Participant Handbook

Sector

Telecom

Sub-Sector

Passive Infrastructure

Occupation

Operations and Maintenance - Passive Infrastructure

Reference ID: **TEL/Q6401,** Version **5.0**

NSQF Level **4**

Optical Fiber Technician

This book is sponsored by
Telecom Sector Skill Council
Estel House,3rd Floor, Plot No: - 126, Sector-44
Gurgaon, Haryana 122003
Phone: 0124-2222222
Email: tssc@tsscindia.com
Website: www.tsscindia.com

Second Edition, November 2025

Skilling is building a better India.
If we have to move India towards
development then Skill Development
should be our mission.

Shri Narendra Modi
Prime Minister of India

Certificate

COMPLIANCE TO
QUALIFICATION PACK– NATIONAL OCCUPATIONAL STANDARDS

is hereby issued by the

TELECOM SECTOR SKILL COUNCIL

for

SKILLING CONTENT : PARTICIPANT HANDBOOK

Complying to National Occupational Standards of

Job Role/ Qualification Pack: "**Optical Fiber Technician**" QP No. "**TEL/Q6401, NSQF level 5.0**"

Date of Issuance: 8th May 2025

Valid up to*: 30th April 2028

**Valid up to the next review date of the Qualification Pack or the 'Valid up to' date mentioned above (whichever is earlier)*

Authorised Signatory
(Telecom Sector Skill Council)

Acknowledgements

Telecom Sector Skill Council would like to express its gratitude to all the individuals and institutions who contributed in different ways towards the preparation of this "Participant Handbook". Without their contribution it could not have been completed. Special thanks are extended to those who collaborated in the preparation of its different modules. Sincere appreciation is also extended to all who provided peer review for these modules.

The preparation of this handbook would not have been possible without the Telecom Industry's support. Industry feedback has been extremely encouraging from inception to conclusion and it is with their input that we have tried to bridge the skill gaps existing today in the industry.

This participant handbook is dedicated to the aspiring youth who desire to achieve special skills which will be a lifelong asset for their future endeavours.

About this book

India is currently the world's second-largest telecommunications market with a subscriber base of 1.20 billion and has registered strong growth in the last decade and a half. The Industry has grown over twenty times in just ten years. Telecommunication has supported the socioeconomic development of India and has played a significant role in narrowing down the rural-urban digital divide to some extent. The exponential growth witnessed by the telecom sector in the past decade has led to the development of telecom equipment manufacturing and other supporting industries.

Over the years, the telecom industry has created millions of jobs in India. The sector contributes around 6.5% to the country's GDP and has given employment to more than four million jobs, of which approximately 2.2 million direct and 1.8 million are indirect employees. The overall employment opportunities in the telecom sector are expected to grow by 20% in the country, implying additional jobs in the upcoming years.

This Participant Handbook is designed to impart theoretical and practical skill training to students for becoming an Optical Fiber Technician. Optical Fiber Technician is responsible for maintaining uptime and quality of the network segment (both optical media & equipment) assigned to him by undertaking periodic preventive maintenance activities and ensuring effective fault management in case of fault occurrence. He is also required to coordinate activities for installation and commissioning of Optical Fiber Cable (OFC) as per the route plan.

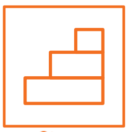
This Participant Handbook is based on Optical Fiber Technician Qualification Pack (TEL/Q6401) & includes the following National Occupational Standards (NOSs):

1. TEL/N4137: Coordinate Installation and Commissioning of Optical Fiber Cables (OFCs)
2. TEL/N6403: Undertake Condition based Maintenance and Planned Repair Activities
3. TEL/N6404: Perform Corrective Maintenance/Restoration of Optical Fiber Faults
4. TEL/N9111: Follow sustainability practices in telecom cabling operations
5. DGT/VSQ/N0101: Employability Skills (30 Hours)

The Key Learning Outcomes and the skills gained by the participant are defined in their respective units. Post this training, the participant will be able maintain uptime and quality of the network segment by undertaking periodic preventive maintenance activities & effective fault management. We hope that this Participant Handbook will provide a sound learning support to our young friends to build an attractive career in the telecom industry.

Symbols Used

Key Learning Outcomes



Steps

Notes

Practical

Unit Objectives

Table of Contents

GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

1. Introduction to the Sector and the Job Role of an Optical Fiber Technician

Telecom Sector Skill Council

TEL/N4137

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the importance of Telecom Sector.
2. Discuss the role and responsibilities of an Optical Fiber Technician.

UNIT 1.1: Introduction to Telecom Sector and Role of an Optical Fiber Technician

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the significance of the telecom sector in the installation and maintenance of optical fiber networks.
2. Elucidate the key skills and technical expertise required for an Optical Fiber Technician.
3. Describe the challenges faced in splicing, testing, and troubleshooting optical fiber cables in telecom networks.
4. Determine the impact of precision and quality control in optical fiber installation and maintenance for reliable telecom services.
5. Discuss the roles and responsibilities of an Optical Fiber Technician in ensuring efficient and high-quality network performance.

1.1.1 Introduction to Telecom Industry

The Indian telecom industry has been one of the fastest-growing sectors in the country, striving to tap almost every potential customer with its services. Today, owning a mobile device is a basic necessity, and the demand for seamless connectivity continues to rise.

With the rapid expansion of the Information Technology (IT) sector, the telecom industry in India has experienced a major boom, leading to continuous market growth. Since the Indian population has become highly dependent on telecom services—and with several companies operating both in India and overseas—the sector often faces challenges in maintaining smooth operations amidst growing customer expectations. This study aims to provide insights into the current telecom sector and the measures being taken to enhance customer relationships.

Post-1991 liberalisation, privatisation, and globalisation, the Indian telecom market has become highly competitive, with multiple players operating simultaneously. In such an environment, companies are keen to understand customer perceptions of mobile services to refine their strategies and capture market share.

India remains the world's second-largest telecommunications market. As of March 2025, the total telephone subscriber base stood at around 1,200 million, with an overall tele-density of 85%. The internet subscriber base reached approximately 944 million, while broadband subscriptions grew to over 935 million wireless and about 45 million wired users by mid-2025.

- **Sector growth and infrastructure expansion:** Telecom infrastructure continues to expand rapidly, with the number of towers and mobile base transceiver stations (BTS) steadily increasing. This expansion has helped improve connectivity and service quality, especially in urban regions, though rural areas still face gaps.
- **Policy targets and initiatives:** The Government has launched the National Broadband Mission 2.0 (2025–30), aiming to provide optical fibre connectivity to all Gram Panchayats and key institutions, with at least 95% uptime, and to raise average fixed broadband speeds to 100 Mbps by 2030. In parallel, the Draft National Telecom Policy 2025 sets ambitious goals such as achieving 100% 4G coverage, 90% 5G coverage, 80% tower fibreisation, broadband access to 100 million households, and the rollout of 1 million public Wi-Fi hotspots by 2030.

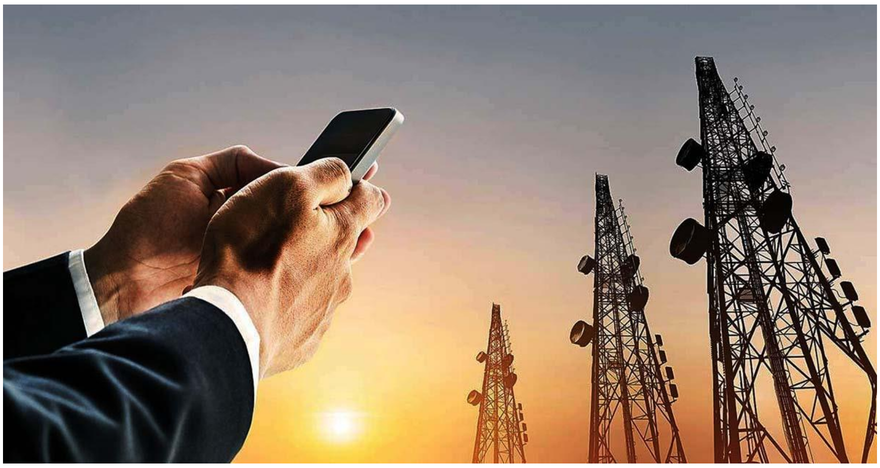


Fig. 1.1.1: Telecom Industry

Subscriber trends and market dynamics:

By May 2025, India's total telecom subscriber base reached about 1,207 million. Reliance Jio and Bharti Airtel together accounted for nearly all new subscriber additions, while Vodafone Idea and BSNL continued to lose market share. By June 2025, the total wireless subscriber base stood at approximately 1,171 million, driven largely by urban growth, though rural subscriptions showed a slight decline.

1.1.2 Various Sub-Sectors of the Telecom Industry

Telecommunication is a multi-dimensional industry. It is divided into the following subsectors:

- Telecom Infrastructure - It is a physical medium through which all the data flows. This includes telephone wires, cables, microwaves, satellites, and mobile technology such as fifth-generation (5G) mobile networks.
- Telecom Equipment - It includes a wide range of communication technologies, from transmission lines and communication satellites to radios and answering machines. Examples of telecommunications equipment include switches, routers, voice-over-internet protocol (VoIP), and smartphones.
- Telecom Services – A service provided by a telecommunications provider or a specified set of user- information transfer capabilities provided to a group of users by a telecommunications system. It includes voice, data and other hosts of services.

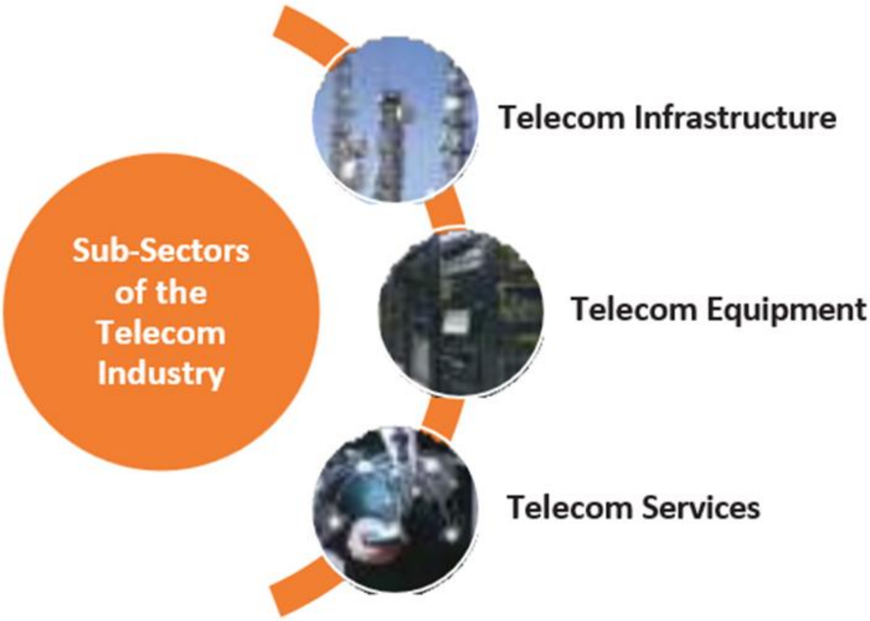


Fig. 1.1.2: Telecom Sub-Sectors

The major segments within these sub-sectors include the following:

- Wireless communications
- Communications equipment
- Processing systems and products
- Long-distance carriers
- Domestic telecom services
- Foreign telecom services
- Diversified communication services

1.1.3 Broadband Industry

Telecommunication plays a major role in economic and social development and has its scope across all technical fields. It integrates all telecommunication-related services in India and acts as a backbone for digital transformation.

The rapid improvement of internet and mobile technologies has had a significant impact on India's economic growth. Recognising this, the Government of India has placed strong emphasis on the development of the telecom industry. India continues to be the world's second-largest telecom market, after China.

However, broadband penetration and fixed broadband speeds in India still lag behind those of China. Strengthening broadband connectivity remains a key driver for digitalisation, economic inclusion, and innovation. The government has therefore prioritised expanding both mobile and fibre-based internet services to bridge the gap.

A major focus is on enhancing network connectivity in rural and semi-urban areas. The primary aim is to provide broadband access to every citizen of the country. Under the National Broadband Mission 2.0 (2025–30), the Government is targeting optical fibre connectivity for all Gram Panchayats and key institutions, ensuring at least 95% uptime. The mission also aims to raise average broadband speeds to 100 Mbps by 2030.

In line with this, rural and village-level networks are being upgraded to support high-speed internet, including the rollout of affordable 100 Mbps connections in villages through Panchayat-level initiatives. By doing so, India is working towards narrowing the rural-urban digital divide.

