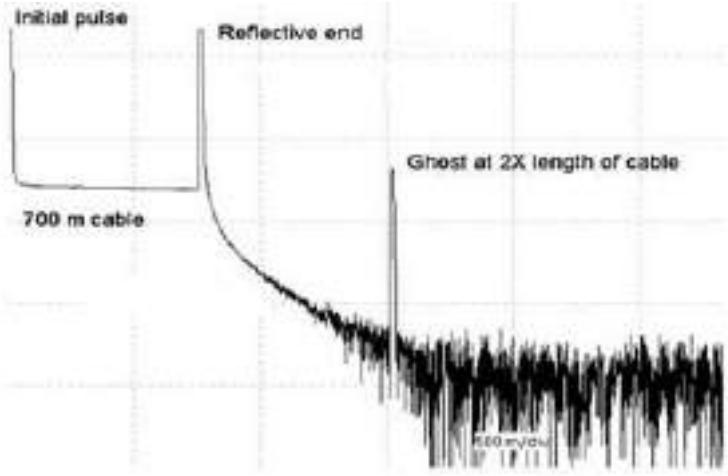
Ø This loss measurement error is overcome by taking Bidirectional OTDR Measurements and calculate Average of the Splice Losses recorded from both the directions.



$$\frac{S1+S2}{2}$$

Ghost

Ø Ghosts are repetitions of a trace or portion of a trace.
Ø The most common cause of 'ghosts' is an 'echo' of light reflected back and forth multiple times.
Ø Correct Distance Range needs to be selected to avoid Ghost in the OTDR trace.



OTDR Type 1 and Mini Type B

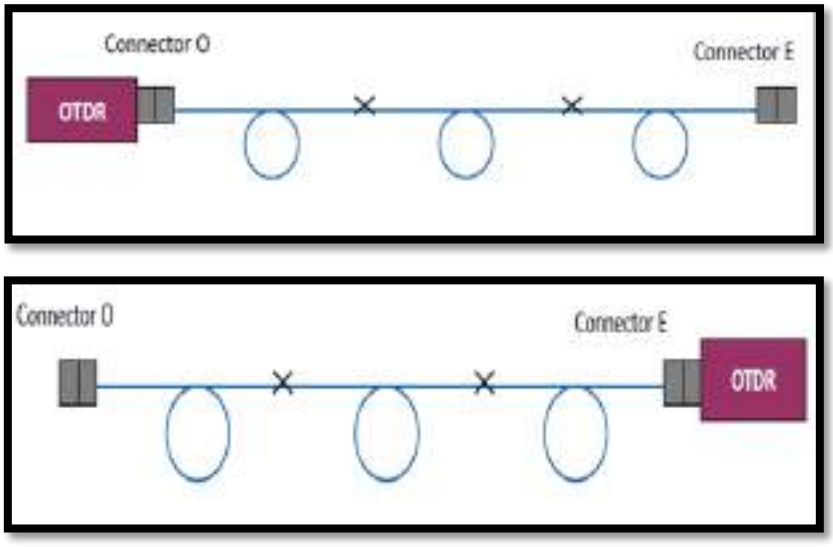
Parameters	OTDR Type 1	Mini OTDR
Wavelength (nm)	Triple (1310, 1550, 1625)	Double (1310 & 1550nm)
Dynamic Range	45 dB	34 dB
Touch Screen Size	7 Inches	5 Inches
Internal Memory	2 GB	1 GB

OTDR Type 1

Mini OTDR

9.7 Bi-directional Analysis using OTDR

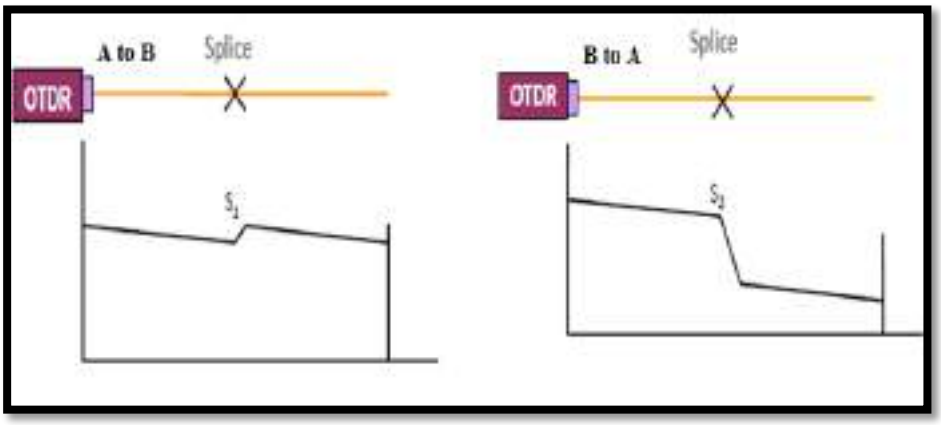
- OTDR tests are often performed in both directions and the results are averaged, resulting in bidirectional event loss analysis.
- Bi-directional analysis determines correct measurement of anomalies such as splice gains.



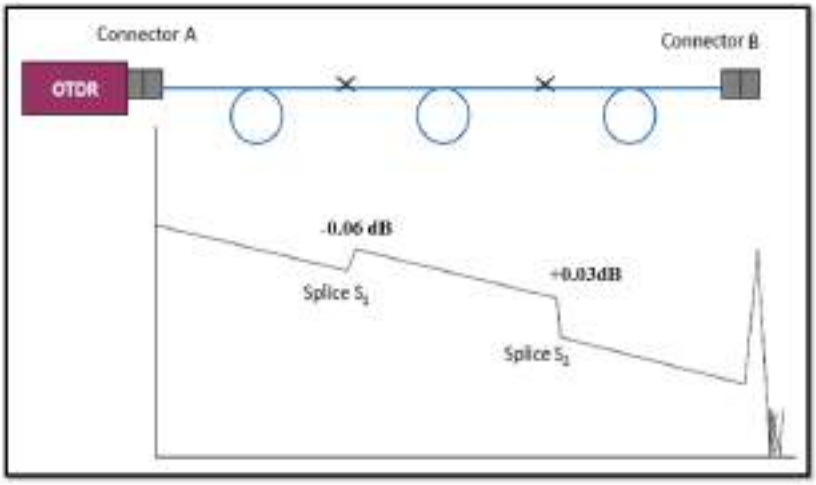
Analyzing Splice Gains

- Splice Gain can occur when two fibers have different core sizes or backscatter coefficients.
- Splice loss of each fiber at every splice location shall be measured from both ends of fibers.
- To arrive at splice loss, average of algebraic sum of splice loss measured from both ends shall be taken.
- Splice loss at any fiber joints at any location shall not exceed 0.1 db.
- Splices that show a gain in one direction will always have a higher loss, if tested in the opposite direction.
- The average splice loss values can be calculated using the following expression:

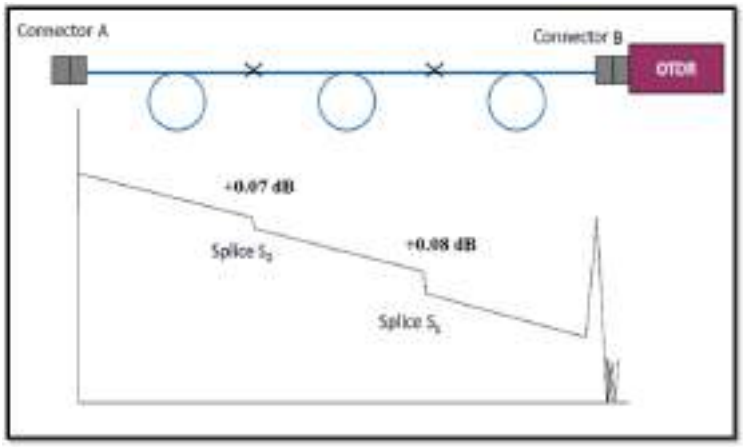
$$S = \frac{S1 + S2}{2}$$



OTDR measurement from connector A to connector B (A -> B)



OTDR measurement from connector B to connector A (B -> A)



Actual Loss

The actual loss of each splice is found by taking the average of the measurement in each direction.

Event	A B	B A	Actual Loss
Splice S_1	-0.06	+0.08	0.01
Splice S_2	+0.03	+0.07	0.05

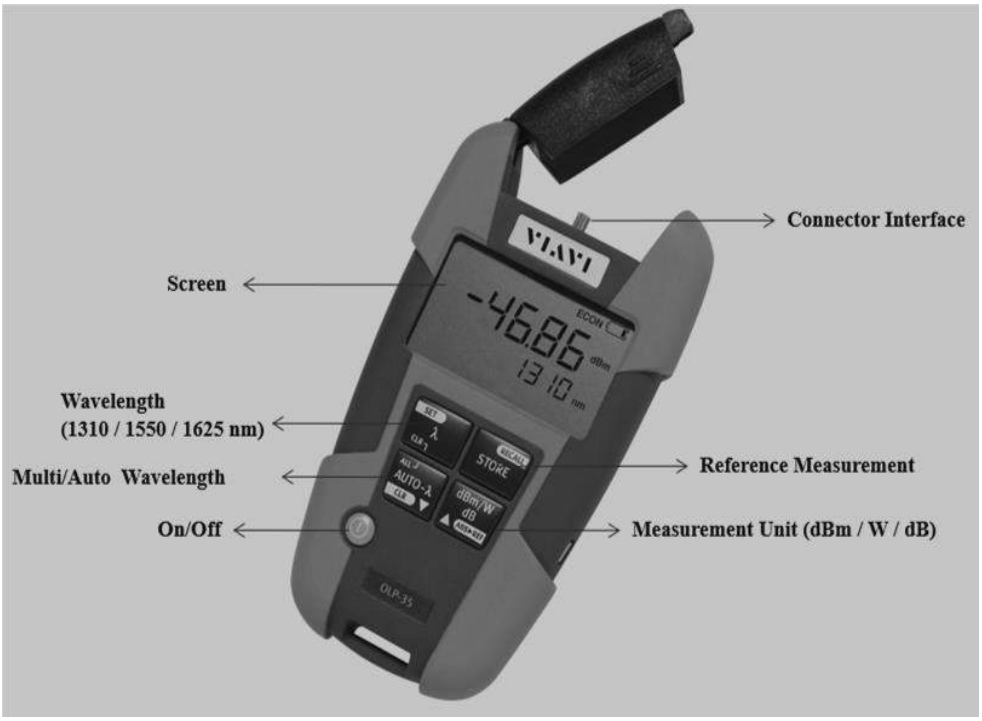
9.8 Light Source and Power Meter (LS & PM) Test

Single Mode Light Source

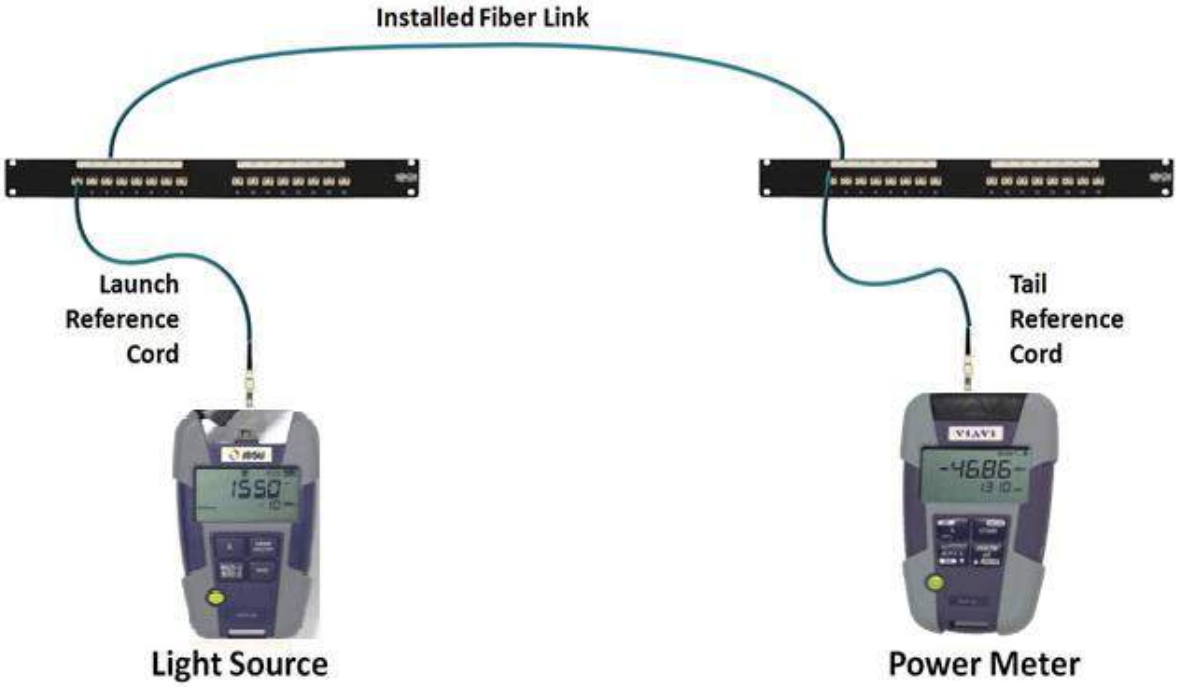
This device is used to insert optical power in fiber. It is a singlemode source with 3 wavelengths on one port for testing networks at 1310 nm, 1550 nm and 1625 nm.