The Draft National Telecom Policy 2025 further outlines ambitious goals such as 100% 4G coverage, 90% 5G coverage by 2030, 80% fibreisation of towers, and 1 million public Wi-Fi hotspots across the country. These steps not only aim to improve connectivity but also attract foreign investment into the telecom sector, thereby creating new avenues for employment and skill development.

5G adoption and economic impact:

India has already rolled out 5G services across major cities and industrial hubs, with rapid expansion into smaller towns and rural regions underway. The adoption of 5G is expected to drive innovation in sectors like smart manufacturing, healthcare, education, transport, and agriculture, enabling applications such as IoT, automation, and AI-driven services. According to projections, 5G technology could contribute around USD 450 billion to India's economy between 2023 and 2040. This transformative impact will strengthen India's digital ecosystem, enhance productivity, and support the government's vision of a digitally empowered society and knowledge economy.

With these initiatives, India is positioning itself strongly in the global telecom space and aspires to move closer to the top rank worldwide.

1.1.4 Optical Fibre Technology

Optical transmissions over the fiber cables need immense strengthen technology associated. Optical cables inner core glass is made in a way to propagate complete ray travelling by giving zero resistance and losses. To achieve connectivity over long distance optical medium proven to be the best even though it is laying and maintenance takes more economy. Unlike in copper cable electrical signal converted into light and it is transmitted over fiber cables. It began about 40 years ago in the R&D labs (Corning, Bell Labs, ITT UK, etc.) and was first installed commercially in Dorset, England by STC and Chicago, IL, USA in 1976 by AT&T. By the early 1980s, fiber telecommunications networks connected the major cities on each coast. By the mid-80s, fiber was replacing all the telecom- copper, microwave and satellite links. In the 90s, transoceanic fiber optic cables replaced sate llites between most continents.

Over the period fiber optics took over the entire major service provider favorite as its effectiveness ruled out the cost. DTH and CATV are few services mostly relied on fiber network. Adding on the Research prove that the network will be the reliable to provide Internet services, mobile services network development.

Slowly the fiber placed in the small networks and then tried with LAN, WAN, MAN, and most of implantations is taking place with fiber network in today's data . As the cables could be routed fascinatingly without disturbing the infra, more company's showed interest in having fiber network. Fiber is effective in huge data transfer and connectivity with reliability. Fiber is implemented in most Multinational companies with fiber LANs backbones, connections to systems for employees or design workstations with many wireless AP (access point).

Some more applications for consideration are: mobile - cell network connections, Ship & aircraft, automation and automobile connecting lines, security like CCTV, & digital stereos for consumers. Fiber optics users in current time zones are systems who use it for connecting social blocks like Educational institutes, stores/ departments, transport& traffic lights, security add on like CCTV surveillance systems. Fiber to home is another upcoming big business which provides the best connections to their users. Optical fiber is either predominant medium or choice made logically for most of communication system. With reduced Costs fiber to the home is most likely accepted by user ends, the fantasy come true for users as fiber to home provides all means of data and services which other medium fails to provide.

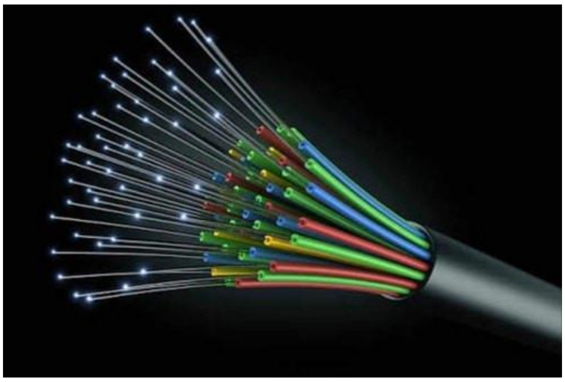
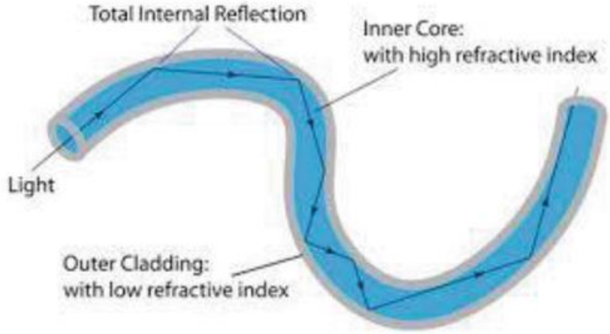


Fig. 1.1.3 An optical fibre

Fiber optics would be used as a channel for communication & networking as it is easy and flexible. Plastic or glass manufactures fibers, it is s used in long-distance applications of telecom. Optical fibers mostly prefer glass inner core medium than plastic as glass provide low absorption. Optical fiber principally uses total internal reflection phenomenon for the light transmission within the material. Due to total internal reflection angle Eliminates distortion, leakage, reflection, signal crosstalk between fibers within the cable and allows the cable routing (supporting twists and turns). Infrared Light is mostly used for communication in case of telecom applications, as wavelengths proven best for the case (minimum absorption with fiber).



1.1.5 Types of Optical Fibre

Optical fibre technology is associated with data transmission using light pulses travelling along with a long fibre which is typically made of glass or plastic. These facilitate the propagation of light along with the optical fibre depending on the requirement of power and distance of transmission.

Multi-mode fibre is used for shorter distances, while single-mode fibre is used for long-distance transmission.

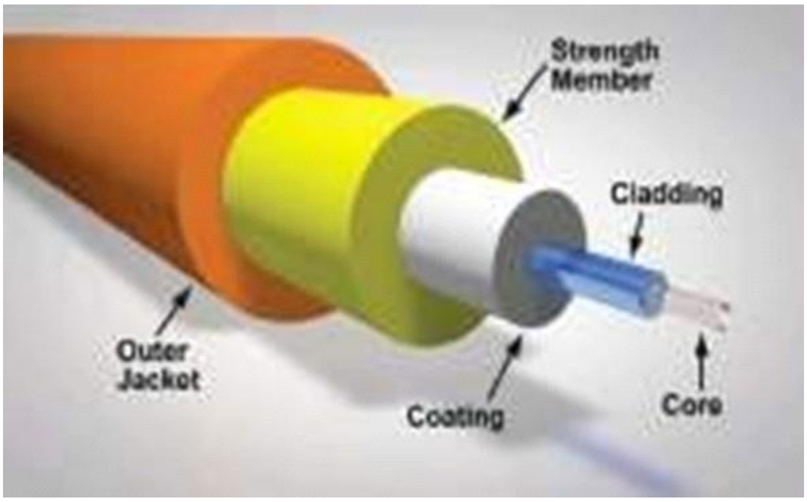


Fig. 1.1.4: Fibre Optics

Classificaion based on the refracive index:

- **Step Index Fibres -** It consists of a core surrounded by the cladding, which has a single uniform index of refraction
- **Graded Index Fibres -** The refractive index of the optical fibre decreases as the radial distance from the fibre axis increases

Classificai o n based on the materials used:

- **Plasic Opical Fibres** - Polymethylmethacrylate is used as a core material for the transmission of light
- **Glass Fibres -** It consists of extremely fine glass fibres

Classificaion based on the mode of propagaion of light:

- **Single-Mode Fibres -** Used for long-distance signal transmission
- **Muli-mode Fibres -** Used for short-distance signal transmission

The mode of propagation and refractive index of the core is used to form 4 combination types of optic fibres as follows:

- Step index-single mode fibres
- Graded index-Single mode fibres
- Step index-Multimode fibres
- Graded index-Multimode fibres

1.1.6 Role and Responsibilities of an Optical Fiber Technician

An Optical Fiber Technician (OFT) is a skilled professional responsible for installing, splicing, testing, repairing, and maintaining optical fiber cables used in telecom, internet, and data transmission networks. They play a key role in ensuring high-speed connectivity, minimal downtime, and safe handling of delicate fiber infrastructure.

Role of an Optical Fiber Technician

- To ensure reliable and efficient fiber optic network installations.
- To carry out splicing, testing, and troubleshooting of fiber optic cables.
- To maintain safety, quality, and compliance with industry standards during fiber operations.
- To support telecom operators, ISPs, and enterprises in providing uninterrupted services.

Key Responsibilities of an Optical Fiber Technician

1. Installation

- Lay, pull, and route optical fiber cables through ducts, conduits, and aerial routes.
- Terminate fiber cables at distribution boxes, patch panels, or customer premises.
- Follow standard layouts, blueprints, and installation plans.

2. Splicing & Jointing

- Perform fusion splicing and mechanical splicing for connecting fiber cables.
- Ensure minimal signal loss and high-quality connections.
- Use protective sleeves, closures, and enclosures for safe splicing.

3. Testing & Troubleshooting

- Use equipment like OTDR (Optical Time Domain Reflectometer), power meters, and light sources to test fiber quality.
- Identify faults, breaks, bends, or signal loss in the cable.
- Carry out corrective measures to restore connectivity.

4. Maintenance

- Conduct preventive and corrective maintenance on fiber networks.
- Replace damaged fiber cables, connectors, or equipment.
- Document and update records of fiber routes and maintenance activities.

5. Safety & Compliance

- Follow electrical and optical safety guidelines (eye safety while handling laser signals).
- Use proper Personal Protective Equipment (PPE) while working on-site.
- Dispose of fiber scraps and waste materials safely.

6. Documentation & Reporting

- Maintain logs of installation, splicing, and testing results.
- Prepare reports for supervisors or clients on network health and repairs.
- Follow telecom industry standards and organizational SOPs.

7. Customer Service

- Assist customers during fiber installations at homes, offices, or industrial premises.
- Explain basic troubleshooting steps to end-users if required.
- Ensure minimal service disruption during repairs or upgrades.

1.1.7 Skills Required to be a successful Optical Fiber Technician

Optical Fiber Technicians need the following skills in order to be successful:

- Technical skills: A technician employs their technical skills and knowledge to carry out tasks. To install and fix fiber optic cables, splice fiber optic cables, troubleshoot fiber optic cable issues, and perform other jobs, fiber optic technicians employ their technical expertise.
- Communication skills: Since fiber optic technicians frequently operate in teams, they must be able to describe their job to others in a clear and straightforward manner. They must be able to explain technological processes and procedures to clients because they work with them frequently.
- Problem-solving abilities: Fiber optic technicians employ their problem-solving abilities to diagnose equipment problems, pinpoint the source of network outages, and fix damaged cables. These abilities are also used to choose the best tools and equipment to employ and to choose the most effective manner to execute jobs.
- Attention to detail: To make sure they are installing the equipment correctly; fiber optic specialists need to pay close attention to every detail. Before they depart a project site, they must also make sure the equipment is in good working order. This is crucial to guarantee the client is happy with the job and to stop any potential problems in the future.
- Teamwork abilities: Being a part of a team can help you learn more about your career and advance your talents. By participating in a club or volunteer organization at your school, you can develop your teamwork skills. Working together with your co-workers to complete tasks and solve difficulties is another way to learn.

1.1.8 Fiber Optic Infrastructure Growth

Fiber optic infrastructure expansion is a trend that is becoming more and more popular all over the world. The demand for experienced professionals to install and maintain these systems will increase as more homes and businesses adopt fiber optic technology Because they possess the knowledge necessary to install, test, and troubleshoot fiber optic systems, fiber optic technicians are in high demand. There will be a rising need for these specialists due to the fiber optic infrastructure's continuing expansion.

Fig. 1.1.5: Fibre Optics

1.1.9 Public Switched Telephone Network (PSTN)

- It is a standard telephone service. Some of the examples are BSNL, Airtel and MTNL.
- Public Switched Telephone Network, operated through "SWITCH" devices to open or close circuits, or it can break the electronic or certain path.
- This integrates the world circuit of telephone networks that are performed by na
- It consists of the fibre optic cable, telephonic lines, communication waves, networks, satellites and telephonic cables. These are interconnected with each other to communicate with anyone around the world.
- The telephone system network consists of mobile and telephones around the world.
- The process of PSTN – Dialling a person with whom we want to connect. The receiver gets the signal, picks the call, and exchanges the information. The circuit completes when they talk to each other.