Optical Power Meter

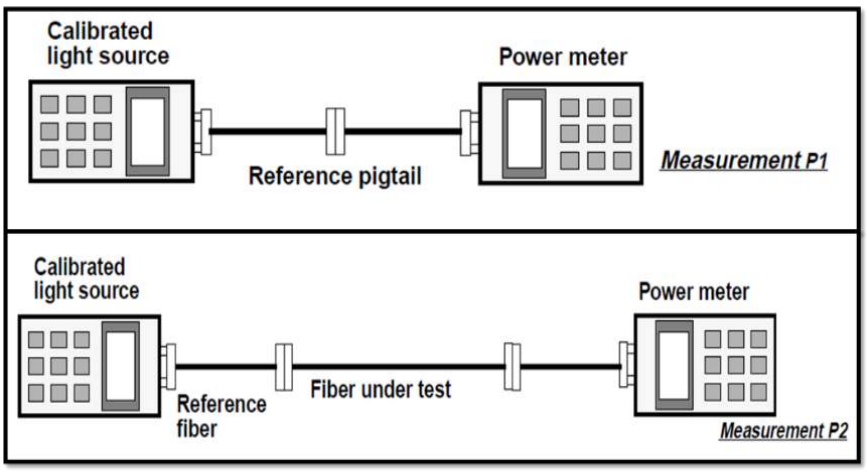
Ø This device is used to measure the power level of optical signal.
Ø Most power measurements are in the range of +10 dBm to -40 dBm.



Light Source – Power Meter Test



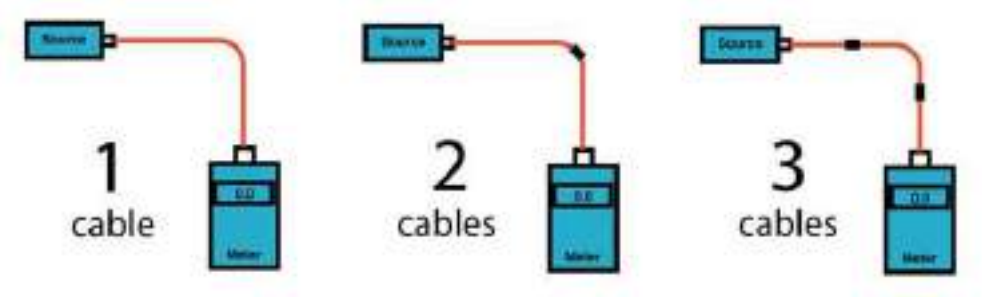
- For Optical Loss Test, a light source and a power meter is needed.
- Measurements are taken at 1310nm and 1550 nm.
- Used in identifying Fiber Swapping and determine Overall Loss.



Optical Loss = "Reading P1" – "Reading P2"

One, Two and Three Cable Reference Methods

- When the cable link is connected up to communications equipment with patchcords, the connections to the patchcords will have loss.
- When the cable link is tested, the reference cables will mate with those connectors on the ends and their loss will be included in the measurements but the results depends on the method used to set the "0dB" reference.
- Testing standards often include 3 different ways of setting the "0dB" reference for testing loss.



All three of these methods are approved in many standards, but it is important to realize they will give different loss readings due to the connections included when making the 0dB reference measurement.

- The reason for the existence of three methods is the compatibility of test equipment to the cable plant; whether the test equipment has connector interfaces that allow direct connection to the cable under test.
- The options for use of these three methods are:
  - If the test equipment has connectors compatible with the cable plant, a one-cable method can be used.
  - If the test equipment does not have connectors compatible with the cable plant, a two- or three-cable method must be used.
  - If the test equipment does not have connectors compatible with the cable plant and the connectors are the “plug and jack” or “male, female” type, a three-cable method must be used.

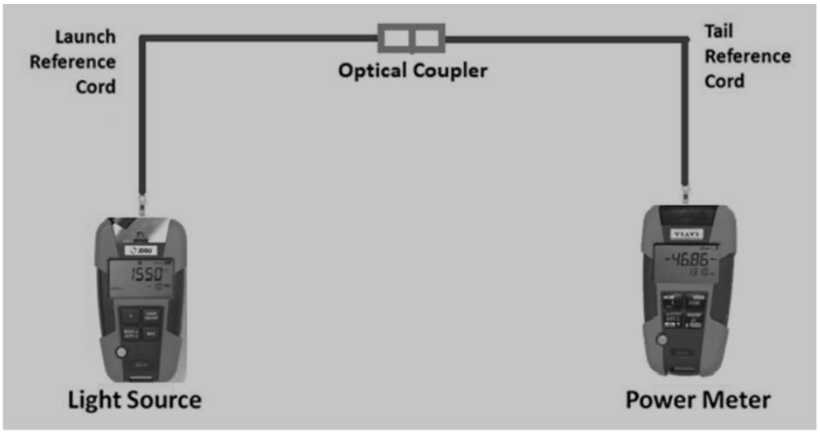
1 Cable Reference: [LS]------ref cable------[PM]

2 Cable Reference: [LS]------ref cable------[1]------ref cable------[PM]

3 Cable Reference: [LS]------ref cable------[1]------ref cable------[2]------ref cable------[PM]

Light Source – Power Meter Test (2 Cable Method)

Step 1: Reference measurement with patch cords.

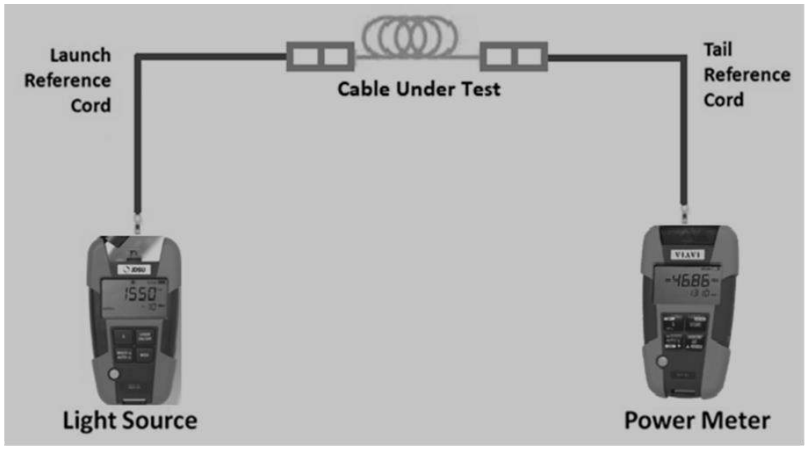


Source Output Power: -7 dBM
Wavelength: 1550nm

Power Meter Reading (Ref): -9 dBM
Wavelength: 1550nm

Optical Loss in Patch Cords = Power Meter Reading (Ref) - Source Output Power

Step 2: Measurement with installed link.



Source Output Power: -7 dBM
Wavelength: 1550nm

Power Meter Reading (Current) : -30 dBM
Wavelength: 1550nm

Total Link Loss = Power Meter Reading (Current) - Power Meter Reading (Ref)

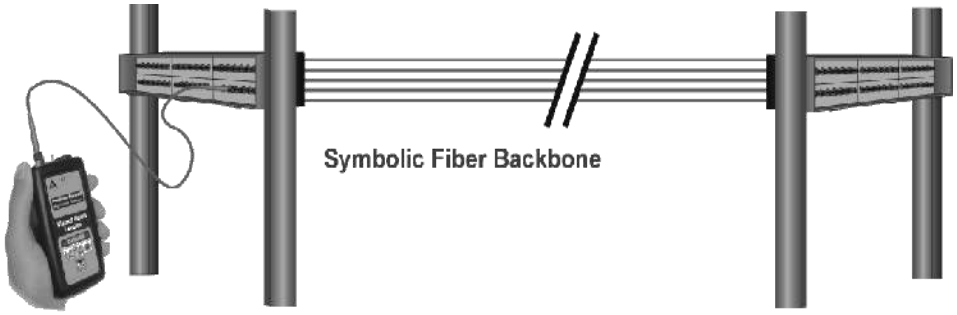
Measurement Tips

- Ø If a light source is used with a power meter to make link loss measurements, the power meter must be referenced to the light source output power before the loss measurement is made.
- Ø To minimize measurement error, optical patch cords attached to the output port of the light source and power meter for the reference power measurement should remain attached for all link loss measurements for the complete session.
- Ø Always make measurements with alcohol dampened clean connectors.
- Ø Avoid kinking or inducing sharp bends (smaller than a golf ball) into fiber patch cords.
- Ø If no wavelengths are specified for the post-construction measurements, measurements should be made at 1310 nm and 1550 nm.

9.9 Visual Fault Locator (VFL)

- A Visual Fault Locator (VFL) is used to inject visible red laser light into the fiber.
- It helps in visually identifying fiber bends in pigtail and patch cord, fiber breaks, faulty connectors and fiber swap.

- When you test fiber optic cable networks, a VFL is connected to one end of the cable that can be used to verify the transmission to the opposite end. The process is called fiber continuity testing.



9.10 Fiber Detection Meter

- Bends the fiber to detect the light
- Can be used on live fiber without interrupting service
- Can detect a special modulated tone sent down a fiber
- Combined with the Tone Generator, the Fiber Detection Meter enables technicians to identify a specific live fiber without having to disconnect it.
- Induces minimal loss: ≤1 dB

This brings key benefits:

- No more network outages as a result of fiber detection/identification procedures.
- The minimized need to access the network helps prevent errors.

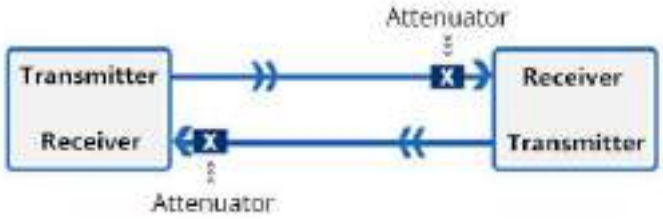
9.11 Optical Attenuators

Ø An optical attenuator is a device, used to reduce the power level of an optical signal.

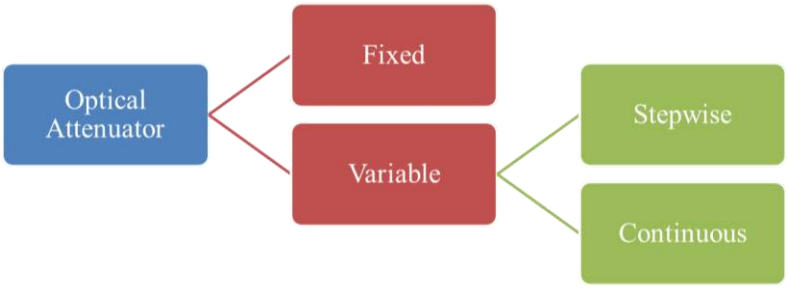
Ø It temporarily adds calibrated amount of signal loss in order to test the power level margins in a fiber optic communication system.

1 dB LC Attenuator

10 dB SC Attenuator



Types of Optical Attenuators



Fixed Optical Attenuator

Fixed attenuators are designed to have a fixed attenuation level.

Fixed Fiber Optic Attenuator, Male-Female

Fixed Fiber Optic Attenuator, Female-Female

Variable Optical Attenuator

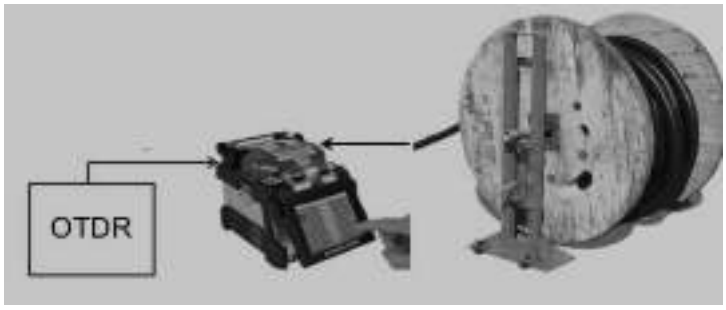
- Ø Stepwise Variable Attenuator is a device that adjusts the attenuation in known steps such as 0.1 dB, 0.5 dB, or 1 dB etc.
- Ø Continuous Variable Attenuator produces precise level of attenuation for desired wavelength.

Stepwise Variable Attenuator

Continuous Variable Attenuator

9.12 Test Procedure of OFC Drum

- Ø One end of the cable drum will be prepared by using the proper tools.
- Ø Take the prepared end of the cable inside the splice van to maintain the temperature and dust-free environment
- Ø Make the OTDR ready for testing.
- Ø When the OTDR is ready, strip the fiber and cleave it by means of a diamond-edged cleaver to ensure the cleaving end should be perpendicular.
- Ø Connect the fiber to the OTDR by making a mechanical joint. The mechanical joint will be done by using two connectors coupled to each other through a mechanical coupler.
- Ø Now the fiber is ready for testing. Keep the OTDR in average mode and shoot the laser through the fiber for 10 seconds.



- Ø When the laser will be off, put the cursor “B” at the end of the cable and Cursor “A” at dead zone distance (Commonly cursor A is places at 50 meters from starting).
- Ø Now note the dB/Km loss of the cable.
- Ø If the loss is more than the standard limits, check the mechanical splice or cleave the fiber again and follow the above procedures again.
- Ø Proceed with the same procedure for all the fibers individually.
- Ø All the readings should be witnessed and checked.

9.13 Housekeeping of OTDR

- Ø To clean body of OTDR, use a lint- free cloth moistened with soapy water. Never use product containing Alcohol, as these will erase the printed markings.
- Ø To clean the screen, use an antistatic product.
- Ø To clean the OTDR connector, use spray cleaner containing Iso-Propyl Alcohol.

9.14 Future Developments in OTDR

- Ø A video microscope for fiber end-face inspection
- Ø Weight (less than 2 pounds)
- Ø OTDR with spectral analysis, polarization mode dispersion and chromatic dispersion functions
- Ø Less Deadzones
- Ø Lower Pulse Width
- Ø Improved speed of measurement
- Ø Easy and versatile user interfacing

Section 3: Exercises

Exercise 1: Write the test parameters that can be determined by the following test instruments.

S. No.	Test Instrument	Test Parameter
1	Optical Time Domain Reflectometer (OTDR)	
2	Optical Power Loss measuring Equipment (Light source & Power meter)	
3	Visual Fault Locator (VFL)	

Exercise 2: Calculate the link budget of the following long route links based on the below given details.

a) Assume a 20 km single mode fiber link at 1550nm with 2 connector pairs and 5 splices.
b) Assume an 80 km single mode fiber link at 1310nm with cable drum length of 4 Kms installed in the link.

Exercise 3: Draw an OTDR trace showing various events.
Exercise 4: Enlist the common parameters to be configured in the OTDR to test an optical link.
Exercise 5: Participate in group discussion on following topics:

a) Fiber Optic Attenuators
b) Working Principle of OTDR
c) Pulse Width vs Distance Range vs Resolution

Section 4: Assessment Questionnaire

1. Name the equipment used for Link testing?
2. Which equipment is used to calculate overall loss in fiber using visual trace?
3. What is the unit of Insertion Loss?
4. _____ is the amount of light that a signal loses as it travels along a fiber cable link.
5. The _____is the theoretical calculated loss that a cable link can have.
6. What are some functions of OTDR?
7. What are some common wavelengths available at which OTDR operates?
8. The wavelength 1490 nm is generally used for:
9. OTDR sends _____along the fiber to identify events?

10. What is the formula that OTDR uses to calculate event distance?
11. What are Test Parameters settings for OTDR configuration?
12. What are two different Acquisition Modes?
13. What distance range is selected if length is unknown?
14. _____is the time duration of pulse that is launched into the fiber. In OTDR, it is mentioned in microseconds and nanoseconds.
15. The ability of OTDR to distinguish between two events in the fiber is called:
16. The time taken by OTDR to calculate the results and show trace on the screen is called:
17. _____is the parameter that signifies the maximum optical loss an OTDR can measure in a fiber link.
18. Higher the dynamic range lower the distance range. True or False?
19. Larger pulse width provides _____Dynamic Range.
20. On what factors, accuracy of OTDR depends?
21. The length of fiber, within which, fiber is not able to detect any event and losses is termed as:
22. What is unit of dead zone?
23. How to reduce Dead Zone?
24. Give reasons for occurrence of non-reflective break in OTDR?
25. _____are repetitions of a trace or portion of a trace.
26. How to avoid Ghost in OTDR trace?
27. When two fibres with different core diameter are spliced and measured with OTDR, splice shows _____ from one direction and _____ from opposite direction.
28. _____ analysis determines correct measurement of splice loss.
29. Which of the following OTDR can detect fiber event at longer distance?
    a) Dynamic Range: 45 dB
    b) Dynamic Range: 30 dB
    c) Dynamic Range: 25 dB
30. If you choose smallest pulse width in OTDR, two closed fiber events can be detected separately. True or False?
31. Using which formula, the average splice loss values can be calculated?
32. Which device is used to insert optical power in fiber?
33. Which equipment is used to measure power level of Optical Signal?
34. In LSPM testing, what is formula of optical loss in patch cords?
35. What is function of VFL?
36. How can we reduce the power level of optical signal?
37. Which mechanism or technique is adopted in attenuators to achieve the desired signal loss?
38. What are two types of optical attenuators?
39. What are two types of Variable Optical Attenuators?
40. Which test equipment can be used to detect fiber swap?
41. Optical attenuators are used in an optical link to decrease the bit rate. True or False?
42. OTDR screen and body should be cleaned using iso-propyl alcohol. True or False?
43. Which equipment is used to test the OFC drum?
44. OTDR trace is a graph between _____ on X axis and _____ on Y axis.
45. Can fiber bend loss be measured by VFL?

----------End of the Module----------

MODULE 10
OSP CONSTRUCTION QUALITY CHECKS

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Check quality of the underground OFC laying practices
- Lay the cable adhering to the sector specific standards
- Describe the quality standards of various practices like:
  - Fiber Termination
  - Mid-span access
  - Ducting and Backfilling
  - Cable pulling, etc.

Section 2: Relevant Knowledge

"Quality is Everyone's Responsibility and We Never Have to Stop Getting Better"

- Ø Quality is the standard of something as measured against other things of a similar kind. It is the degree of excellence of doing something.
- Ø Doing things First Time Right (FTR) successfully
- Ø Delivering what is promised

10.1 Quality Checks in Underground OFC Rollout

Precautions and Safety Measures	Trench Straightness
Undulation	Offset and Depth Measurements
Duct Laying	Turnings
Railway/Road Crossing	Bridge/Culvert Crossing
Backfilling	Manhole and Handhole Placement
Duct Entry and Duct Exit	Cable Blowing
Splice Closure Sealing	Chamber Housekeeping
Chamber Sealing	Route Marker
Termination & Markings	Link Testing
Document Accuracy	

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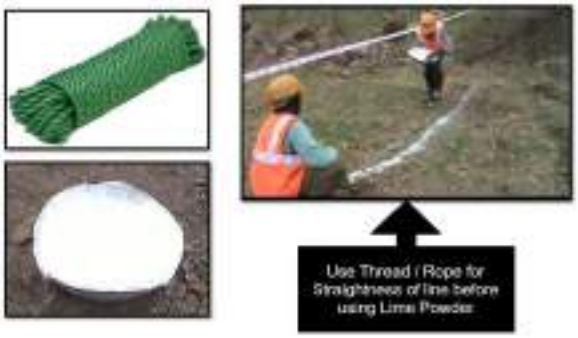
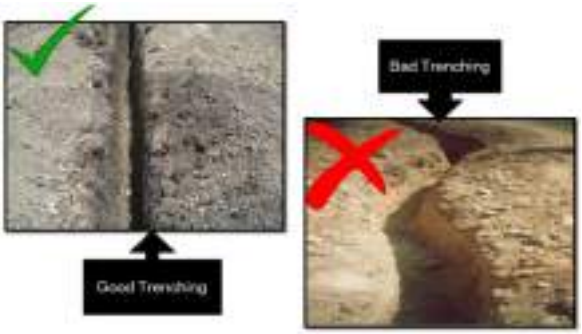
Trenching Quality





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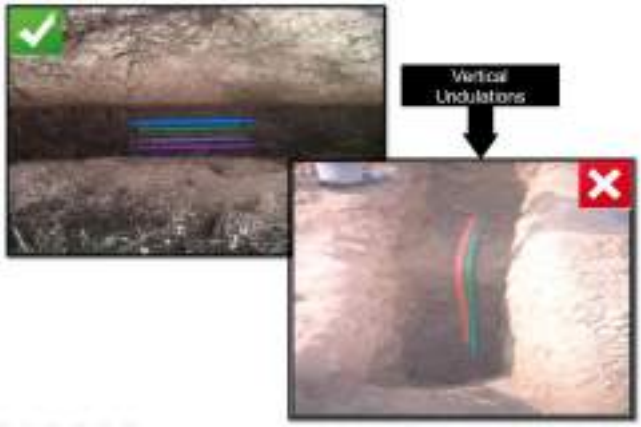
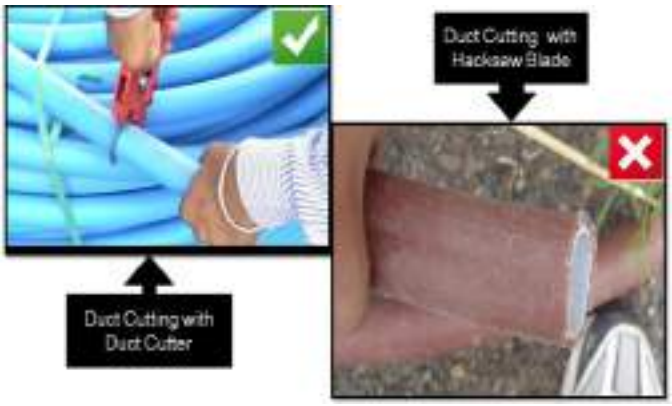
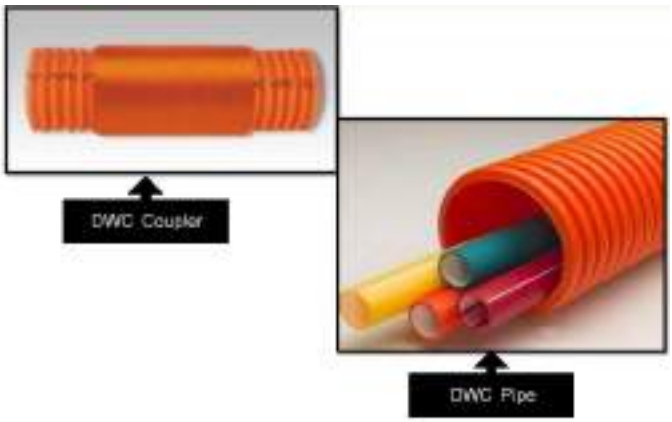
Ducting Quality



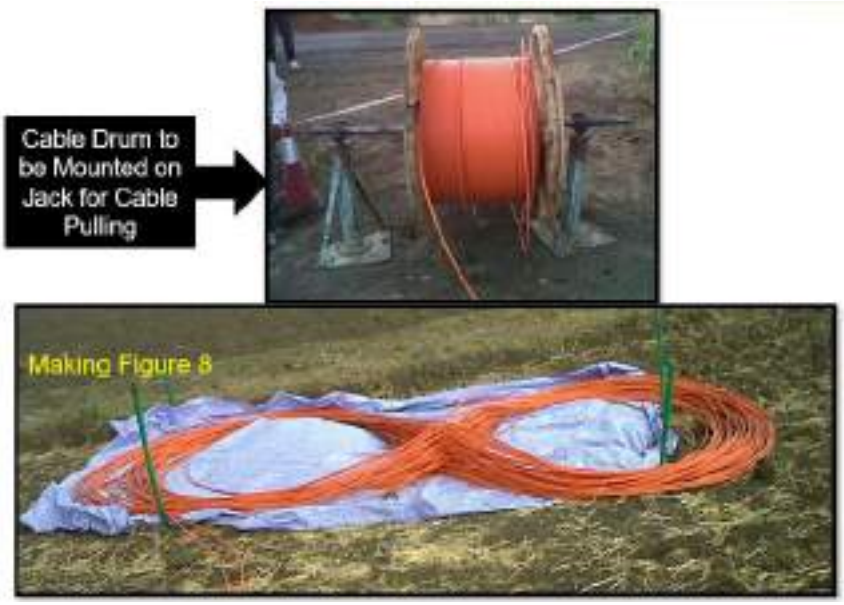


Simplex Plug to be used to cover the Duct ends containing cable inside



Backfilling Quality

Proper Cable Pulling



Joint Closure & Chamber Housekeeping

- Fiber Management should be as per standards in Joint Closure.
- Effective joint closure sealing should be ensured.
- Chamber housekeeping should be ensured as per standard.

Termination

- All fibers to be correctly terminated on Fiber Distribution Management System.
- Proper racking and clamping of cable within the building is to be ensured.
- The optical fiber cable should be properly clamped to the FDMS.
- Optical fiber cable should be properly tagged for identification and every fiber to be identified when spliced to the pigtails and terminated on the frame.

Section 3: Exercises

Exercise 1: Enlist the quality checks to be performed in underground OFC laying.

Exercise 2: Participate in group discussion on following topics.

a) Best Practices of Fiber Termination
b) Importance of Quality in Fiber Optic Cable Laying

Section 4: Assessment Questionnaire

1. What are the quality parameters to be checked during Trenching?
2. What are the quality parameters to be checked during Ducting?
3. What are the quality parameters to be checked during Backfilling?
4. What items can be used to improve quality at fiber termination premises?
5. Cable Drum should be mounted on _____ for cable pulling.

----------End of the Module----------

MODULE 11
NETWORK DOCUMENTATION & ACCEPTANCE TESTING

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Comprehend Survey Report and its various formats and diagrams
- Draft RoW application and understand RoW permission
- Fill details in Measurement Sheet of Trenching and Cable Blowing work
- Make HDD graph
- Design Single Line Diagram (SLD) of OFC Route
- Interpret details in Route Index Diagram (RID)
- Make and Understand the As Built Drawing (ABD)
- Differentiate between Civil and Optical Acceptance Testing
- Enlist Tools, Test Equipment and Documents used in Acceptance Testing

Section 2: Relevant Knowledge

11.1 Network Documentation

Survey Report

Link ID : From _____ To _____
Sub Section Name_____

Date of Survey:_____

1. **Route Description**

(a) This route starts from Point A ..... and goes ..... through ..... then from ..... goes to ..... road via ..... and turns left ..... and route is proposed left ..... upto point ..... and then turns right towards ..... road, and then turns left ..... road and then goes to ..... and then turns right and goes to ..... and route from ..... is proposed ..... RMS ..... and point of ER.