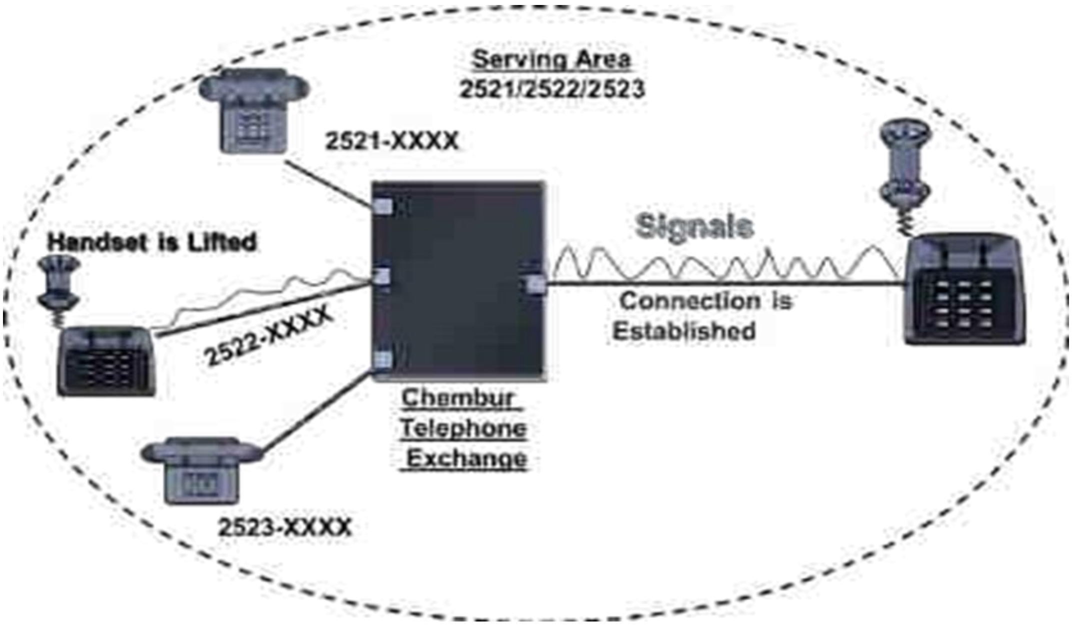


Fig. 1.1.6: Public switched telephone network

1.1.10 Tradiional Forms of Retailing in India

In telecom terminology, a transmission medium is a physical path between the transmitter and receiver, i.e., the channel through which data is exchanged from one place to another. Transmission Media can be broadly classified into the following types:

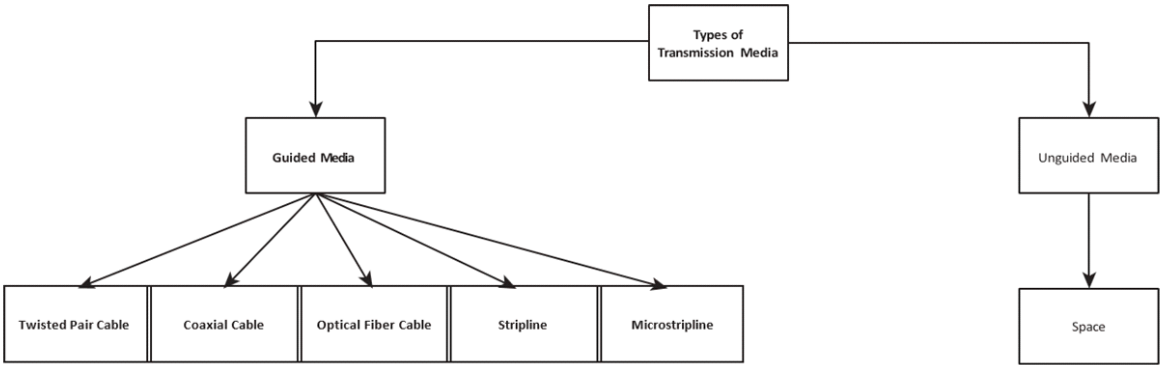


Fig. 1.1.7: Types of Transmission Media

Twisted pair cabling refers to wiring type. This consist of two conductors in a single circuit in which the conductors are twisted to cancel the electromagnetic induction from external sources.

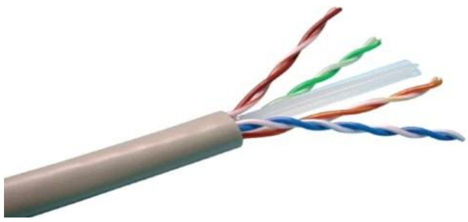


Fig. 1.1.8: Twisted Pair Cable

Coaxial cable was invented and designed in 1880 by the English engineer named Over Heaviside. It has a conductor which is layered by a tube insulator and a shield. Most of them have an outer jacket. This term coaxial is used as the inner conductor and jacket share the same geometric axis.

Fig. 1.1.9: Co-Axial Cable

Optical fibre cable consists of one or more than one optical fibre. These are coated with plastic plates and contain protective tubes which are stable in all climatic conditions.

Fig 1.1.10: Fibre Optics

A microwave is an electromagnetic wave. It has a wavelength in the range of 0.001 –0.3 m, or sometimes shorter than that of a normal radio wavelength. They are larger than the IR. These wavelengths are used in microwave oven and other industrial processes. These are also used to carry the telecommunications.

Fig. 1.1.11: Microwave Antena

A satellite is a system that receives signals from any part of the earth and transmits them to a receiver on earth. The main function is communicating and transmitting the signal from the sender to the receiver.

Fig. 1.1.12: satellite system

Exercise

Short Questions:

1. Explain the significance of the telecom sector in modern communication and economic development.
2. List three key technical skills an Optical Fiber Splicer must possess.
3. Describe one major challenge faced in fiber optic splicing and how it can be addressed.
4. How does fiber optic technology impact internet speed and overall connectivity?
5. Outline the main roles and responsibilities of an Optical Fiber Splicer in network deployment.

Fill in the Blanks:

1. An Optical Fiber Splicer is responsible for ___________ and ___________ optical fibers.
2. The telecom sector contributes to economic development by enabling faster ___________ and ___________ transmission.
3. Precise ___________ of fiber cores is critical to reduce signal loss during splicing.
4. Fiber optic cables provide high-speed data transmission due to the principle of ___________.
5. One challenge in splicing optical fibers is ensuring proper ___________ alignment to maintain signal quality.

Multiple Choice Questions (MCQs):

1. The telecom sector is crucial for modern communication primarily because it:
   a) Generates electricity
   b) Facilitates high-speed data and voice connectivity
   c) Manufactures optical fibers
   d) Regulates government policies
2. Which of the following is a key technical skill required for an Optical Fiber Splicer?
   a) Welding metal cables
   b) Precision fiber cleaving and splicing
   c) Installing electrical transformers
   d) Designing software algorithms
3. One major challenge faced in optical fiber splicing is:
   a) High voltage current in fibers
   b) Aligning fiber cores precisely to minimize signal loss
   c) Excessive fiber flexibility
   d) Overheating of fiber jackets
4. Fiber optic technology primarily improves:
   a) Electrical power transmission
   b) Internet speed and connectivity
   c) Radio signal quality
   d) Cable durability for plumbing

5. The responsibilities of an Optical Fiber Splicer include:
    a) Designing network routers
    b) Installing, splicing, and testing fiber optic cables
    c) Manufacturing telecom hardware
    d) Drafting government policies

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=77dOO5hvd58

What is Fiber-Optic Cable with Full Information

GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

2. Coordinate Installation and Commissioning of Optical Fiber Cables

TEL/N4137

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the key steps involved in inspecting the route plan for optical fiber cable installation.
2. Elucidate the process of coordinating cable laying and pulling to ensure compliance with industry standards.
3. Discuss the importance of adhering to health and safety guidelines in optical fiber installation projects.
4. Explain the significance of reporting and recording installation activities for project tracking and fault management.

UNIT 2.1: Site Visit and Route Inspection

Unit Objectives

By the end of this unit, the participants will be able to:

1. Demonstrate how to obtain and review the OFC route plan from the planning team or supervisor.
2. Show how to verify the proposed route, ensuring compliance with manufacturer-specified bend ratios and industry standards.
3. Demonstrate how to identify dependencies and create an effective installation work plan.
4. Show how to determine the required statutory permissions and liaise with relevant authorities to secure clearances.
5. Discuss the different types of clearances and municipal approvals required for optical fiber installation work.
6. Demonstrate how to supervise trenching to ensure it is carried out as per the route plan and site terrain.
7. Show how to use specially designed dispensers for accurate duct placement in trenches.
8. Demonstrate how to check pipe/duct depths for compliance with laying standards and rectify collapsed or twisted ducts.
9. Show how to confirm ducts are clean and sealed with appropriate end plugs to prevent contamination.
10. Show how to confirm the use of protective materials such as GI or RCC pipes where necessary.

2.1.1 Site Visit

Site visit is essential before making any plan of action. The visit gives the necessary information about the changes to be needed for the ideal plan. Site visit also emphasizes the action list with necessary competency needed. By doing effective site visit one could make the best plan of installation and avoid ambiguities. Obstruction which may prevent transportation of various equipment's to the site could also be taken care. It is necessary to note down all the points observed start from layout view while site visit. While in the site data collected will equip information so that proper, complete & accurate package for the same could be estimated. Site visit will make us understand actual equipment locations, routing for conduits, and proper elevations. It will help you to apply methods to overcome the challenges by applying the architectural drawings/ layouts. If found Site drawing details incomplete, then update it by site actual data. Note down the physical status, changes needed and plan further.

Fig. 2.1.1: A site visit in progress

2.1.2 Route Inspection and Its Benefits

Route Inspection

Route inspection will give you an insight into what may confront you while performing your job. You may see obstructions, issues or gaps which you would have not known unless you conducted this 'inspection'.

Route Inspection Benefits

Following are the benefits of a detailed route inspection:

- Route inspection will give you an insight into what may confront you while performing your job.
- You may see obstructions, issues or gaps which you would have not known unless you conducted this 'inspection'.
- Plan is verified with the actual physical location to identify gaps. Helps in meeting manufacturer's specifications regarding 'bend ratios'. Plan is designed keeping in mind the health and safety standards. Any re-work due to lack of proper plan is avoided.
- Accidents are avoided due to proper planning.

Fig. 2.1.2: Effective route inspection

2.1.3 Steps – Route Inspection

Following are the steps for route inspection:

- Step 1– Obtain an OFC route plan
- Step 2– Verify the plan through a Route Walk
- Step 3– Take corrective actions

2.1.4 Step 1 – Obtain OFC Route Plan

Obtain a 'layout' describing the proposed OFC route from the planning team so as to identify the:

- Physical locations (premises or outside plant) along the route. Other utilities, cables etc. so that damages are avoided.
- Departments involved – electricity, water, municipality, etc.
- Permission(s) required to carrying out the entire activity.
- Physical obstacles & health hazards along the route.

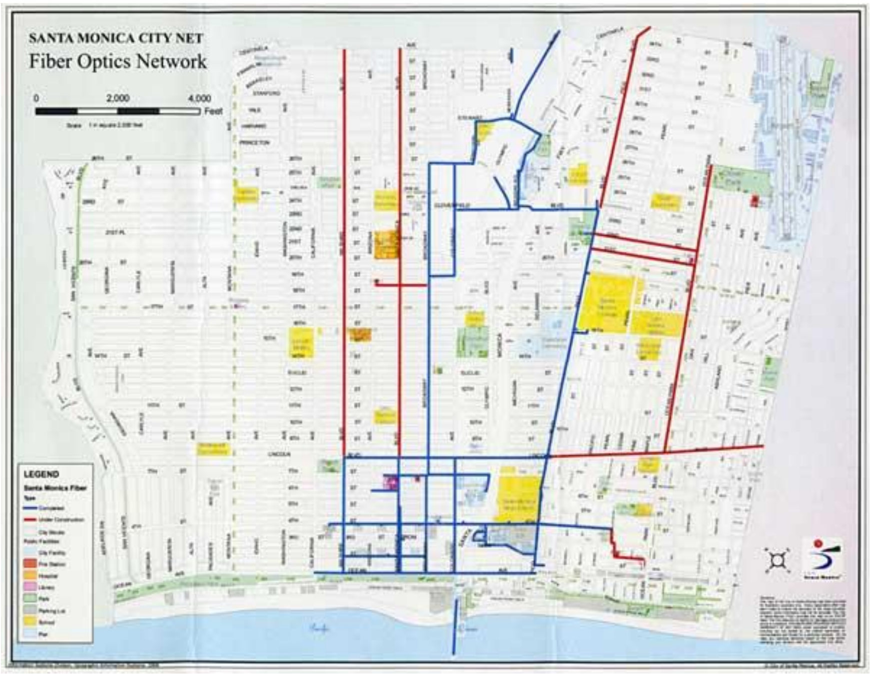


Fig. 2.1.3: OFC route plan

2.1.5 Step 2 – Verify Plan – 'Route Walk'

Conduct a 'Route Walk' along with 'Fiber Optic Technician' and an experienced 'Fiber Optic Splicer' so as to:

- Verify the 'plan' for accessibility and availability as per design. Verify construction methods, special tools, splice locations, etc.
- Verify ground characteristics including subsurface investigation; it helps allay fears related to trenching / ploughing
- Draw and mark bends, conduit size, splice locations, manholes, etc., so as to begin any preparatory or co-ordination work (Ref. next page).
- Mark the proximity to AC power areas to avoid possibility of damages / accidents Check for material storage areas, ventilation, etc.