(b) Mentioned any road expansion activity also

1. **Soil Strata of OFC Route**

The general condition of the soil is varies from Normal to Soft & hard rocky. On the basis surface survey and as per route seen visually, the tentative length and depth chart as given below:-

Type of Soil	Length in KM
Normal	
Mix Soil	
Sandy	
Hard Rock	
Other (If any)	
TOTAL	

Chainage (in Km)	Intersection of Duct in KM					Aerial Cable
	Culvert/ Bridge/ Road Crossing	Less than 60 CM	Greater than and equal to 60 CM and less than 120 CM	Greater than and equal to 120 CM and less than 150 CM	Greater than and equal to 150	
0/00						
10/15						

Note:-During the execution of route all effort shall be made by PIA to achieve the maximum possible depth. Hence above quantity of items are likely to change during execution of route as per actual site conditions.

1. **Crossing Details:-**

SN	Type of Crossing	Details of Location	Method (HDD/OT/Chemging)	Length in Mtr
	Culvert	At chainage 15.2		
	Gas			
	Railway			
	Road			
	Any other			
	TOTAL			

4. **Details of ROW authority: The details of ROW of proposed OFC route:-**

SN	Authority Name	Length in KM
1	HH	
2	DH	
3	Railway	
4	PWD	
5	CPWD	
6	Gas authorities	
7	Forest	
8	Any Other as per OFC route	
	TOTAL	

1. **Name of amplifier locations:-**

Particular	Location No.1	Location No.2	Location No.3	Any other ...
Name				
Distance (KM) (From Start Point to Amplifier location)				

4. Any other important information required for laying OFC route.

7. Detailed route diagram with calculations for route are enclosed in this respect.

SURVEYED BY

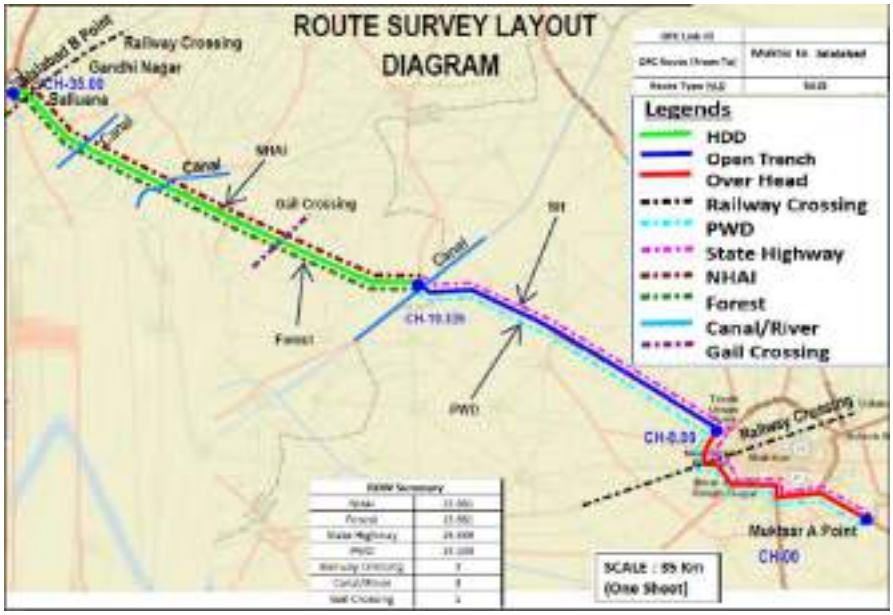
Signature of PIA Rep. (With Stamp)
Name
Date

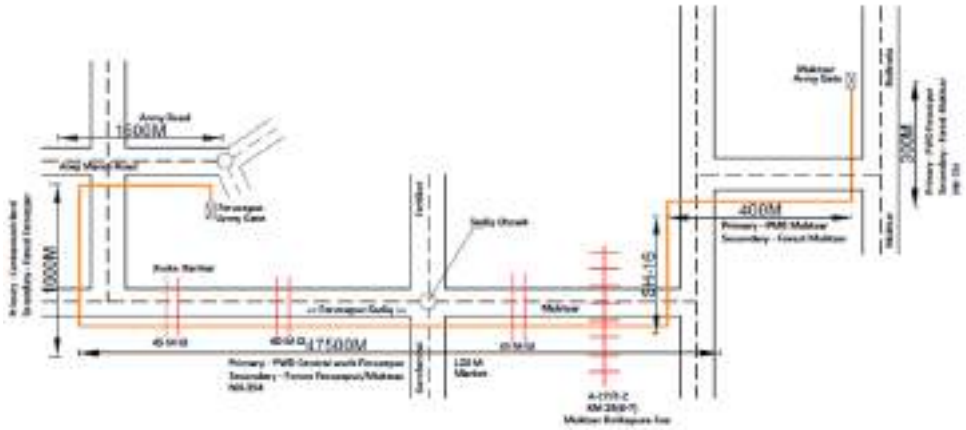
Signature of UHBL Rep. (With Stamp)
Name
Date

PIA: Project Implementation Agency
Calculation of OFC Length

Calculation of OFC Length											
OFC Link ID	6201/23										
OFC Route	5-86 to 5-90										
Route Type											
Survey Date											
OFC Link ID	Planned Route Length (Km)	Actual Route Survey Length (Km)	No. of proposed Joint Chambers (Nos.)	No. of proposed Handholes (Nos.)	Total number of load in/head out locations	No. of proposed wall mount FDMS (for access network only) (Nos.)	Extra slack to be left at joint chambers@ 20m per fiber end (g) = 0.040 x (c) km per OFC link	Extra slack to be left at every handhole @ 10m OFC per fiber end (h) = 0.020 x (d) km per OFC link	Extra slack to be left at every load in/load out @ 20m per location (i) = 0.020 x 2 x (e) km	Extra slack to be left for wall mount FDMS @ 5m per FDMS (k) = 0.05 x (f) km	Total length of OFC (km) (l) = (b) +(g)+(h)+(i)+(k)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(k)	(l)
6201		7.8	3	59	8	6	0.12	0.28	0.32	0.03	8.66

Route Survey Layout Diagram





Signature of PICG Rep
(Name & Appt)

Signature of Bidder Rep
(Name & Appt)

Summary of BoM

OFC LINK ID							
OFC ROUTE (From-To)							
Route Type	NLD						
SUMMARY OF BILL OF MATERIAL (BoM)							
Link ID	OFC			PLB Duct (incl Wastage 2.5% (M)	Joint Enclosures (Nos)	FDF (No)	Remarks
	Underground 24 Fibre	Over Head (OH)	Total (M)				
	Signature of PIA Rep. (with stamp)						
	Name						
	Date						

OFC LINK ID												Survey Dates (From -To)					
OFC ROUTE (From-To)												Date From ..... To.....					
Route Type	NLD																
SUMMARY OF BILL OF MATERIAL (BoM)																	
Link ID	OFC			PLB Duct (incl Wastage 2.5% (M)	Joint Enclosures (Nos)	GI Pipe (Mtrs)	DWC Pipe (Mtrs)	RCC Pipe (Mtrs)	RCC Route Marker (No)	Electronic Route Marker Underground (Nos)	Electronic Route Marker Overhead (Nos)	FDF (No)	Warning Tape (M)	Bricks (Nos)	Remarks		
	Underground 24 Fibre	Over Head (OH)	Total (M)														
	Signature of PIA Rep. (with stamp)										Signature of USER Rep (with stamp)						
	Name										Name						
	Date										Date						

Format of RoW Application

Ref: _____ Date:

.....

CONFIDENTIAL

To,

_____

_____

_____

Sub: Request for grant of Right of Way Permission for laying Optical Fiber Cable along the route from..... (Total Length .....Km).

Dear Sir,

_____ intends to rollout Optical Fiber Cable Network to be owned and operated by the Services under Ministry of _____ Government of India. A highly resilient exclusive OFC based nationwide optical backbone for various Defence sites and access networks shall be rolled out under this project on pan India Basis.

OFC link from _____ is falling under your jurisdiction is also required to be rolled out as part of this project.

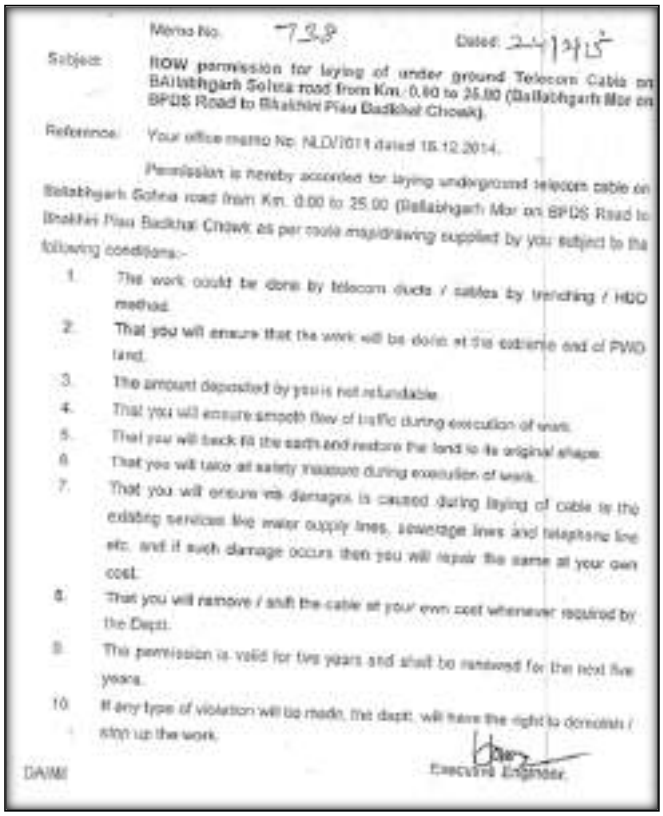
The work will be executed by _____ through HDD method and as per standards, policies and guidelines laid by you for laying the OFC Cable. In this HDD (Trenchless) method with pits generally of dimensions 1.5m X 0.80m X 0.45m at the average interval of approx _____ meter. We would request you to give permission for lying of our network in exclusive corridors (i.e. wherever less utilities of other operators) to the extent possible to ensure safety and security of the network to be laid by us.
We are enclosing herewith the requisite documents for the permissions to lay the Optical Fiber Cable along with Route Diagram for your perusal.
Since this project is of National Importance to be implemented in "Mission Mode" to meet stringent timelines of Indian Army and any delay in network rollout activities may adversely affect Mission Critical Capabilities of _____, you are requested to kindly arrange to issue Right of Way (RoW) Permission as sought by us, at the earliest to ensure implementation of project in time bound manner.
We request you to issue BT Bill Demand note in favour of _____ and which is solely the executor of the project. Please note the payment of the said BT DD Bill will be made by _____

In case you need any further details, documents, clarifications in respect of the above please let us know.

As the Information pertaining to this project is highly confidential you are requested to restrict any unauthorized disclosure or use of Information which may cause irreparable harm and significant injury to Indian Army, the degree of which may be difficult to ascertain.

Authorised Signatory

RoW Permission



Memo No. 738 Dated: 24/3/15

Subject: ROW permission for laying of under ground Telecom Cable on Ballabhgarh Sohna road from Km. 0.00 to 25.00 (Ballabhgarh Mor on BPDS Road to Bhakhri Piau Badkhal Chowk).

Reference: Your office memo No. NLD/1011 dated 16.12.2014.

Permission is hereby accorded for laying underground telecom cable on Ballabhgarh Sohna road from Km. 0.00 to 25.00 (Ballabhgarh Mor on BPDS Road to Bhakhri Piau Badkhal Chowk as per route map/drawing supplied by you subject to the following conditions:-

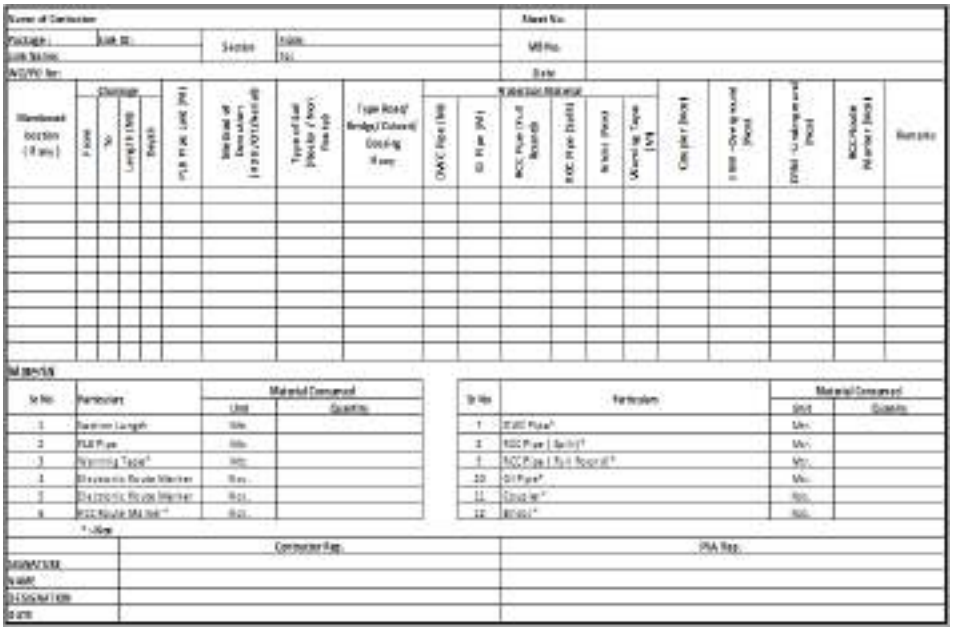
1. The work could be done by telecom ducts / cables by trenching / HDD method.
2. That you will ensure that the work will be done at the extreme end of PWD land.
3. The amount deposited by you is not refundable.
4. That you will ensure smooth flow of traffic during execution of work.
5. That you will back fill the earth and restore the land to its original shape.
6. That you will take all safety measure during execution of work.
7. That you will ensure no damages is caused during laying of cable to the existing services like water supply lines, sewerage lines and telephone line etc. and if such damage occurs then you will repair the same at your own cost.
8. That you will remove / shift the cable at your own cost whenever required by the Deptt.
9. This permission is valid for two years and shall be renewed for the next five years.
10. If any type of violation will be made, the deptt. will have the right to demolish / stop up the work.

DA/Nil

Executive Engineer

Measurement Sheet (Trenching/HDD Execution Work)

“Measurement Book” is a document in which measurements are recorded for the work done by the contractor, or for the materials consumed at the site or services rendered.



Measurement Sheet (Cable Blowing Work)

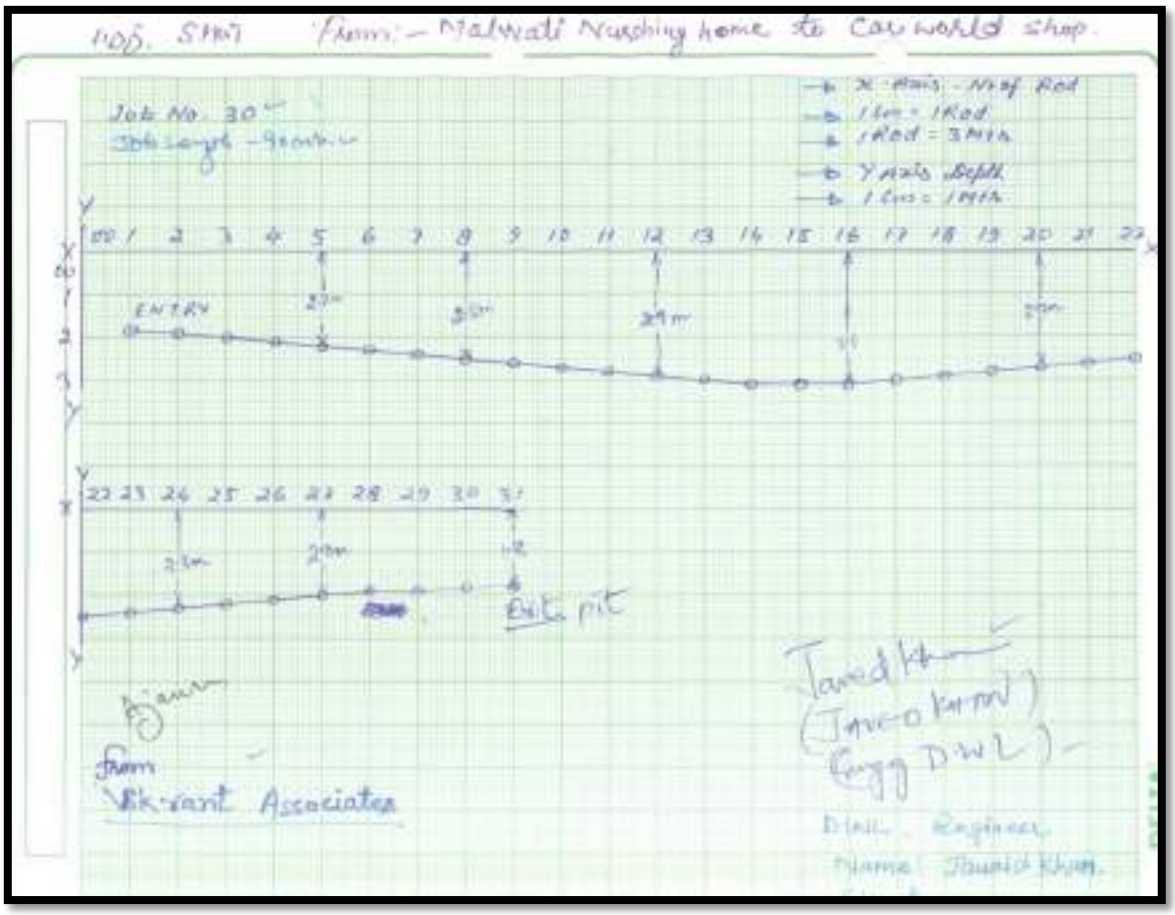
Name of Contractor:														Sheet No.	Date
Package :		Link ID:-				Section	From :							WO/ PO No.	
Link Name:-							To:								
Mentioned Location (If any)	Chainage		Section Length (M)	OFC Cable ID (Drum No.)	Type of Cable	OFC Length Start Point Reading	OFC Length End Point Reading	OTT Test Passed (Y/N)	OFC Cable Laid (M)	OFC Cable Loop (M)	Total of Cable Laid (M)	Loop Chamber (Nos)	Splice Chamber (Nos)	Joint Closure (Nos)	FDF Nos	Remarks
	From	To														

Material Consumed

Sr.No.	Particulars	Material Consumed	
		Unit	Quantity
1	OFC Cable 24F	Mtr.	
2	Joint Closures	Nos	
3	Manhole	Nos	
4	Handhole	Nos	
5	FDF	Nos	

	Contractor Rep.	PIA Rep.
SIGNATURE		
NAME		
DESIGNATION		
DATE		

HDD Graph



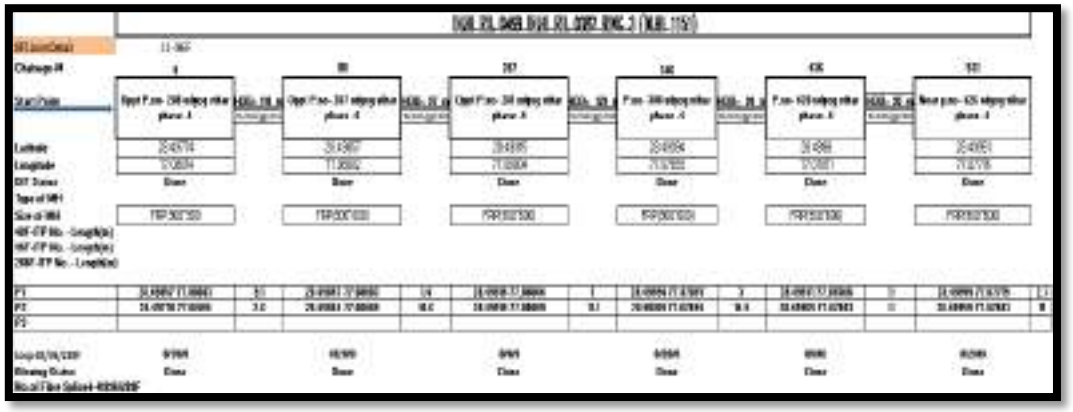
Format for Approval of Depth Relaxation

Package				Link Name							
Link ID:				Section Name						State	
SN	Location (chainage)		Category (Utility/Strata)	Length in mtrs	Soil Type	Depth Bifurcation				Protection Used	Reasons/ justifications
	From	To				31 to 60 cms	61 to 90 cms	91 to 120 cms	121 to 150 cms		
			TOTAL								
Contractor Rep.				Officer-1				Officer-2			
Name				Name				Name			
Signature				Signature				Signature			
Stamp				Stamp				Stamp			

Format for Hindrance Register

Link ID :							
Sl. No.	Nature of Hindrance	Mentioned Activity not performed due to Hindrance	Date of start Hindrance	Date of Removal of Hindrance	Hindrance in Days	Sign of PIA Rep.	Remarks if any

Single Line Diagram (SLD)