Fig. 2.1.4: OFC Route Walk

Avoid proximity to AC power areas to avoid any accidents. Although the fiber does not conduct electricity yet, fiber could be means to conduct electricity, installer should take precautions with live electrical wires in working when close to AC power. Mark other utility lines so as to avoid damage. Thereafter make a sketch as per the route walk. It is called the 'Route Walk Sketch'.

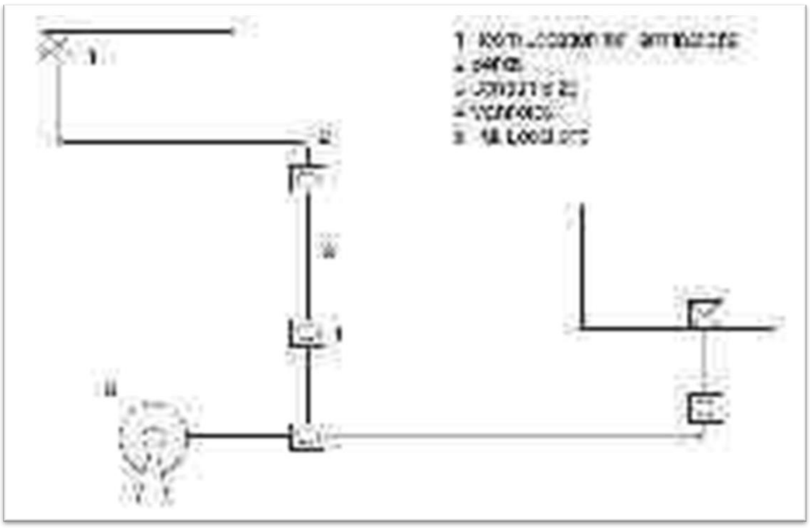


Fig. 2.1.5: OFC 'Route Walk'sketch

2.1.6 Step 3 – Take Corrective Actions

Prepare the site so that it is ready for installation by taking corrective actions with the help of laborers:

- Take permissions from other departments, etc., if required. Revise routes – bends, splicer locations, etc., if required.
- Arrange for the availability of any special tools if required. Remove or circumvent any obstruction / conflict along the route. Prepare the site thoroughly and properly for better productivity. Protect optical fiber cable from high temperature.
- Take measures to prevent optical cables from direct stress.
- Determine locations where reels are to be positioned during the installation.

Fig. 2.1.6: Take corrective actions

2.1.7 Benefits of Route Inspection

Route inspection, especially in contexts like optical fiber installation, logistics, construction, or transportation, plays a critical role in ensuring the efficiency, safety, and effectiveness of operations. Here are the key benefits:

1. Identifying Obstacles and Risks

- Detects physical barriers such as trees, poles, underground utilities, or difficult terrain.
- Helps avoid potential hazards that could delay or complicate the project.

2. Accurate Planning

- Allows proper assessment of distances, materials needed, and equipment requirements.
- Helps in preparing a detailed project plan with realistic timelines and budgets.

3. Improved Safety

- Identifies unsafe areas or zones where accidents are likely.
- Ensures that safety protocols are built into the planning phase rather than being reactive.

4. Cost Efficiency

- Prevents unnecessary expenses by identifying the best paths and reducing redundant work.
- Helps avoid costly rerouting or redesigning after work has started.

5. Compliance and Documentation

- Ensures that all inspections meet regulatory or industry standards.
- Provides documentation required for permits, audits, or safety reports.

6. Enhanced Communication

- Provides stakeholders with a clear understanding of the route.
- Ensures that teams, contractors, and clients are aligned with expectations and challenges.

7. Resource Optimization

- Helps in selecting optimal points for equipment setup, access roads, or staging areas.
- Reduces fuel, labor, and time wastage.

8. Environmental Considerations

- Identifies sensitive areas to avoid damaging ecosystems or violating environmental guidelines.
- Helps create routes that minimize disruption.

9. Improved Quality Control

- Ensures that routes meet technical requirements like signal strength (for fiber optics) or gradient levels (for roads).
- Prevents installation errors and increases the longevity of the infrastructure.

10. Better Emergency Preparedness

- Identifies alternate routes or access points in case of emergencies.
- Ensures quick response times during incidents or breakdowns.

2.1.8 How to Verify a Proposed Route Ensuring Compliance with Standards

When inspecting and verifying a proposed route—whether for optical fiber installation, transportation, pipelines, or other infrastructure projects—you need to ensure that the route complies with technical, safety, regulatory, and environmental standards. Below is a structured approach to verify the proposed route:

Step 1 – Review Applicable Standards and Guidelines

1. Identify relevant standards:
    - Local government regulations (e.g., road safety norms, utility clearance).
    - Industry-specific standards (e.g., telecom, electrical, mining, or environmental codes).
    - Safety standards such as PPE, trench depth, access control, etc.
2. Document requirements:
    - Right-of-way permissions
    - Maximum gradient, curvature limits, and allowable materials
    - Environmental impact assessments
    - Utility protection protocols

Step 2 – Conduct a Detailed Survey of the Route

1. Physical inspection:
   - Walk, drive, or drone survey the entire route.
   - Note natural obstacles, unstable terrain, or erosion-prone areas.
2. Mapping:
   - Use GPS tools to create accurate coordinates.
   - Compare with existing infrastructure and utility maps.
3. Cross-verification:
   - Ensure the proposed route matches the layout and engineering drawings.

Step 3 – Evaluate Safety and Accessibility

1. Access points:
   - Confirm availability of safe access for equipment and emergency services.
2. Identify hazards:
   - Look for unsafe slopes, water bodies, wildlife corridors, or other risk zones.
3. Worker safety measures:
   - Ensure PPE requirements are practical.
   - Evaluate whether temporary signage and barriers can be installed where necessary.

Step 4 – Check Utility and Environmental Clearances

1. Consult utility providers:
   - Avoid interference with power lines, underground cables, water pipelines, etc.
2. Environmental assessments:
   - Avoid protected areas, wetlands, and forest boundaries unless proper clearances are obtained.
3. Mitigation plans:
   - Prepare steps to handle potential spills, waste disposal, or habitat disruption.

Step 5 – Confirm Technical Feasibility

1. Design validation:
   - Confirm that gradients, bends, and terrain features conform to engineering standards.
2. Load-bearing capacity:
   - Evaluate whether the ground supports machinery or installations without risk.
3. Signal or service efficiency (for telecom routes):
   - Ensure that bends, reflections, or interference won't disrupt the service quality.

Step 6 – Obtain Approvals and Document Compliance

1. Prepare inspection reports:
    - Include photographs, measurements, and technical assessments.
2. Engage with stakeholders:
    - Get written approvals from regulatory bodies, clients, and safety inspectors.
3. Maintain documentation:
    - Store all permits, inspections, and environmental compliance reports for future audits.

Step 7 – Final Checklist Before Execution

- Route aligns with all mapped infrastructure
- Safety hazards are either avoided or mitigated
- Technical parameters match engineering standards
- All necessary permissions and clearances are obtained
- Emergency access and evacuation routes are verified
- Environmental concerns are addressed
- Documentation is complete and accessible

2.1.9 Identify Dependencies in a Route Inspection

Dependencies are factors, resources, or conditions that need to be in place for a project or task—like a route inspection—to proceed successfully. Identifying these early helps prevent delays, avoid conflicts, and ensure proper coordination between teams, vendors, or authorities.

How to systematically identify dependencies in a route inspection:

Step 1 – Understand the Scope of the Route

Ask:

- What is the purpose of the route? (e.g., installation, transportation, surveying)
- What are the start and end points?
- What are the technical and regulatory requirements?

This helps highlight the elements that must be ready before inspection starts.

Step 2 – List All Activities Related to the Route Inspection

For example:

- Surveying the terrain
- Verifying utility lines
- Obtaining permits
- Safety audits
- Equipment deployment
- Environmental assessments

Each of these may depend on something else.

Step 3 – Identify Types of Dependencies

Resource Dependencies

- Availability of survey equipment (GPS tools, drones, measuring devices)
- Qualified personnel (engineers, safety officers)
- Transportation or access vehicles

Regulatory Dependencies

- Permits for digging, trenching, or accessing restricted zones
- Environmental clearance approvals
- Local authority permissions for working in public areas

Technical Dependencies

- Existing maps or infrastructure data
- Communication systems for coordination
- Data from utility providers (e.g., power, water pipelines)

Environmental Dependencies

- Weather conditions (no heavy rain, landslides)
- Seasonal restrictions (wildlife protection zones)
- Ground stability and water drainage patterns

Inter-team Dependencies

- Coordination with operations teams, safety teams, and contractors
- Scheduling surveys around other ongoing activities
- Clear handover between inspection and execution teams

Step 4 – Create a Dependency Map or List

Dependency	Type	Impact if Missing	Who Provides It
GPS equipment available	Resource	Survey accuracy compromised	Equipment supplier
Local authority permit	Regulatory	Inspection cannot proceed	Local government
Utility data map	Technical	Risk of damaging pipelines	Utility provider
Weather forecast clearance	Environmental	Safety hazards increase	Meteorological dept.
Survey team availability	Resource	Delay in execution	Project manager

Step 5 – Validate Dependencies

- Are all dependencies confirmed or planned?
- Are there fallback options if a dependency fails?
- Who is accountable for each dependency?
- What's the deadline for each dependency to be ready?

Step 6 – Document and Monitor

- Record dependencies in project management tools or checklists.
- Set reminders or alerts for critical dependencies.
- Ensure communication lines are open between stakeholders.

Notes

UNIT 2.2: Choosing the right type of Optical Fiber

Unit Objectives

By the end of this unit, the participants will be able to:

1. Show how to select the appropriate optical fiber mode (Single Mode or Multi-Mode) based on the project location and network design.
2. Elucidate the basics of network design, including LAN/WAN integration and patch panel management.

2.2.1 Choosing between Single Mode vs Multimode Optical Fiber

The manner an optical wave is transmitted is often referred to as the mode. As they reach the optical fiber, uniformly frequencies optical waves are dispersed along several transmission routes. Mode is the name given to the specific path that each individual optical wave takes.

The Helmholtz equation for waves is used to compute the number of modes in a fiber optic cable. Applying boundary conditions to Maxwell's equation results in the actual Helmholtz equation. The projectile solutions of Maxwell's equation are the fiber optic modes as a result.

The modal dispersion phenomena that occur inside the fiber optic cable causes the modes.

Note: The quantity of glass fiber strands wrapped inside the cladding has absolutely no bearing on the modal dispersion.

2.2.2 Overview of Single Mode Optical Fiber

Single mode optical fiber is a specific kind of optical fiber made for the transmission of single mode light. This indicates that this particular type of optical fiber allows the transmission of various light waves with various frequencies along a single channel. The preferred abbreviation for these single mode optical fibers in the sector is SMF. Transverse mode optical signals are carried via the SMF. This indicates that although the electromagnetic oscillation occurs in a perpendicular or transverse direction to the length of the fiber optic core strand, the path of the optical wave transmission is parallel to it.

Characteristics of Single Mode Optical Fiber

The following features of single mode optical fiber (SMF) make them exclusive :

- SMF features a micro core diameter of sizes ranging amid 8 to 10.5µm. The diameter cladding of SMF is approximately 125µm
- Laser rays being the basis of optical signals in SMF, the categorized optical wavelengths for SMF is 1310 nm and 1550 nm
- Ideally, SMF offers limitless bandwidth, as it offers a single light transmission mode at a time
- According to TIA-598C, the industrial color-coding or sheath colour for an SMF is yellow for non-military uses

- Owing to higher fidelity for all pulse of light wave coupled with smaller diameters, these
- SMFs are appropriate for long-distance transmission without excessive signal/data loss
- The SMFs can transfer the optical signal over hundreds of kilometres at a transmission speed of 40Gbps and above thousands of kilometres at the transmission speed of 10Gbps by using dispersion-compensation devices
- Depending on the variation in features, the single mode optical fiber (SMF) is classified. Let us discuss the classification of SMF further

Types of Single Mode Optical Fiber

The general types of single mode SMF are listed below.

- OS1: The first type of SMF described in ISO/IEC 11801 is OS1. The core diameter of this kind of optical fiber is between 8 and 9 m. This fiber, however, experiences a greater attenuation of roughly 1dB/km. The signal weakens from one end to the other due to increasing attenuation. Because of this, this SMF is utilised for interior fiber-optic connections and relatively small distances.
- OS2: OS2 is an SMF variant that is generally superior. In ISO/IEC 24702, it is described. Although it has a similar diameter of 8 to 9 m, the signal only experiences a slight attenuation of 0.4 dB/km. Lower attenuation means that the transmission's signal strength is constant. Installations of outdoor and long-distance optical fibers favour this kind of SMF.