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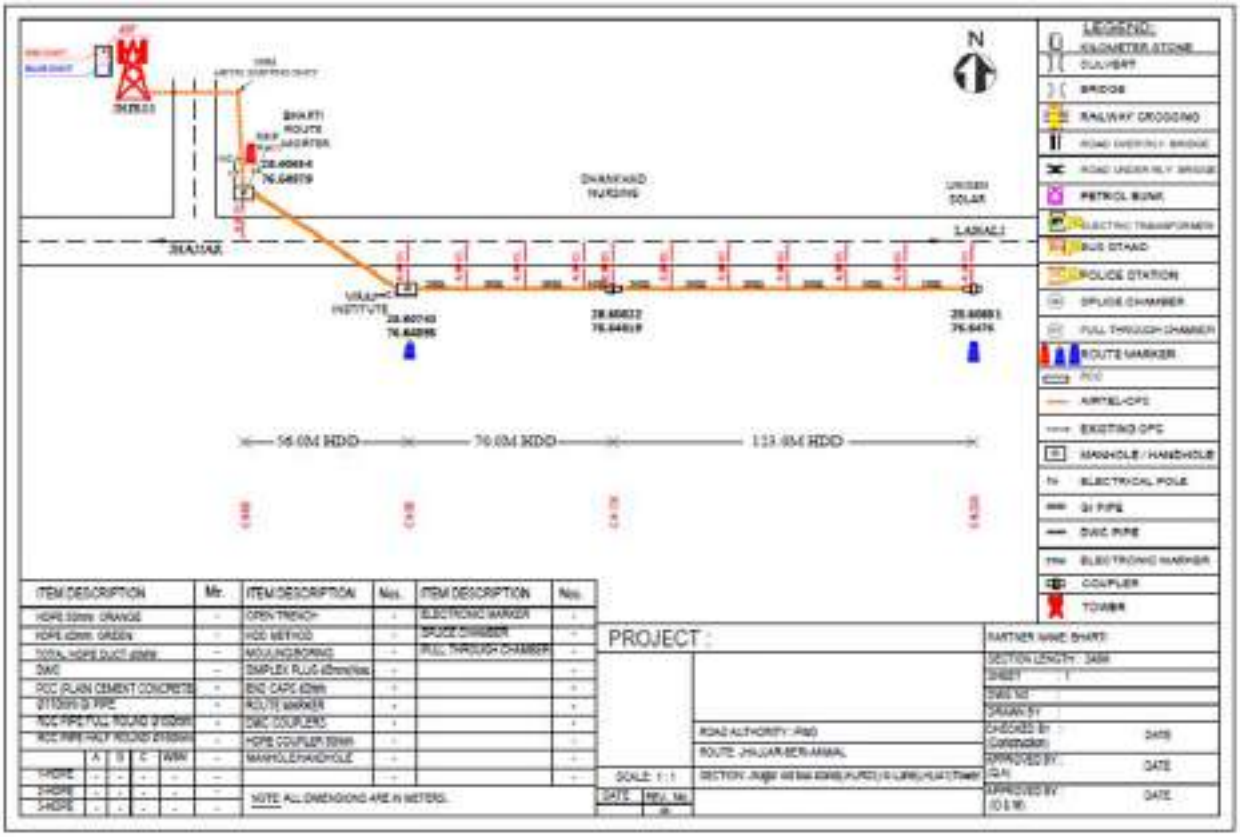
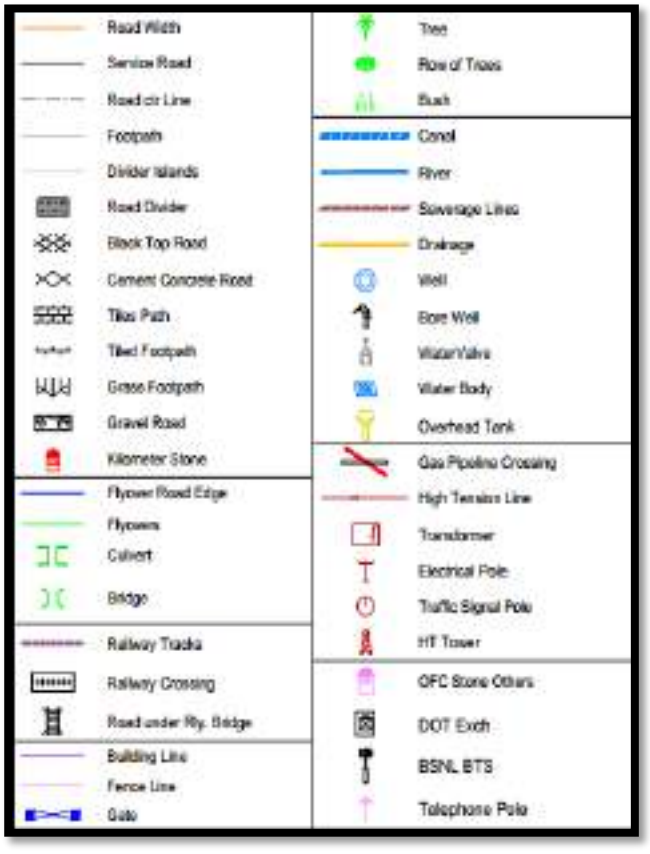
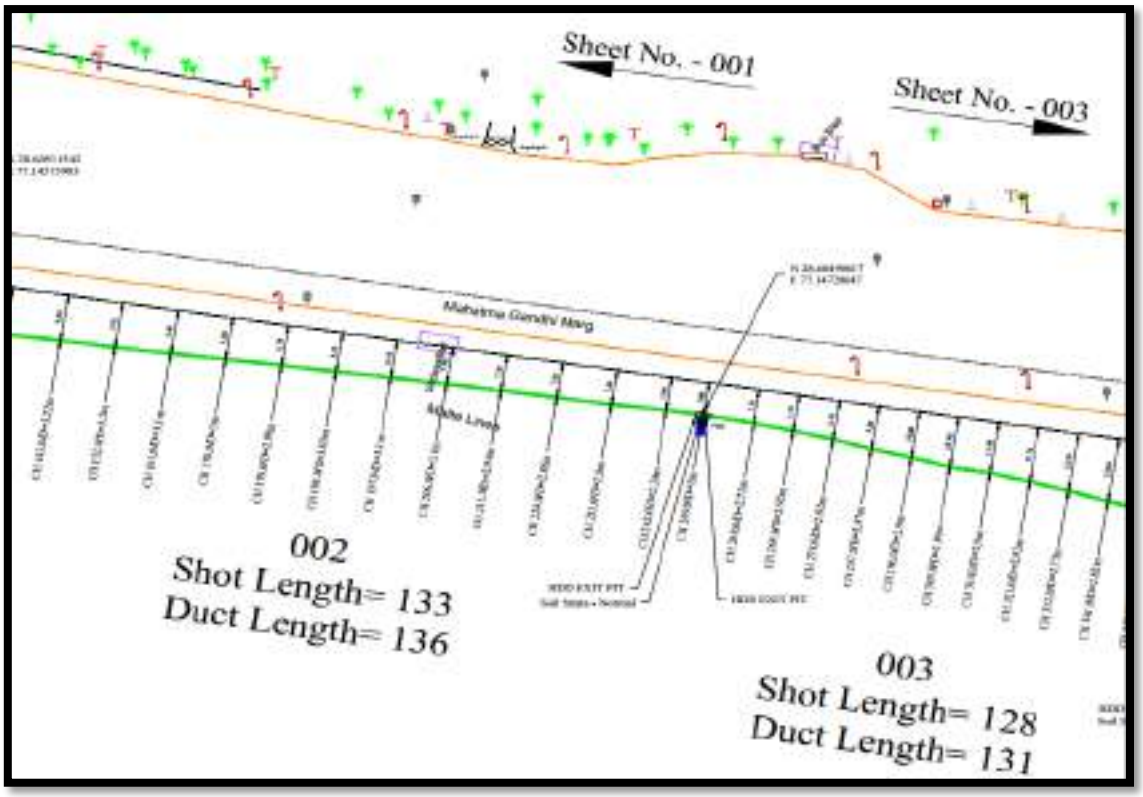
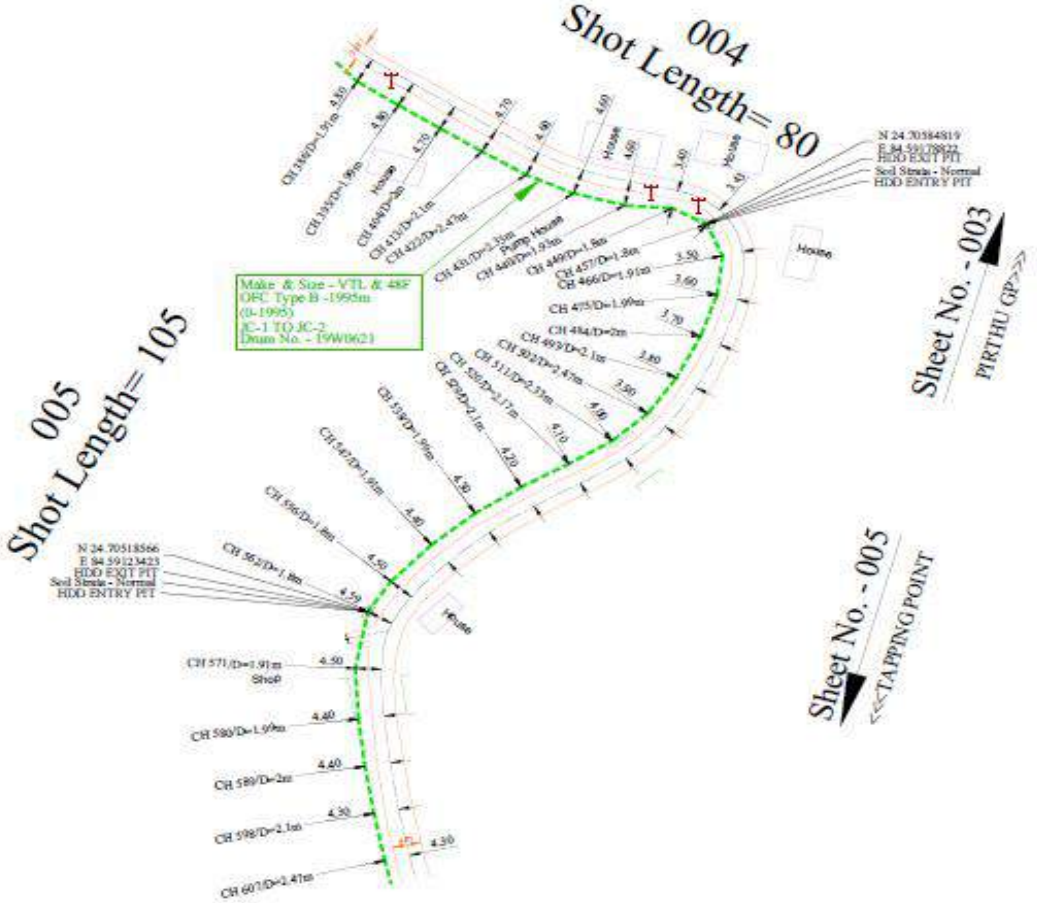
Route Index Diagram (RID)



As Built Drawing (ABD)







11.2 Acceptance Testing

- Ø Acceptance testing, a testing technique performed to determine whether or not the network construction has met the requirement specifications.
- Ø The main purpose of this test is to evaluate the network compliance with the business requirements and verify if it is having met the required criteria for delivery to end users.

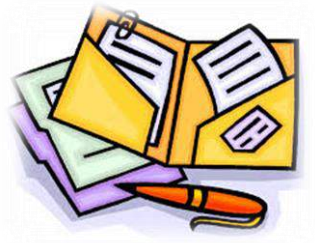
Civil AT	Optical AT
Trench Depth	Link Test using OTDR
Road Crossing	Link Test using Light Source - Power Meter
Railway Crossing	
Culvert Crossing	
Bridge Crossing	
MH/HH Chambers	
Route Markers	

Stakeholders

Tools & Test Equipment Used in AT

- Ø Power Meter
- Ø Light Source
- Ø Rodometer and Measuring Tape
- Ø OTDR
- Ø Cable Locator
- Ø Camera
- Ø Measuring Tape

Documents to be availed for AT



- Ø Trenching, Ducting & Backfilling Report
- Ø HDD Graphs
- Ø DIT Report
- Ø Drum Test Report
- Ø Blowing Report
- Ø Splicing Report
- Ø OTDR Traces
- Ø Event Table
- Ø LSPM Test Report
- Ø As Built Drawing
- Ø Termination Report

Acceptance Testing and Documentation

- **Causes of AT Failure:**
  - ✓ Mismatch in MB, SLD and ABD
  - ✓ Deviation in documented data and on ground data
  - ✓ GIS data mismatch with documents and ground realities
- **Remember to Document:**
  - ✓ Identical records
  - ✓ Actual activity performed on field (HDD, OT, etc.)
  - ✓ Actual chainages, lengths, depths and offsets
  - ✓ Verified protection material and actual consumption
  - ✓ Duct in which cable is blown
  - ✓ Accurate three-point offsets of chambers
  - ✓ Real landmarks and correct Lat-Longs
  - ✓ Actual cable loops in the chamber

Key Points to Remember

- Trenching in ROW permission limits
- Duct alignment (check undulation and zigzag)
- Proper Backfilling / Crowning
- Cross check deviation approved patches
- Protections (DWC/GI/RCC) as per specifications
- Route Markers – Specification & Placement
- Chambers – Specification & Placement
- Route length Vs OTDR length difference within defined limits (%)
- No Gap between MB sheet and AT observation
- Loop length in Manholes/Handholes

Depth AT Format

- There are two test pits on an average for every Km of cable length for depth AT.
- Generally, Test Pit is not required if already inspected during the execution by user.

NO											
DATE	:										
LINK ID	:										
SECTION ID	:										
Sl No	Location of sample pit	Type of trench (open / HDD)	Sheet No	Depth from top of PLB (mtr)	Depth recorded in MB/SMB (mtr)	OK / NOK	Offset from center of Road (mtr)	OK / NOK	Type of protection found	Protection Recorded in MB/SMB (mtr)	Remarks (nature of soil/less depth relaxation any other points)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
PSA Representative							Representative				
NAME							NAME				

Optical AT

- OTDR Test (A to B, B to A)
- LSPM Test (A to B, B to A)
- Link Budget Calculation at Standard Wavelength
  Total Link Loss = (Fiber Attenuation dB/km x Section Length) + (0.1 x No. of Splices) + (0.5 dB x No. of Connectors)

Section 3: Exercises

Exercise 1: Read and interpret details in following documents:

1. Survey Report
2. Measurement Sheet (Trenching and Cable Blowing)
3. HDD Graph
4. Single Line Diagram
5. ABD

Exercise 2: Enlist the tools, test equipment and documents used in Acceptance Testing.

Exercise 3: Participate in a group discussion on following topics:

a) OFC Link Acceptance Testing
b) Formats and Details Captured in As Built Drawing (ABD)

Section 4: Assessment Questionnaire

1. Which document helps in determining the material consumption at site?
2. _____, a testing technique performed to determine whether or not the network construction has met the requirement specifications.
3. To perform depth AT, there are generally, _____ test pits on an average for every Km of cable length.
4. Which tests are performed in Optical AT?
5. Which tests are performed in Civil AT?
6. What could be the causes of AT failure?
7. In HDD graph, 1 cm = ___ Rod = ____ meters.
8. Full form of PIA is:
9. Which document can show distance of trench from road center?
10. Which document is used to determine cable loop length in chamber?

----------End of the Module----------

MODULE 12
OCCUPATIONAL HEALTH AND SAFETY

Section 1: Learning Outcomes

After completing this module, you will be able to:

- Explain the importance of safety
- Types of workplace hazards
- Use various Personal Protective Equipment (PPE) at workplace
- Adhere to optical fiber safety procedures at workplace
- Differentiate between various Laser Classes
- Perform procedures for safety of utilities
- Describe material handling facts
- Manage traffic
- Adhere to travel safety
- Use safety signage and barricading
- Gauge and perform fire safety actions
- Perform medical care at site (First Aid and CPR)
- Encourage safety communication at site

Section 2: Relevant Knowledge

12.1 Introduction to Workplace Safety and Hazards

What is Safety?