2.2.3 Overview of Multimode Optical Fiber

A type of optical fiber created for the propagation of several light signals is the multimode optical fiber. MMF is the abbreviation used in industry for multimode optical fiber. According to the different optical signal wavelengths, modal dispersion occurs in MMF. The MMF has increased modal dispersion as a result. Depending on the refractive index of the glass core material, the optic wave propagation route in the MMF is either zigzag or semi-elliptical in shape.

Characteristics of Multimode Optical Fiber

The following characteristics of Multimode optical fiber (MMF) make them ideal for certain applications.

- The core diameter of MMF is greater, ranging from 50 to 100 m. The typical core sizes for the basic types of MMF, however, are 50 mm and 62.5 mm. The cladding's diameter stays at 125 meters.
- The classified optical wavelengths in MMF remain 850nm and 1300nm since the light sources are either vertical-cavity surface-emitting lasers (VCSELs) or light-emitting diodes (LEDs).
- Modal dispersion limits the MMF's range of operation. MMF bandwidth has a theoretical value of 28000MHz*km.
- The industrial color-coding or sheath colour for MMF is an orange or aqua jacket, per TIA- 598C

Types of Multimode Optical Fiber

Refractive index and signal behaviour, along with a classification scheme, are the major two criteria used to divide the multimode optical fiber (MMF) into two categories.

- Based on System of Classification: Both the ISO 11802 and the TIA-492-AAAD classification methods are used to categorize multimode optical fiber. Let's understand about the following categories: OM1: According to ISO 11802, OM1 is a category of MMF. It has a core diameter of 62.5 mm. These optical fibers provide more bandwidth and are FDDI-grade cable compatible.
- OM2: According to ISO 11802, OM2 has a core diameter of 50 mm. It is intended to provide users more control over how light signals spread.
- OM3: The core diameter of OM3 is 50 m, and it is also described by ISO 11802. This particular MMF, however, is made for laser-optimized propagation over VCSELs.
- OM4: It is an MMF type that is specified by TIA-492-AAAD. Although it has a 50 m core diameter, it is made for high bandwidth, long-distance transmission. It supports transmission rates of 40 and 100 gigabits per second over a 125 meter distance.
- Based on the Refractive Index and Signal Behavior: The behaviour or course of a signal varies depending on the refractive index of the material that makes up the core of the glass. The following types of MMF are established based on the same.
- Multimode Graded Index Fiber: This kind of optical fiber has a core made of a substance with a graduated refractive index. This indicates that the refractive index of the core gradually decreases during signal transmission across a cable. The signal behaviour or path of propagation in this type of cable is semi-elliptical due to the graded refractive index. In this cable, attenuation and optical dispersion are reduced because of the same type of propagation.
- Multimode Step Index Fiber: This variety of MMF has a core with a diameter of 100 m. There is a variation in the refractive index throughout the fiber as a result of the big diameter. Complete or partial refraction inside the core is caused by a randomly fluctuating refractive index at various refraction angles

2.2.4 Difference between Single Mode and Multimode Optical Fiber

In addition to the features, there are several ways to describe the distinctions between single mode and multimode optical fiber. The highlighted distinctions between single mode and multimode optical fibers are listed below.

Impact of Optic Wave Propagation

As was said in earlier sections, it is understood that the modal dispersion and refractive index of the code glass material affects how optical waves propagate in different ways. The input and output signals sent by fiber optics are impacted by this variation in the propagation path. Let’s talk about the effects of optical fiber cables that are single mode and multimode.

Single Mode Optical Fiber

Since modal and light dispersion are negligible in single-mode optical fiber, the light wave propagates linearly. As a result, there is less attenuation and the signal strength is constant. As a result, across a great transmission distance, the input signal and output signal are of equal strength in SMF. Additionally, all of the data packets arrive at the output end of the optical fiber since many optical waves with different frequencies may Communicate via SMF but they all take the same path. As a result, the security of data transfer from the source device to the receiver is maintained.

Multimode Optical Fiber

Let's understand about how both of the ways that multimode optical fiber cable transmits information affect the input and output signals.

- Zigzag Light Propagation: Due to increased refraction, light dispersion and attenuation are higher in the zigzag form of light propagation in the MMF. As a result, with this kind of MMF light propagation, signal loss occurs. Additionally, because optical waves have zigzag transmission due to refraction at various angles with variable frequencies, each optical wave follows a distinct transmission path. As a result, light signals are transmitted at varying speeds using MMF. As a result, there is a chance that certain optic data packets will arrive at the recipient later than expected. Data is lost as a result.
- Semi-elliptical Light Propagation: Because the light beam does not hit the core wall during semi-elliptical propagation, there is less refraction and optical dispersion. The same causes just slight attenuation. Additionally, all light waves that propagate in this manner have a point-to-point semi elliptical shape. As a result, each wave arrives at the same location and is then transferred to the receiving device as a whole. Because of this, there is a very small loss of data packets.

Optical Resource Requirement

Both SMF and MMF installation require specific resources like light sources, connectors,

Single Mode Fiber

If placed for long-distance use, the SMF needs optical amplifiers to lessen dispersion in addition to a laser diode as a light resource. To inject the laser beam into the optical fiber, these components need to be calibrated precisely.

Multimode Optical Fiber

The MMF needs VCSELs or LED diodes as its light source. Additionally, if the MMF is installed for longer distance transmission, then the integrated circuit may need signal amplifiers, connections, and rectifier

Cost of Deployment

Despite being less expensive than multimode, single mode optical fiber cable nevertheless costs more to install than multimode fiber. This is due to the higher capital expenditure required for optical sources and integrated devices in the SMF network than MMF. In general, the equipment for laser diodes is 1.5–5 times more expensive than that for LED diodes. Additionally, SMF implementation costs may be higher than MMF due to the potential need for amplifier upgrades and system upkeep.

Application Compatibility

One of the distinctions between SMF and MMF is their compatibility with various applications.

- Long-distance optical fiber networks, where the signal intensity is anticipated to remain at its greatest, use SMFs. Campus fiber optic connections, submarine fiber optic connections, distant office connections, etc. are examples of common applications for SMFs.
- Fiber optic cables are mostly utilised with MMFs. These are utilised for telecom connections, LANs, video/audio/multimedia transmission, CCTV optic fiber connections, etc.

2.2.5 How to Select between Single Mode vs Multimode Optical Fiber

One must take into account a number of criteria while choosing between single mode and multimode fiber optics for a particular application. Considerable aspects include application requirements, fiber costs, installation system costs, equipment installation requirements, transmission distance and speed, among others. These selection parameters must be thoroughly compared before choosing either single mode or multimode optical fibers.

Comparison Chart for Convenient Selection

S.No	Selection Parameter	Single Mode Optical Fiber	Multimode Optical Fiber
1	Price of Fiber	Low	High
2	Price of Equipment and Installation	High (1.5-5 times more)	Moderate
3	Attenuation/ Signal Dispersion	Low	Moderate
4	Bandwidth	High	Low
5	Transmission	Low	High
6	Transmission Distance	High	Low
7	Data Reliability	High	Moderate

2.2.6 Basics of Network Design

Network design is the process of planning and structuring how devices and systems will communicate with each other. A well-designed network ensures efficient data flow, scalability, security, and reliability. Below is a breakdown covering fundamental principles, LAN/WAN integration, and patch panel management.

1. Basics of Network Design

Purpose of Network Design

- Enable seamless communication between devices
- Support data sharing and collaboration
- Ensure scalability, performance, and security
- Allow for monitoring, troubleshooting, and maintenance

Key Elements of Network Design

1. Topology – Defines how devices are connected.
    - Star, bus, ring, mesh, hybrid
2. Protocols – Rules for communication
    - TCP/IP, HTTP, FTP, SNMP
3. Hardware – Physical components
    - Routers, switches, cables, servers, firewalls
4. IP Addressing – Allocates unique identifiers
    - Static vs dynamic IPs
5. Security – Protects data and access
    - Firewalls, VPNs, authentication methods
6. Redundancy & Reliability
    - Backup links, failover systems, load balancing
7. Scalability
    - Designing for future expansion and increased traffic

2. LAN/WAN Integration

Local Area Network (LAN)

- Covers a small area like an office or building
- Provides fast data transfer speeds
- Typically uses switches, routers, and wired/wireless connections
- Example: Computers, printers, servers connected within a campus

Wide Area Network (WAN)

- Connects multiple LANs across cities, regions, or globally
- Uses technologies like leased lines, MPLS, or VPN
- Enables remote communication between offices
- Example: Corporate branch offices connected via the internet or private links

Integration of LAN & WAN

1. Router Configuration
    - Routes traffic between internal LAN and external WAN
2. VPN Setup
    - Secure remote access over public networks
3. Bandwidth Management
    - Ensures optimal usage for both local and remote traffic
4. Addressing & Routing
    - Use of subnetting to organize LANs and efficient routing protocols for WAN
5. Redundancy and Failover
    - Ensures connectivity if one path fails
6. Security Policies
    - Firewalls and encryption protocols to protect data as it moves across networks

3. Patch Panel Management

A patch panel is a passive networking device that connects and manages cables within a network.

Purpose of Patch Panels

- Organize and centralize cable management
- Simplify troubleshooting and maintenance
- Allow flexible connections between devices and network ports
- Improve airflow and reduce clutter in server rooms or data centers

Best Practices for Patch Panel Management

1. Labeling
   - Each port and cable should be clearly labeled
   - Maintain documentation mapping cables to devices or switches
2. Cable Management
   - Use structured cabling (Cat5e, Cat6, fiber optics)
   - Avoid tangling and stress on cables by using cable trays and ties
3. Port Utilization
   - Group ports logically based on department or floor
   - Leave spare ports for future expansion
4. Maintenance
   - Regularly inspect connections for loose cables or wear
   - Ensure cables are properly seated and avoid over-bending
5. Color Coding
   - Use different colored cables to distinguish between types of connections (e.g., data, voice, video)
6. Documentation
   - Keep updated diagrams and cable schedules for quick reference

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=jZOg39v73c4

Optical fiber cables, how do they work?

UNIT 2.3: Fiber Optic Tools and Tool Kit

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the importance of maintaining a proper and complete tool kit
2. Demonstrate how to arrange tools, including advanced cable-handling equipment and spares, for installation.
3. Show how to confirm the proper placement of the cable drum at the site.
4. Demonstrate how to test cables on the drum for optical continuity.

2.3.1 Fiber Optic Tool Kit

Right tools in best condition will ensure the best result in splicing and connectorization. It is suggested to keep the complete set of fiber optic tools needed for splicing, connecting, troubleshooting and testing. Fiber optic installer requires full list of fiber optic tools (needed start from installation to troubleshooting).

The tool kit primarily consists of:

- Testing equipment and testing supplies and consumables
- Cable handling tools.
- Termination/splicing tools and consumables
- Splicing splices

Fig. 2.3.1 Fiber optics tool kit

Basic Checks

Ensure tools, equipment availability for testing, splicing, cable laying. Refer to the list of tools needed in the tools manual. In case of unavailability of any tool, get in touch with logistics team. In case of faulty tools and equipment, get in touch with logistics team. Keep your tool-kit absolutely clean.

Remember that these tools vary from organization to organization depending on their need and budget as the case may be.

2.3.2 Various Optical Equipment

Fibre Optic Tools:

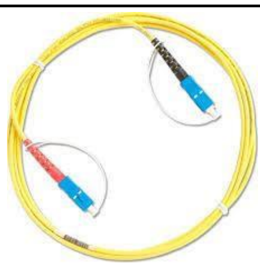
It is important to have proper tools and fibre for complete telecom communication.

Tools for Installer's Toolbox		Overview
1. Cable Preparation Tools		
Tubing Cutter		It is used to cut the cable jacket, and armour, cleanly without damaging fibers.
Rotary Cable Slitting & Ringing Tool		Used for slitting and ringing (circumferential cuts) on cable jackets.
Cable Jacket Stripper		Removes the protective outer jacket of fiber optic cables, approximately 2-3mm.
Fiber Optic Stripper		Helps to remove primary coating from fiber without nicking the optic fiber. It can also cut 2-3mm cable jacket.
Buffer Tube Stripper		Cuts jacket/buffer tubes in loose tube cables. It is similar to UTP jacket cutters and prevents fiber damage
Kevlar Scissors		Super sharp scissors used to cut Kevlar fibres in FO cable.

Tools for Installer's Toolbox		Overview
Lineman Scissors		Heavy-duty scissors for Cutting thicker cable materials.
2. Splicing & Termination Tools		
Crimp Tool		Crimps fiber optic connectors onto the cable. It is used in termination.
Scribe		Used to score and cleave fiber during termination. Sapphire or carbide are best.
Needle Nose Pliers		Used when accessing ripcords or strength members inside the fiber optic cable.
Tweezers		Used to handle and position individual fibers during splicing or termination.
Fusion splicer		Core tool that aligns and fuses fibers with electric arc.

Tools for Installer's Toolbox		Overview
Fibre cleaver		Precisely cleaves fiber ends for fusion splicing.
Fusion splice protectors		Protect the splice joint from stress and environmental factors. Use the type recommended by the fusion splicer, manufacturer
Mechanical splices		Alternative to fusion, used for joining fibers with mechanical alignment.
3. Polishing & Connectorization Tools		
Polishing Plate		Base surface for polishing.

Tools for Installer's Toolbox		Overview
Polishing Pad		Soft underlay beneath polishing film.
Polishing Puck		Insert connector into this polishing tool, lay on polishing paper. Holds the Ferrule connectors in place during polishing.
Connector Curing Oven		Used to cure epoxy in connectors. Portables and easy handling
Heat Cure, 2-Part Epoxy, 2.5 Gram		Adhesive for fixing connectors. "BiPax" package has epoxy and hardener in plastic pack-age that is mixed in the package. Can be used with many connectors at one time
Cheap scissors		Used to cut corner off epoxy package. Cheap once are available which can be used and throw.

Tools for Installer's Toolbox		Overview
Anaerobic Adhesive + Accelerator (optional)		Faster adhesive method. Used in anaerobic connector termination.
4. Testing & Inspection Tools		
Flashlight Continuity Tester (MM only) or Visual Fault Locator (VFL-red laser-SM or MM)		Used for Testing purpose- bright, visible light source for checking continuity or tracing fibers, VFL can find faults also.
Light source		Provides stable optical signal for testing.
Power meter adapters		Measures optical power at fiber ends. Can be used on 2.5mm ferrules.
Reference Test Cables		Pre-tested, low-loss cables for accurate measurements. To be used based on connector Types.
Connector Mating Adapters		Connectors with precision alignment sleeves (ceramic/metal preferred)- ST/ST, SC/SC, etc, or hybrid ST/SC

Tools for Installer's Toolbox		Overview
Connector inspection microscope		Inspects end-faces of connectors for dirt, cracks, or defects.
ST Bare fiber adapter		Used in testing and it allows direct testing of bare fibers.
Optical Time Domain Reflecto meter (OTDR)		Used in OSP cables and troubleshoot problems. Advanced tool to measure loss, locate faults, and characterize fiber spans.
5. Cleaning & Safety Equipment		
Alcohol-saturated pads		Used to clean fibers and connectors before splicing/termination.
Wipes & Reagent-Grade Alcohol (99%+ ethanol)		For precision cleaning of fiber ends and equipment.

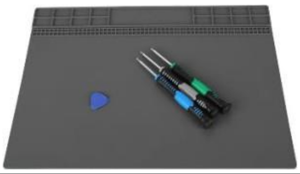
Tools for Installer's Toolbox		Overview
Lab wipes		Lint-free wipes for cleaning connectors/tools.
Dry connector cleaner		Dry connector cleaner
Trash Bin (with lid)		Safe disposal of fiber scraps. 1-pint deli container with lid works well.
Black work mat		Provides contrast background to easily see thin fibers. It helps see the fiber scraps to Clean.
Safety glasses		Protect eyes from fiber shards and laser light.

Table 2.3.1 Tools and Equipment used in Fibre Optics

2.3.3 Optical Power Meter (OPM): A Must for Fiber Cable Testing

A testing tool used to precisely measure the power of fiber optic equipment or the power of an optical signal transmitted through a fiber cable is an optical power metre (OPM), also known as an optical power metre tester or OPM tester. The OPM tester, which consists of a calibrated sensor that measures an amplifier circuit and a display, can be used to install, troubleshoot, and maintain any fiber network.

Additionally, it can adapt to different connector types like SC, ST, FC, etc. The optical power metre typically has five buttons: the POWER button, the LIGHT button, the dB button, the ZERO button, and the button. Below is a list of each button's functions:

An intuitive way to measure optical power is by looking at the optical power metre reading on the OPM screen, which is displayed in dBm units. The milliwatt reference power is indicated by the letter "m" in the term "dBm." The power of a source with a power level of 0 dBm is therefore 1 milliwatt. Similar to how 0.1 milliwatt equals -10 dBm and 10 milliwatts equals +10 dBm. The loss increases as a number becomes increasingly negative. OPM tests measure a negative number for loss, but in everyday speech, it is referred to as a positive number. For instance, the loss is 3.0 dB if the optical power metre reads "-3.0 dB". In addition, different network types result in different optical power ranges.

Fig. 2.3.2 Optical Power Meter

Network Type	Wavelength (nm)	Power Range (dBm)	Power Range (W)
Telecom	1310, 1550	+3 to -45 dBm	50 nW to 2 mW
Datacom	650, 850, 1300	0 to -30 dBm	1 to 100 uW
CATV, DWDM	1310,1550	+20 to -6 dBm	250 uW to 10 mW

Types of Optical Power Meter

OPM testers come in a variety due to resolutions that range from 0.001dB to 0.1dB. Depending on the requirements of the test, one should select an acceptable resolution for measurement. For instance, laboratory networks often require OPM testers with a precision of 0.01dB, whereas a few specialist fiber optic power metres have a resolution of 0.001dB.

Additionally, the physical limitations of transferring standards using optical connectors result in measurement uncertainties for fiber optic power metres that are essentially the same across the board. No matter what the display's resolution, most metres have an error of +/-5 percent, or roughly 0.2dB.

Fiber Optic Power Meter Test Procedure

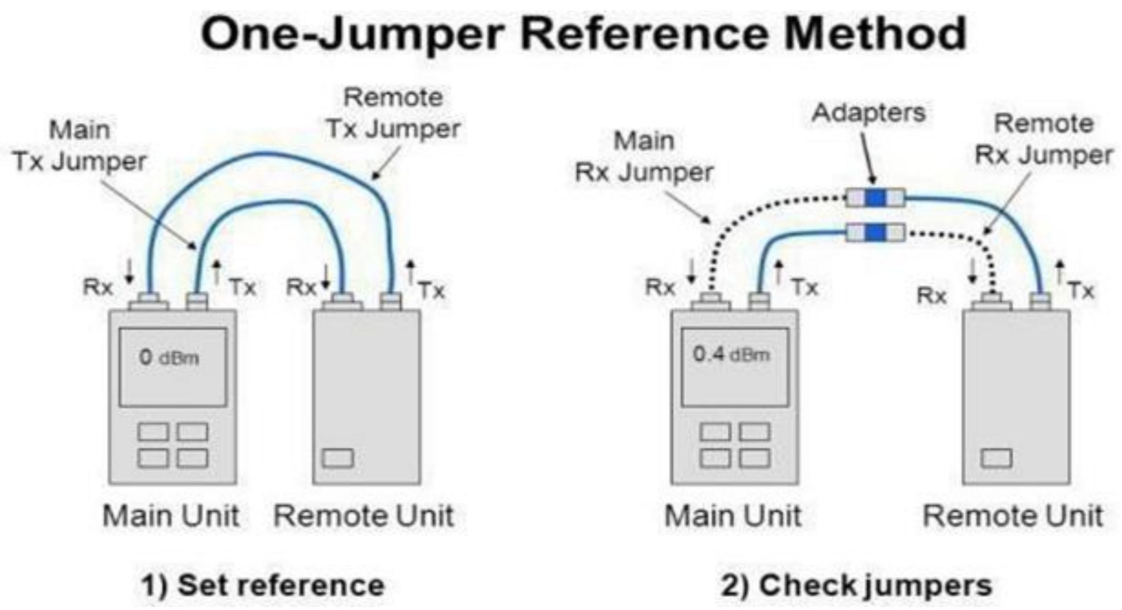
An OPM tester and a light source are two pieces of handheld equipment required to evaluate a fiber optic system's performance from beginning to end. A wavelength of light is transmitted along the fiber by the light source. The power metre reads the optical power level of the light at the other end of the cable and calculates the amount of signal loss. Optical power metres should utilise the same wavelength as the light source since optical fiber loss varies with wavelength. For instance, the optical power metre should be set to 1310nm testing if the light source runs at that wavelength.

Loss budget (TIA/EIA specification limits)

Element	Insertion Loss
Splice	< 0.3 dB at all wavelengths
Connector Pair	< 0.75 dB at all wavelengths

The connection attenuation allowance should be matched to test results as follows:

Link Attenuation Allowance (dB) = Cable Attenuation Allowance (dB) + Connector Insertion Loss Allowance (dB) + Splice Insertion Loss Allowance (dB)



Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=fCX7U2oCWes

Fiber Optic cable splicing

UNIT 2.4: Installation of Fiber Optic Cable

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the standard procedures for trenching, cable laying, splicing, jointing, blowing, and back-filling.
2. Discuss the procedures for sealing joints using heat shrinking, multi-diameter seals, and mechanical seals.
3. Determine the key steps involved in developing an effective installation work plan.
4. Describe the methods for managing labor and coordinating with third-party vendors in optical fiber projects.
5. Demonstrate how to ensure adherence to manufacturer-specified bend radii and manage tension during installation.
6. Demonstrate how to oversee cable blowing/jetting using advanced blowing machines.
7. Show how to verify additional cable length (loop) is available at jointing locations for future use.
8. Demonstrate how to ensure proper uncoiling and alignment of PLB ducts.
9. Explain the installation procedures for ultra-low loss cables and their significance in network performance.
10. Demonstrate how to ensure compatibility of ultra-low loss cables with project requirements.
11. Explain the importance of standard reporting, documentation, and as-built diagram protocols in optical fiber installation.

2.4.1 Fiber Optic Cable Specifications – Tensile Strength

Tensile Strength - is the maximum load that can be set upon a link before any harm strikes the strands or their optical attributes:

- The maximum load that a cable can withstand at the time of laying is the short- term or installation load.
- The operating load is the load that impact on cable after the installation and it will be less compared to the installation load
- At the time of installation, the main concern will be to lay the cables with minimum load as possible. That’s why there will be a definite tensile load value on every cable and the actual practical load should not be exceeded it.
- This is the practical permissible limit but not a cable damaging load.
- The maximum load that a cable can withstand at the time of laying is the short- term or installation load. The force may be because of pulling over sharp objects/corners or pulling through the ducts.
- At the time of installation itself, installers will measures and control the stress with which they pulling optical fibers to avoid sudden hard pulling.
- The load which will effect on installed cable will be less and this load value is termed as operating load or long term load.
- According to the application in which where we are laying the cable, both the tensile loads will be indicated on the cable sheath.

2.4.2 Fiber Optic Cable Specifications – Bend Radius

Bend Radius is the minimum radius that one can bend an optical fiber cable without damaging it. If the Bending is more than the permissible limit, the fiber loss will be more at the following points:

- Do not bend the fiber cable over a permissible radius limit.
- Like tensile loads there are 2 bend radiuses, installation radius and Static radius.
- The minimum bend radius value that a cable can sustain the attributes without any breakage at the time of installation is called installation bend radius. This bend will be higher (Radius should be minimum)
- The bend radius which is acceptable after the installation of optical fiber without any pulling force is called long term bend radius. The bend value will be less (Radius should be higher)
- Depends on the application of cable which where it is using these values will be different.
- The carelessness in the fiber handling will normally make the bend radii to exceed permissible value. Normally it will happen at the time of pulling cable through duct when the bend radii are too small.
- Cable should not bend exceed a permissible limit when it is going through trays or when installing.
- Optical fibers are very flexible to use in outdoor and indoor applications. Even though there should be chances of bending optical fiber cables in corners or at the near to equipments. These over bending can damage the fibers permanently.
- Another cause of damages in optical fiber is tight wraps around the cable normally at the user end.

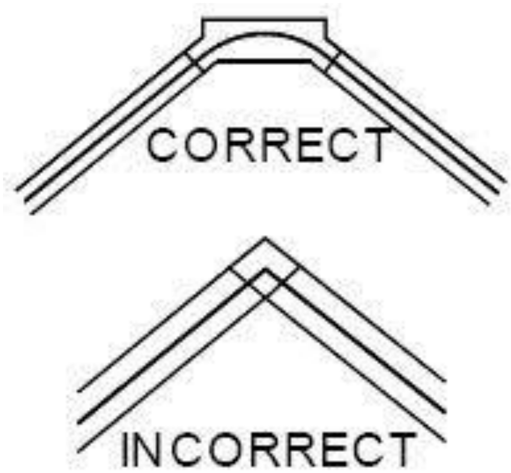


Fig. 2.4.1: Bend radius

2.4.3 Fiber Optic Cable Specifications - Crush & Impact

Crush and Impact helps to make sure however well an optical fiber can live through slow crushing or compression impact. The live cable will be crushed or compressed at any point to measure changes in optical power loss as per the test procedure. For every customer requirement permissible attenuation will be specified for a particular compression or impact force.