Safety is:

Ø A general condition of being safe
Ø Living without fear of getting injured
Ø Being protected from the dangers of our work environment

"No work is so important that it, need be done without due consideration for safety"

Safety Basics

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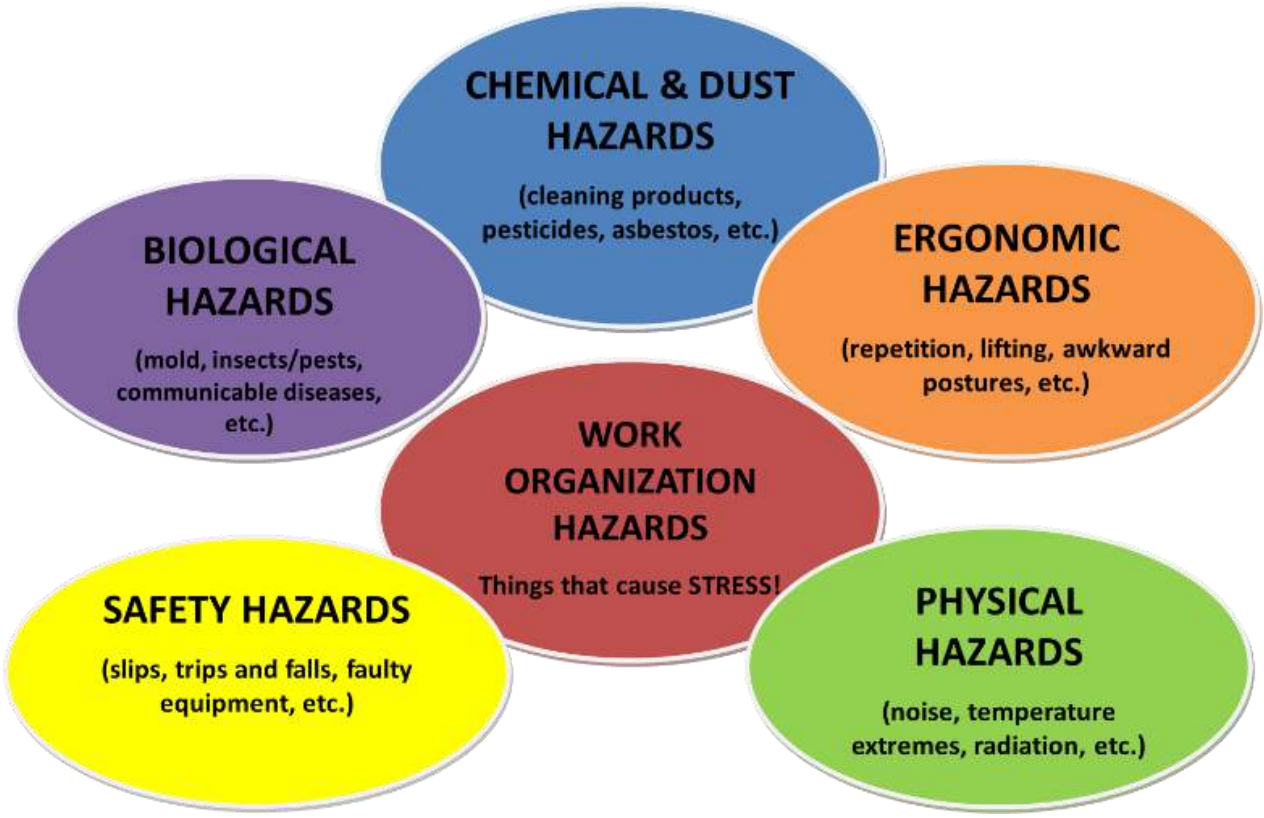
Types of Hazards



"Work organization" is at the center of the chart and all the other hazard categories surround it. This is because for many workplace health and safety issues the way our jobs are designed can be a contributing factor to other hazards we might experience.

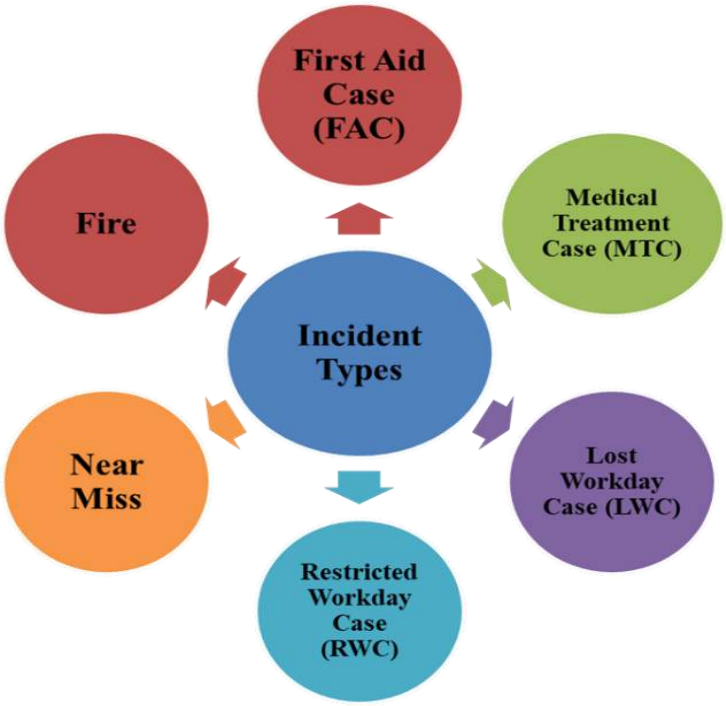
For example, a staff member may trip and fall in a hallway because they're rushing to get back to their desk because of an important deadline they must meet. The slip and fall results in an injury but the job demand is the ***root of the problem****. We have to keep asking WHY something happened until we find the true cause of the problem. In order to start thinking of solutions, we need to know ALL of the potential hazards.*

Effective Health and Safety Procedures for the Workplace

- Create a Safety Plan - It's important for every worker, contractor, and visitor to have access to a thorough safety plan
- Record Keeping
- Proper Safety Equipment
- Eliminate Potential Hazards
- Provide Proper Training

Types of Incidents

What are the incident types?



All Incidents irrespective of their nature/magnitude should be reported within 24 hours of occurrence by the respective area in-charge/supervisor

12.2 Personal Protective Equipment (PPE)

Types of PPE

PPE can be categorized by:

- The Area of the Body Protected
- The Types of Hazard
- The Type of Accessory
- Head protection
- Eye and Face protection
- Hearing protection
- Arm and Hand protection
- Respiratory protection
- Foot and Leg protection
- Protective clothing
- Other protection

Recommended PPEs for Optical Fiber Safety

Head Protection

- **Equipment:** Safety Helmet
- **Purpose:** For protection against falling object or when hit against any obstructions
- **Specification:** HDPE helmet as per ISI 2925 standard

Eye Protection

- **Equipment:** Safety spectacles
- **Purpose:** For protection against flying particles or any sudden impact while executing the job
- **Specification:** Clear polycarbonate lens for low energy impact resistant as per EN 166

- **Equipment:** Laser goggles
- **Purpose:** For protection against radiation from a laser system to eliminate the possibility of potentially hazardous eye exposure.
- **Specification:** Class EN 207

Respiratory and Ear Protection

- **Equipment:** Ear plugs
- **Purpose:** For protection of ear from high noise. Noise level above 85 dB is hazardous for an exposure more than eight hours/day or 48 hours/week.
- **Specification:** Disposable type Ear plugs made of poly urethane foam with a noise reduction level of 25 dB

- **Equipment:** Dust mask
- **Purpose:** For protection against fine particulate/dust
- **Specification:**
  - Particulate Respirator 9004IN
  - AS/NZS P1 and BIS P1, 500/cs

Arm and Hand Protection

- **Equipment:** Cotton knitted gloves
- **Purpose:** For protection against cuts/abrasion during work execution and material handling
- **Specification:** Seamless 100% cotton

- **Equipment:** Electrical gloves
- **Purpose:** For protection against electrocution while working on live line
- **Specification:** Electrical resistant gloves made of rubber as per EN 609033

Foot and Leg Protection

- **Equipment:** Safety shoes
- **Purpose:** For protection of foot against sudden impact
- **Specification:** Lace shoes with steel toe, as per IS 15298 standards

- **Equipment:** Gum boots
- **Purpose:** Useful during rainy seasons or when work is to be done in wet areas to prevent slippage
- **Specification:** 16" knee boot in rubber material, with durable cotton lining inside and with firm heel

Body Protection

- **Equipment:** Full body harness
- **Purpose:** For any maintenance, repair and inspection work at height more than 6 feet
- **Specification:** Full body harness as per EN 361 with shock absorber as per EN 355 and double lanyard as per EN 354

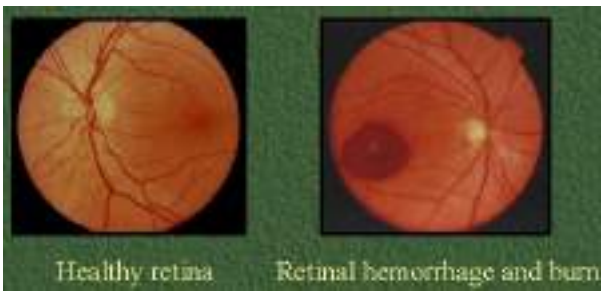
- **Equipment:** Reflective jackets
- **Purpose:** For field jobs (Excavation/repairs/Night jobs) to raise visibility of the working people
- **Specification:** Made of 100% cotton jacket with fluorescent colour and reflective tape of 2-inch width

Personal Protective Gear usage at Site

Helmet, Shoes & Reflective Waist Provided to every worker

PPE's available on site for use

12.3 Optical Fiber Risks & Safety



- Ø Never look directly into the fiber. It may burn retina.
- Ø Always cap connectors.
- Ø Glass shards, if injected in skin/body, can cause internal hemorrhages.
- Ø The broken ends of fibers and scraps of fiber should be disposed-off properly.
- Ø Wear protective Apron to avoid fiber particles from attaching to clothing.
- Ø Isopropyl alcohol, used as a cleaner, is flammable and should be handled carefully.
- Ø Keep hands away from face.
- Ø Do not touch your eyes while working with fiber optic systems.
- Ø Mark enclosures with warning labels.
- Ø Laser test sources are dangerous, don't leave them lying around.

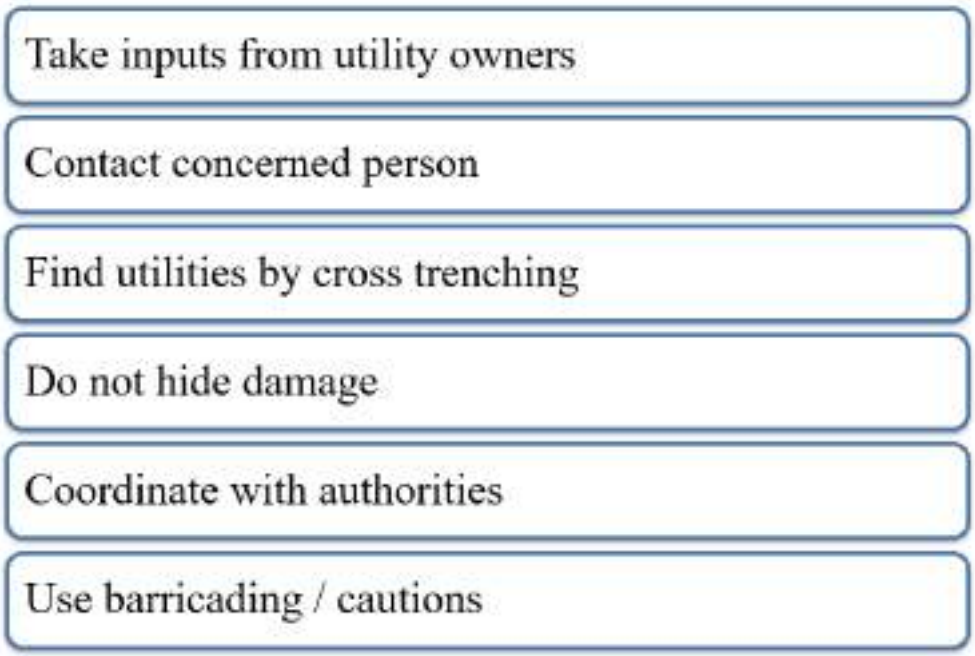
Laser Classes

- Ø Lasers are classified for safety purposes based on their potential for causing injury to humans' eyes and skin.
- Ø For visible-beam consumer lasers, there are four main classes. Class 2, Class 3R, Class 3B and Class 4 or in Roman numerals (I, II, IIIa, IIIb, IV).
- Ø The first two Classes are relatively safe for eye exposure; the last two are hazardous.

MSDS: Material Safety Data Sheet is a document that lists the risks of a chemical

- **Alcohol** – Flammable
- **Adhesives** – Irritate skin, require ventilation
- **Index matching gel** – Irritate eyes
- **Silicone adhesives** are used as mechanical sealant – can irritate skin or eyes

12.4 Safety of Utilities



12.5 Unsafe Act /Unsafe Condition

12.6 Material Handling

Material Handling Activities

Materials handling involves five types of activities:

Material Handling—Some Facts

- Ø Material handling accounts for 36% of production cost
- Ø About 20 % to 80 % of total labour cost goes into labour used in handling and rehandling the material
- Ø About 2/3 of manufacturing cycle time spent on material handling
- Ø 40 % of industrial accidents are in material handling
- Ø About 50 to 100 tons of material is handled and rehandled for every 1 tone of finished product

12.7 Traffic Management and Travel Safety

Traffic Management

- Ø Use of high visibility waistcoats for protection against speeding vehicular traffic.
- Ø Legal permission to be obtained by the contractor from the concerned authorities for Traffic Diversion and alternate route selection.