- To measure the changes in optical fiber characteristics and for the fiber breakage values the optical fiber cables may be tested.
- For the practical installation these crush and impact measurements are essential.
- The duct or tray which is using to run the heavier power cable can be used by optical fiber cables.
- It is better to avoid large compressive load on optical fibers, and to make that optical fiber cable should be lay on the top or sides of heavier cables. If the compressive load is more on fiber cables, it can produce physical damages.
- The chances of getting damage in installed optical fibers are more if they are shifting with a large weight on it.

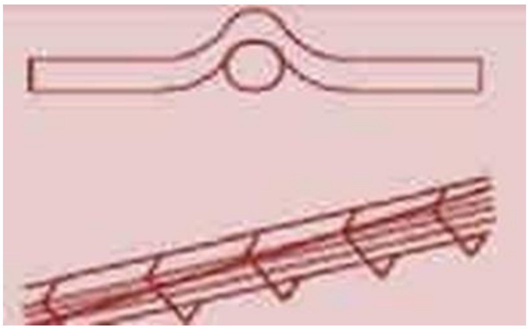


Fig. 2.4.2: Bend radius

Refraction of Light

The phenomenon of a light ray changing direction as it travels through a transparent medium is known as refraction of light. The refractive index of the mediums determines how much the direction of the light ray varies.

Total internal reflection is the only foundation upon which optical fibers are built. The illustration below explains this.

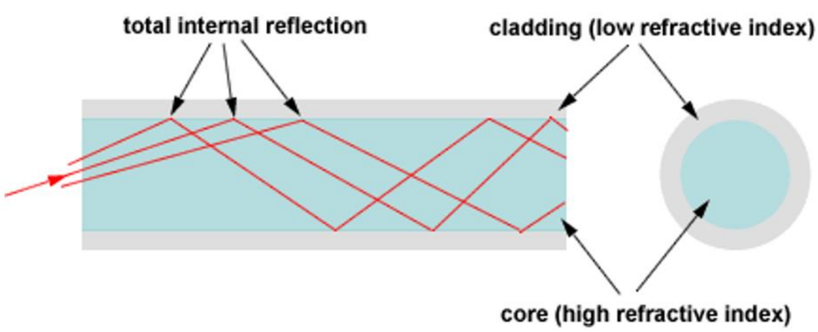


Fig. 2.4.3: Refraction of Light

A long, thin strand of ultra-pure glass, roughly the size of a human hair, is an optical fiber. To carry light messages across great distances, optical fibers are bundled together into optical cables.

The core, cladding, and buffer coating make up typical optical fibers. The fiber's interior, or core, is where light travels. The entire core is encased with cladding. Light in the core that strikes the cladding's boundary at an angle less than the critical angle will be reflected back into the core by total internal reflection because the refractive index of the core is higher than that of the cladding.

The core diameter spans from 8 to 62.5 m for the most popular varieties of optical glass fiber, which include 1550 nm single mode fibers and 850 nm or 1300 nm multimode fibers. The most typical diameter for cladding is 125 m. Typically, buffer coatings are made of acrylic or nylon, two types of soft or hard plastic with diameters ranging from 250 to 900 m. The fiber is protected mechanically and has bending flexibility thanks to buffer coating.

Polarization-maintaining optical fiber:

In fiber optics, polarization-maintaining optical fiber (PMF or PM fiber) is a single-mode optical fiber in which linearly polarized light, if properly launched into the fiber, maintains a linear polarization during propagation, exiting the fiber in a specific linear polarization state; there is little or no cross-coupling of optical power between the two polarization modes. Such fiber is used in special applications where preserving polarization is essential.

Specialized uses for polarization-maintaining optical fibers include quantum key distribution, interferometry, and fiber optic sensing. Since polarised light is needed as input for the modulator, they are also frequently employed in telecommunications to connect a source laser and a modulator. Due to its high cost and lower attenuation than single-mode fiber, PM fiber is rarely employed for long-distance transmission. Fiber-optic gyroscopes, which are frequently utilised in the aerospace sector, are another significant use.

The polarisation extinction ratio (PER), which is the ratio of correctly to wrongly polarised light and is given in dB, is commonly used to describe the output of a PM fiber. With the use of a PER metre, PM patch cord and pigtail quality can be assessed. Extinction ratios in excess of 20 dB are a sign of good PM fibers.

Polarization control using different fiber squeezes.

2.4.4 Fiber Optic Cable Specifications Attenuation

Attenuation is the decreasing optical power when a light signal is travelling from sender to receiver. There are different classifications of attenuation, according to the cause of loss in power. Attenuation can happen because of Absorption, Scattering, Birefringence, and Bending etc. Optical attenuation is termed in dB (decibel).

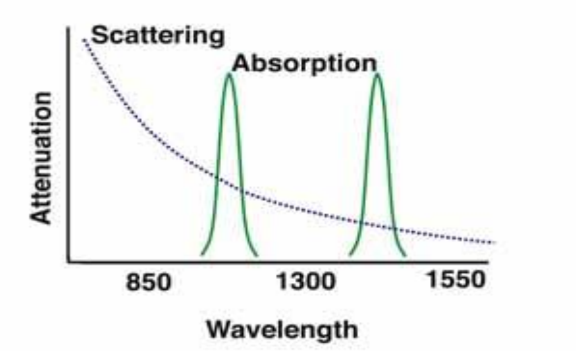


Fig. 2.4.4: Cable

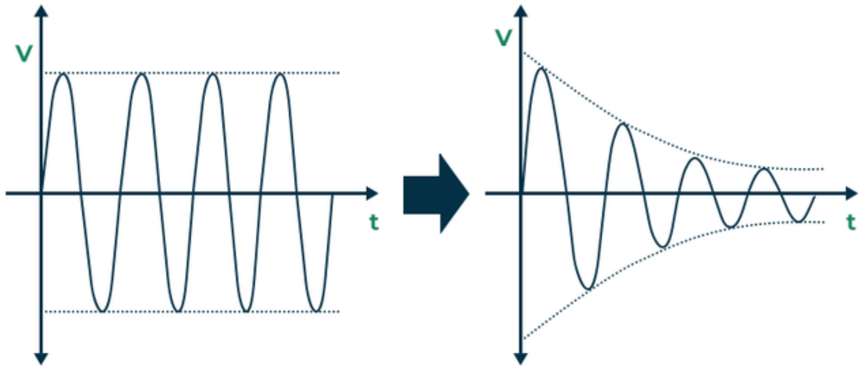


Fig. 2.4.5: Attenuation in Optical Fiber

Attenuation:

Attenuation refers to the weakening of a signal and can affect any sort of transmission, analogue or digital. Because this is a typical result of a signal while it is transmitting across long distances, in some circumstances it might be referred to as attenuation loss. This can be expressed in terms of DBs (decibels) for each foot, kilometre, thousand feet, etc. in some cables, such as conventional or FOCs (fiber optic cables). When the attenuation for each unit distance is low, the cable efficiency is high.

A repeater or repeaters must be added to the length of any cable when it is necessary to transmit signals over vast distances. Because repeaters are crucial in boosting the signal's intensity to overcome this. So, this improves communication at its highest possible level.

There are different types of attenuations which include deliberate, automatic, and environmental.

- **Deliberate:** Wherever a volume control can be used to lower the sound level over consumer electronics, this form of attenuation may occur.
- Automatic: By detecting automatic level to activate attenuation circuits, this type of attenuation is used to stop the distortion of sound in TVs and audio equipment.
- **Environmental:** This type of attenuation refers to a reduction in signal strength caused by the transmission medium, which may be wireless, fiber optic, or coupled to copper wire.

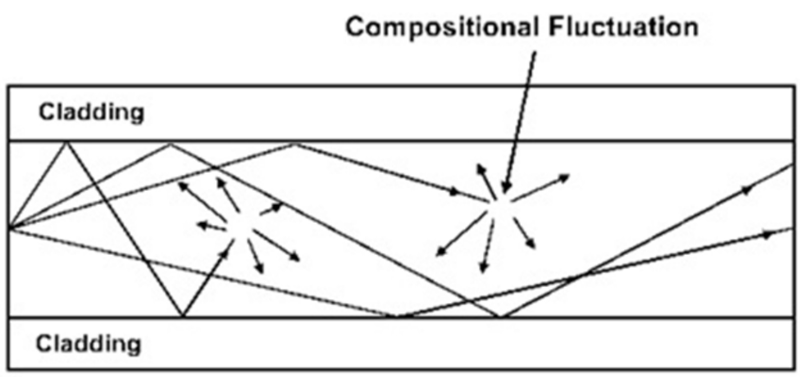


Fig. 2.4.6: Attenuation

2.4.5 Fiber Optic Cable Specifications Continuity

Fiber end continuity is the testing method using to verify the optical signal delivery at the receiver side of the communication system. It is working by measuring the optical signal power at the both end of the fibers and also can be works by checking the reflecting light intensity. If the reduction in the intensity of light pulses is ‘insignificant’ or ‘zero’ the continuity is good and the OFC is fine.

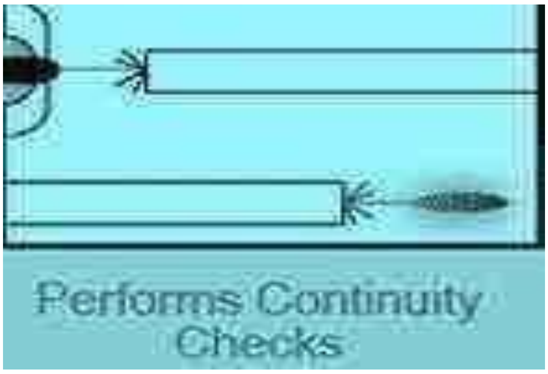


Fig. 2.4.7: Fiber optics continuity checks

2.4.6 Dispersion in Fiber Optic Cable

Dispersion in optical fibers

The process by which an input signal broadens/spreads out as it propagates/travels down the fiber is referred to as optical fiber dispersion. Modal, chromatic, and polarisation mode dispersion are the typical types of dispersion in fiber optic cable.

In multimode fibers and other waveguides, a distortion mechanism known as modal dispersion causes the signal to be spread out in time as a result of the various modes' varying rates of propagation. As is common knowledge, light rays entering a fiber at various angles of incidence will follow various routes or modes. As shown below with a step-index multimode fiber, some

of these light rays will travel directly through the fiber's centre (axial mode), while others will continually bounce off the cladding/core barrier and zigzag their way through the waveguide. Modal dispersion (or intermodal dispersion) occurs whenever there is a bounce off. The model dispersion will increase as the path lengthens.

The varying speeds of light rays cause a phenomenon known as chromatic dispersion, which is the spreading of a signal across time. The effects of material and waveguide dispersion combine to create chromatic dispersion.

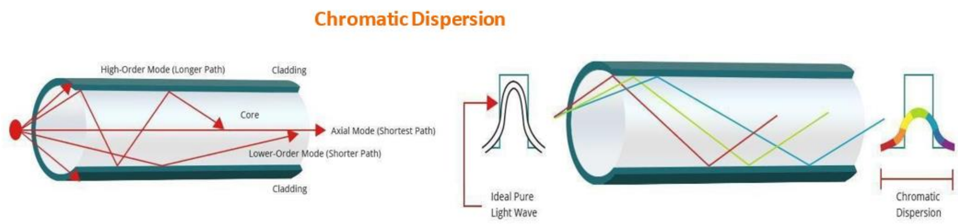


Fig. 2.4.8: Chromatic Dispersion

The polarisation dependency of the properties of light wave propagation in optical fibers is represented by polarisation mode dispersion (PMD). The propagation characteristics of light waves with various polarisation states typically varies slightly in optical fibers. When considered as an energy wave or area, light has two axes that are perpendicular to one another, the electromotive force and the magnetomotive force. PMD happens when the energy in these two axes moves at a different rate in a fiber.