Traffic Safety Equipment

Barricading Tapes

Portable Cone Connecting Bar

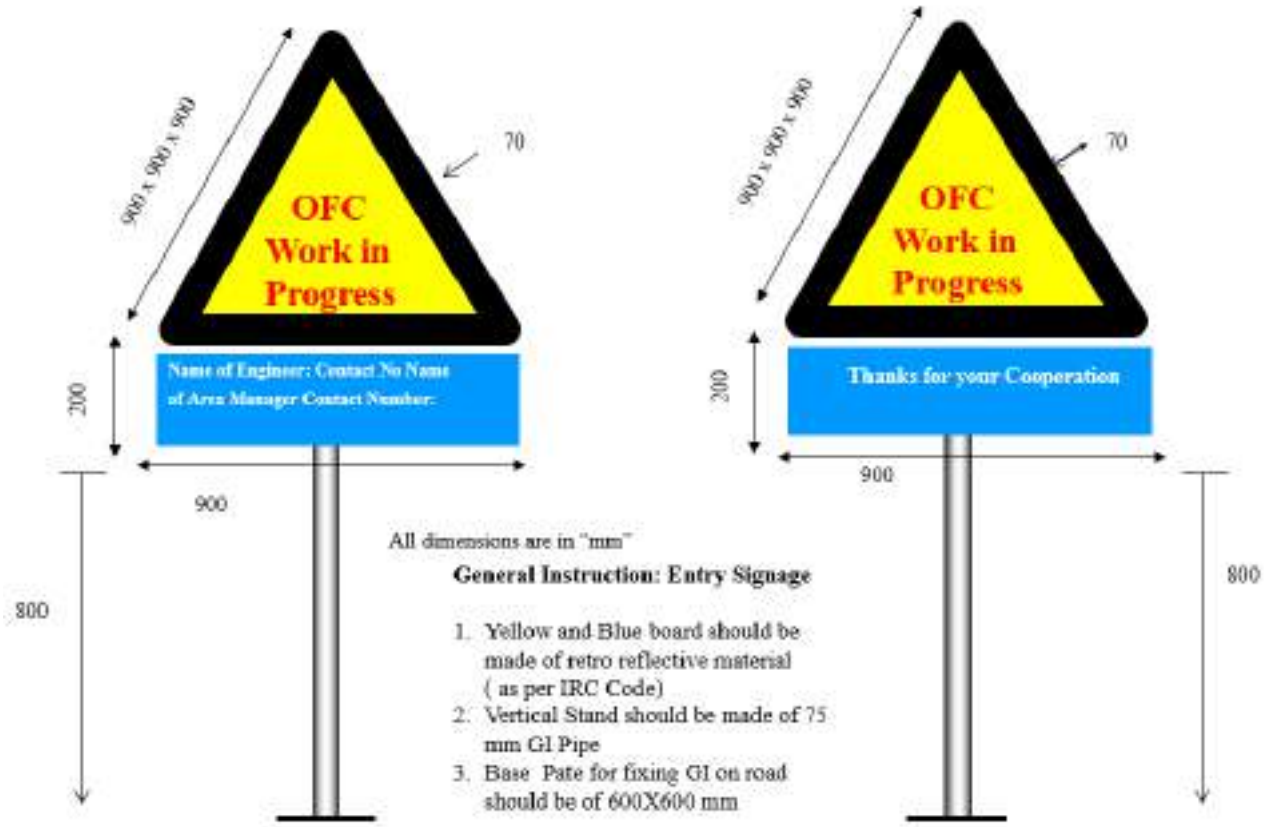
Barricades

Travel Safety

- Do not panic
- Speed control
- Expert driver
- Sleep necessary
- Disturbed area
- Take care during Fog
- Learn driving for emergencies

12.8 Safety Signage and Barricading

Project Site – Warning Signage



Safety Signage

Barricading of Sites

Plastic Barricade

Metallic Barricade

Portable Cone Connecting Bar

Barricading Tapes

Pathway provided to road users

Barricading Boards for nosing

Proper use of Safety Signage's

Retro Reflective Traffic Sign Boards

Illumination at site in night

Safety Signage for trench excavation

12.9 Fire Safety

Fire Prevention at site

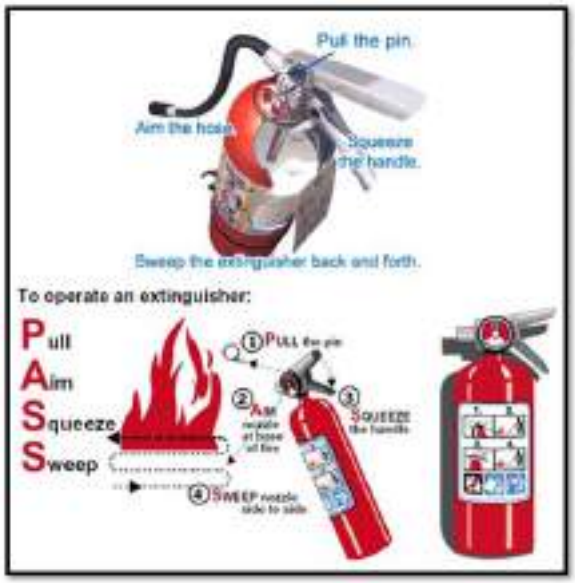
Use of Fire Extinguishers are Fire Buckets help workmen to prevent fire at site.

Types and Classes of Fire Extinguishers

Fire Extinguisher Type

Fire Type		Powder	Foam	CO^2	Water	Wet Chemical
CLASS A	Solids (e.g. wood, plastic, paper)	✓	✓	✗	✓	✗
CLASS B	Flammable Liquids (e.g. solvents, paint, fuels)	✓	✓	✓	✗	✗
CLASS C	Gases (e.g. butane, propane, LPG)	✓	✗	✗	✗	✗
CLASS D	Metals (e.g. lithium, magnesium)	✓	✗	✗	✗	✗
ELECTRICAL	Equipment (e.g. computers, servers, TVs)	✓	✗	✓	✗	✗
CLASS F	Cooking Oils (e.g. cooking fat, olive oil)	✗	✗	✗	✗	✓
Some examples of businesses that may need this extinguisher		Outdoor locations, garages, welding workshops, forecourts.	Schools, offices, hotels, shops, hospitals, apartments.	Offices, server rooms.	Schools, hospitals, shops, apartment blocks.	Kitchens, canteens, restaurants.

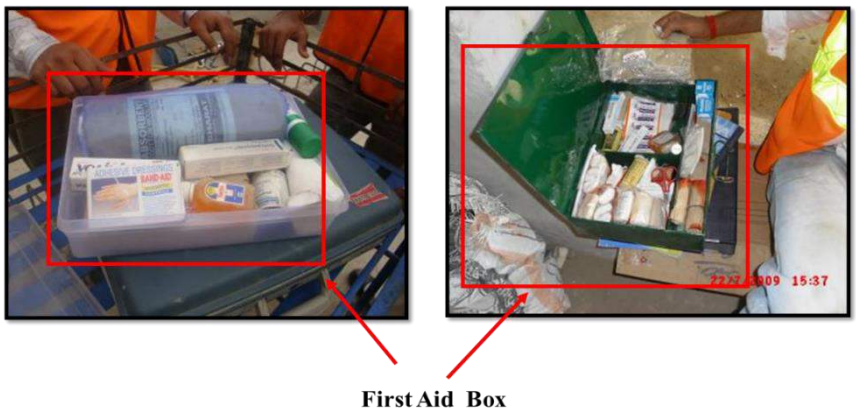
How to use Fire Extinguishers?



On Discovering Fire

- Ø Inform Fire brigade.
- Ø Break the glass of the nearest pill box.
- Ø Attack the fire with nearest accessible extinguisher.
- Ø Handle the extinguisher only if you know how to operate it.
- Ø Do not use water for extinguishing fire in electrical installations unless power supply is disconnected.
- Ø Ensure that mains & battery is switched OFF in case of fire in equipment/ power distribution system.
- Ø Always position yourself with an exit or means of escape at your back before you attempt to use an extinguisher to put out a fire.

12.10 Medical Care at Site



First Aid Box

First Aid Kit

Cardiopulmonary Resuscitation (CPR)

CPR is a life-saving technique.

- Ø CPR is administered whenever heart and/or breathing stop (cardiac and/or respiratory arrest).
- Ø CPR can keep a person alive until more advanced medical procedures can treat the cardiac arrest.

CPR steps are called CAB.

- Ø **Chest Compression** - Providing artificial circulation via chest compressions.
- Ø **Airway** - Opening and maintaining the airway.
- Ø **Breathing** - Providing artificial ventilation through artificial breathing.

Steps before starting CPR

Within 5 to 10 seconds, check for:

- Responsiveness
- No breathing [or only gasping]
- Check responsiveness by gently tapping on shoulders and asking loudly “Are you OK?” or “Do you hear me?”

- Ø CPR provides circulation of blood to the brain and air to the lungs in order to prevent damage to the brain.

- Ø If breathing stops → brain damage occurs within few minutes usually 4 minutes, and brain death could occur within 8-10 minutes

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Carotid Artery Checking

1.

Hands Placements for Compressions:

- Ø Put the heel of one hand on the center of bared chest over the lower half of the breastbone, then put the heel of the other hand over the top of the first.
- Ø Your shoulder should be right over your hands and your elbows should be straight/extended.

You should deliver compressions in a smooth fashion at a rate of at least 100 compressions per minute. At the end of each compression, allow the chest to recoil completely.

2. Airway step

- Ø Put the victim on his back on a firm surface.
- Ø Kneel close to the victim neck or shoulders.
- Ø To open the airway, tilt the forehead backward and the chin upward. (called head-tilt/chin-lift maneuver)

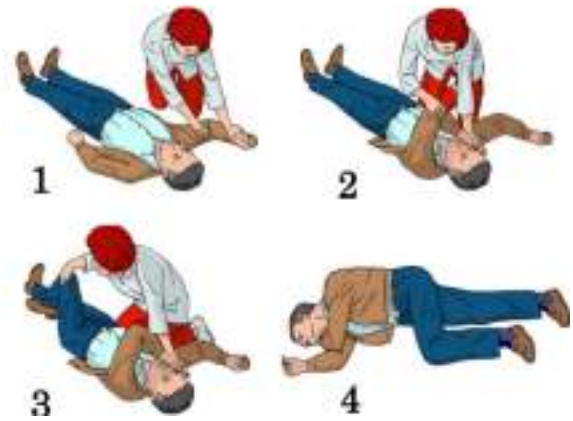
3. Breathing

- Ø Close the nostril and give 2 breaths (mouth to mouth) and observe the chest rises.
- Ø Give each breath over one second to allow chest recoil.

After two (2) minutes of "compression: ventilation CPR cycles"

- Ø If the victim has no pulse, give chest compressions and resume CPR.
- Ø Check for a pulse every approximately 2 minutes.
- Ø If the pulse is present BUT breathing is absent, continue artificial breathing only (called rescue breathing).
- Ø Give 1 breath every 5-6 seconds for about 10-12 breaths/minute.
- Ø Each breath should be delivered over 1 second, making the chest rise.
- Ø Re-check the pulse every two minutes.
- Ø If the pulse and breathing returned to normal, place the victim in recovery position.

Recovery Position



When should CPR be Stopped?

- Ø Patient is recovered.
- Ø You are too exhausted to continue.
- Ø The victim is pronounced dead.
- Ø The cardiac arrest continues for 30 minutes (controversial).

Why CPR may fail?

- Ø Improper procedures and techniques (example, forget to pinch nose).
- Ø Delay in administration of CPR procedure.
- Ø Terminal disease or unmanageable disease
- Ø Massive heart attack

12.11 Safety Communication at Site

HSE Communication at Site

HSE Training at Site

In addition to providing PPEs it is a must to equip the workmen with necessary know how of how to use the PPE and conduct knowledge sharing training sessions to educate them regarding proper use of all equipment and safety guidelines on the whole.

Display Board for Safety, Health & Environment at Site Offices

Emergency Contact Numbers

ID Card for all Workforce

Safety Slogans at Site

Key Points for OFC Workplace Safety

- Ø Keep responsibility of own's and Other's safety
- Ø Prevent accidents from occurring by following guidelines
- Ø Follow rules and no shortcuts
- Ø Don't operate machinery without training
- Ø Use right tools and equipment
- Ø Assess risk before initiating work
- Ø Never wear loose cloths

Section 3: Exercises

- Ø Stand away from deep trenches while work is in progress

Exercise 1: Make a chart of occupational hazards at workplace.
Exercise 2: Enlist the PPEs used in fiber optic industries.
Exercise 3: Enlist firs aid kit items.
Exercise 4: Perform a role play on Cardiopulmonary Resuscitation (CPR).
Exercise 5: Participate in group discussion on following topics.

a) Optical Fiber Risks & Safety
b) Traffic Management & Travel Safety
c) Types of Fire Extinguishers
d) Laser Classes

Section 4: Assessment Questionnaire

1. What are different types of Hazards?
2. What are various types of Incidents?
3. Devices used to protect employees from injury or illness resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards are known as:
4. Categorize PPE kits.
5. What material is used for safety helmet?
6. Which item is used for protection against radiation from a laser system to eliminate the possibility of potentially hazardous eye exposure?
7. Upto which level noise can be reduced by using Ear plugs?
8. Why harness is used?
9. Which protective gear is used for protection against electrocution while working on electric line?
10. What is use of cotton knitted gloves?
11. What material is used for cotton knitted gloves?
12. What safety precautions should be adhered while using optical fiber?
13. Document that lists the risks of a chemical is called as:
14. What is use of Silicon Adhesives?
15. What are effects of Silicon adhesives on human body?
16. How many types of Material Handling activities are there?
17. What can keep a person alive until more advanced medical procedures can treat the cardiac arrest?
18. What do we call the steps of CPR?
19. CPR provides circulation of blood to the brain and air to the lungs in order to prevent damage to the brain. True or False?
20. When should CPR be Stopped?
21. Why CPR could fail?
22. What information is shared in safety training sessions?
23. What are three constituents of fire?
24. Tell some travel safety practices.
25. Which boots are useful during rainy seasons or when work is to be done in wet areas to prevent slippage?
26. Match the Column.

PPE	Application
1. Harness	P. Eye Protection
2. Safety Glasses	Q. HDD Operator Safety
3. Dielectric Gloves	R. Fall Protection

27. What are some good Health and Safety procedures for the workplace?
28. Which chemical can be hazardous while performing fiber splicing?
29. What is difference between caution tape and warning tape?
30. What are various types of fire extinguisher and their classes?
31. Which classes of Laser are relatively safe for eye exposure?

----------End of the Module----------

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