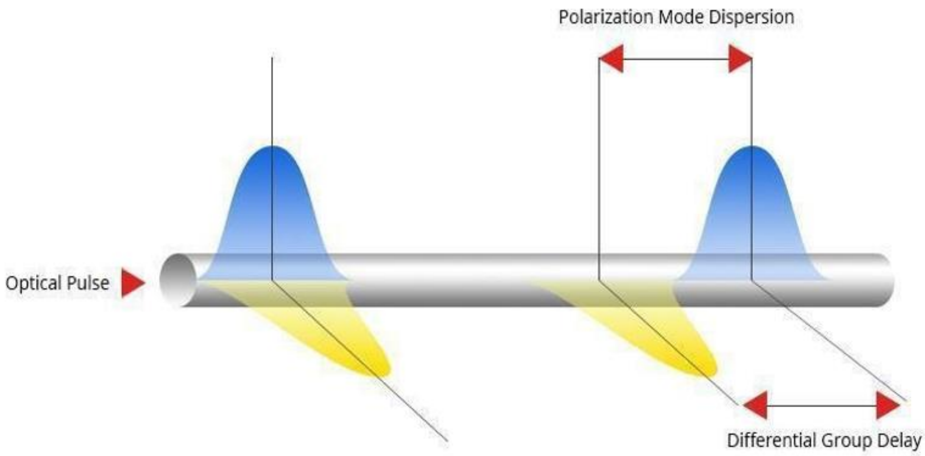


Fig. 2.4.9: Polarization Dispersion

Despite the fact that optical fiber dispersion can spread and distort information in many different ways over time, it is not always detrimental to the transmission of telecom signals across fiber optic networks. When employing wavelength division multiplexing, it is really preferable to have some dispersion because it could lessen the impacts of nonlinearity.

A technique for multiplexing several services onto optical light lines is provided by the telecommunications industry standard protocol known as optical transport networking. It was initially intended to encourage the expansion of networks beyond SONET/SDH.

Technological solutions like OTN are being modified as network service providers deal with the ever-growing challenge of rapid user growth and increasing digital traffic, with things like mobile apps, social media, cloud computing, VoIP, and video chatting.

The majority of contemporary networks are packed-based and feature multiple services and applications with varying demands on bandwidth and transmission performance, in contrast to circuit-based networks of the past, which frequently consisted of predictable connections between pairs of endpoints.

The information structure is called the Optical Transport Module (OTM).

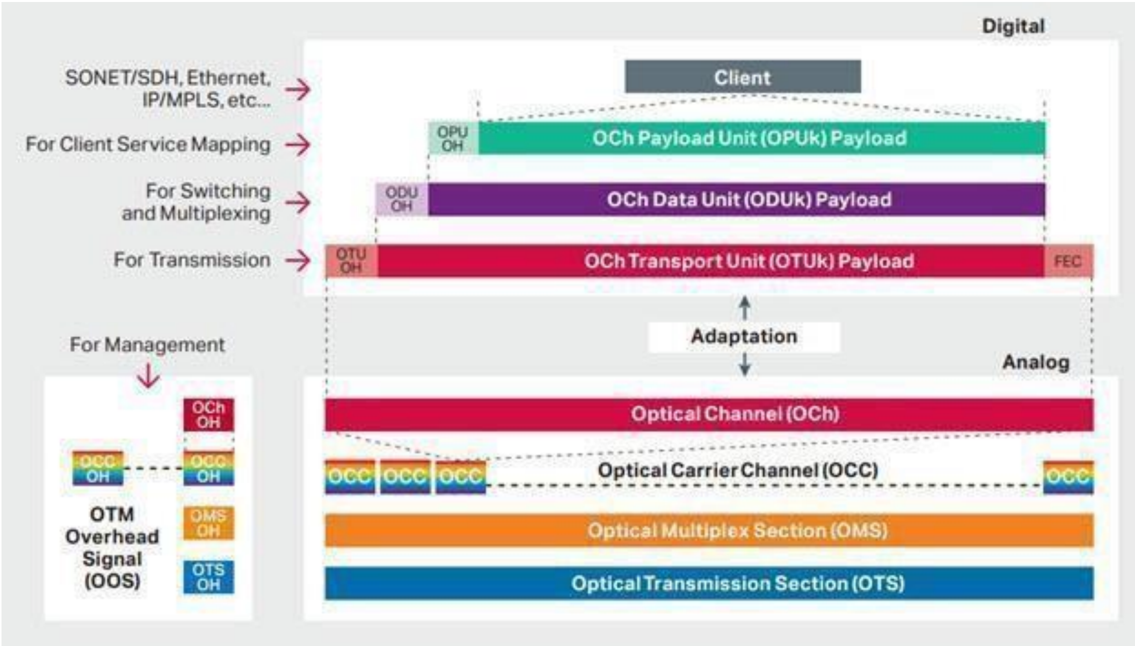


Fig 2.4.10: Optical Transport Module

Benefits of Optical Transport Networking

Lower cost: OTN provides an economical method of filling optical network wavelengths and eliminating excessive expenditure by transporting numerous clients on a single wavelength.

Performance: OTN enables performance to be managed for each client by allowing individual configuration of bandwidth to each service or group of services.

Spectral efficiency: By guaranteeing constant fill rates all throughout a network, OTN offers efficient use of DWDM capacity.

Flexibility: OTN networks let operators customise the technologies they use at the moment while also allowing for the adoption of new ones as and when clients demand them.

Security: OTN offers a high level of privacy and security because to the use of hard segmentation of traffic on dedicated circuits.

2.4.7 Signal Strength and Quality KPIs of Optical Fibre

The Three C’s of an Optical Fiber: The "three C's" are the fundamental components of an optical fiber in terms of fiber testing:

- Core: A carefully treated glass or plastic that makes up the fiber cable's centre. This must be as pure and clean as possible because it serves as the conduit for the transmission of light throughout the entire wire.
- Cladding: To enable consistent reflection of the light source back into the core, an extra layer made of material comparable to the core but with a lower refractive index is added.
- Coating: The cable's outer layer, which encircles, shields, and insulates the core and cladding.

- Optical Loss Measurement: The power output of the light source drops as it travels through the fiber. Decibels are used to express the optical loss, or drop in power level (dB).
- Fiber testers can measure the overall optical loss in a fiber most precisely by injecting a known amount of light into one end and using an OLTS to measure the amount of light at the other end. This approach needs access to both ends of the fiber because the optical light source and power metre are attached to different ends of the network.

Optical Power Measurement: A power measurement is a test of the transmitter's signal intensity once a system has been turned on or activated. An optical power metre, which can be attached to the output of the optical transmitter or to a fiber cable at the location of the optical receiver, will show the optical power received on its photodiode. The unit of measurement for optical power is "dBm," where "m" stands for 1 milliwatt and "dB" for decibels.

Testing Fiber for Optical Loss

Fiber testers must be connected to a test source to provide an optical light standard and a launch cable to offer a calibrated "0 dB loss" reference for testing fiber optic cables for optical loss. To determine the loss in dB of the fiber itself, a power metre at the other end of the circuit will measure the light source with and without the fiber under test.

Launch cables and "receiving" cables attached to the power metre are additional ways to verify fiber optic cable connections. The loss measurements at both test cable connection ends are included in this standard test for loss in an installed cable plant. Because of this, a crucial component of every fiber test is making sure all connections are exceptionally clean.

You may assess optical loss in fiber optic cables using an optical time domain reflectometer (OTDR). The OTDR equipment examines the backscatter of light that is returning to the source location using high intensity laser light that is emitted at pre-determined pulse intervals through a connecting connection.

2.4.8 Factors Effecting OFC

Incorrect Specification of Fibre Optic Cabling

If the speed you wish your network to run on doesn't have the correct fibre optic cabling installed, it will never run at the desired speed. For example for 10Gig speeds and links the maximum cable length you can run the fibre optic cable ranges from OM1 (33metres), OM2 (82metres), OM3 (300metres) to OM4 (400metres). Exceed this distances or pick the wrong fibre optic cable and your network will not

Perform at the Desired Speed and Standard

Consideration between singlemode and multimode fibre optic cable choice. Singlemode fibre cable is a single core of fibre cables vs a multimode fibre cables is made up or glass modes along the cable.

Singlemode light transmission is via a laser rather than a light source so although the speeds and distances achievable are greater the overall cost of the link and hardware are greater.

Poor Connector Terminations

- The connector starts with firstly making the correct choice of fibre optic connector. The fibre optic connector chosen must match the existing patch panel connectors as the different types are not interchangeable and don't fit into one another
- The ST fibre connector was the connector of choice for some time but has been surpassed by the SC and LC connectors with the LC now the connector of choice for its performance and low density patching characteristics
- Additionally if the fibre optic cabling connector ends are poorly terminated or the ends bent too sharply then the light passing through will either be limited or at too low a range for the transmission to be connected. Light could still be shining through a fibre optic cabling links but not have enough transmission quality to create the data link.
- With fusion splicing and correct terminations, standard optical fibre cabling speeds can be guaranteed.

Dirty Connector Ends

- If the fibre optic cabling connector ends become dirty then the transmission can be intermittent or not work at all. Keeping the unused optical fibre cabling connectors covered when not in use goes a long way to alleviating this problem
- Dirty connector ends can be caused during the termination process but are more commonly caused during un-patching and re-patching of fibre optic patch leads and links. Care should be taken to clean the fibre optic ends each time patching is undertaken.

Poor Installation

- Fibre optic cabling has a specific bend radius and pulling tension guideline when installing the main cabling runs. If the cable becomes stretched or bent too tightly then the quality of light down the cable is compromised resulting in a poor or.

2.4.9 Factors Effecting OFC – Choosing Cable

Let us understand how to choose cables on the basis of various factors performance that affect the cable.

Cable	Cable Structure		
Parameter	Loose Tube	Tight Buffer	Breakout
Bend Radius:	Larger	Smaller	Larger
Diameter:	Larger	Smaller	Larger
Tensile Strength: (Install):	Higher	Lower	Higher
Impact Resistane:	Lower	Higher	Higher
Crush Resistance:	Lower	Higher	Higher
Attentuation Change at Low Temperatures:	Lower	Higher	Higher

Fig 2.4.11: Choice of cables consideration factors

2.4.10 Handling Optical Fiber Cable

Optical fiber Cable Handling:

- Optical fibers are easily getting damage at the time of installation because of careless handling. These damages will largely affect the performance of the communication system and sometimes cable need to be replaced.
- We must handle the cable appropriately as described in subsequent pages to avoid these situations.

Cable Unloading:

Following precautions need to be taken during the cable unloading:

- At the time loading and reloading the optical fiber cable drum should not drop from height as the load can damage the fibers inside the cables.
- At the time of reloading from truck roll the drum from it to floor or platform, which should be in a same height or otherwise use forklifts.
- Forklift has to be used when unloading it from truck.
- Use inclined ramps to roll the drum with control
- Roll cable drums one at a time on ramp.

Cable Unwrapping:

Following precautions need to be taken during the cable handling:

- Every cable drum has to be wrapped by wooden laggings to avoid damage by impacts or to protect from sudden rolling of drum on rough surface. So it has an essential role in cable protection.
- Remove the wrapping completely only at the time of installation
- Cable Storage
- The best storage position of the drum is upright; otherwise winding effects can cause damage on it.
- In some situations, storage space will be less and on these places drums should be stacked. So the stack should be wrapped with the flanges edge of drums.
- To avoid the overlapping of flanges with the cables after removing entire wrap the drum should be aligned as the flanges should touch each others.

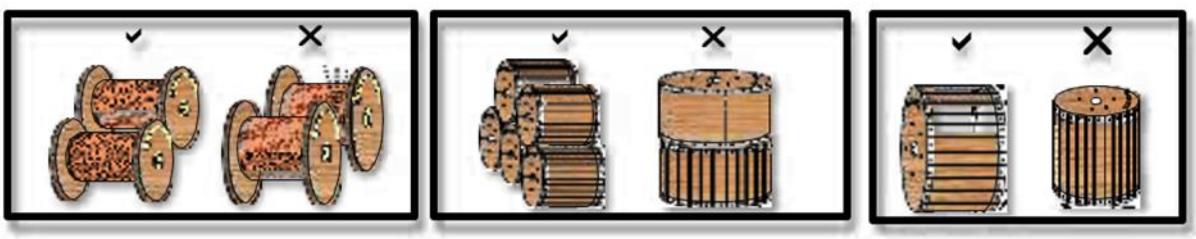


Fig 2.4.12: Handling OFC

Environment Storage Issues

- Wooden drums are using to wound optical fiber cables. After some duration of time these wood gets degraded due to environmental actions.

Important Way to Address the Same

- Recommending Indoor storage of drum to avoid the degradation.
- The storing platform should be hard and moist free to avoid degradation.
- The wooden parts should not be in touch with any moist soil to avoid the generation of wooden degrading insects.
- Use polythene sheets to cover the drum stacks in outdoor storage areas to avoid degradation due to rain. The drum moisture content should not more than 25%.To protect the drums from these situations in-house storage prefers.

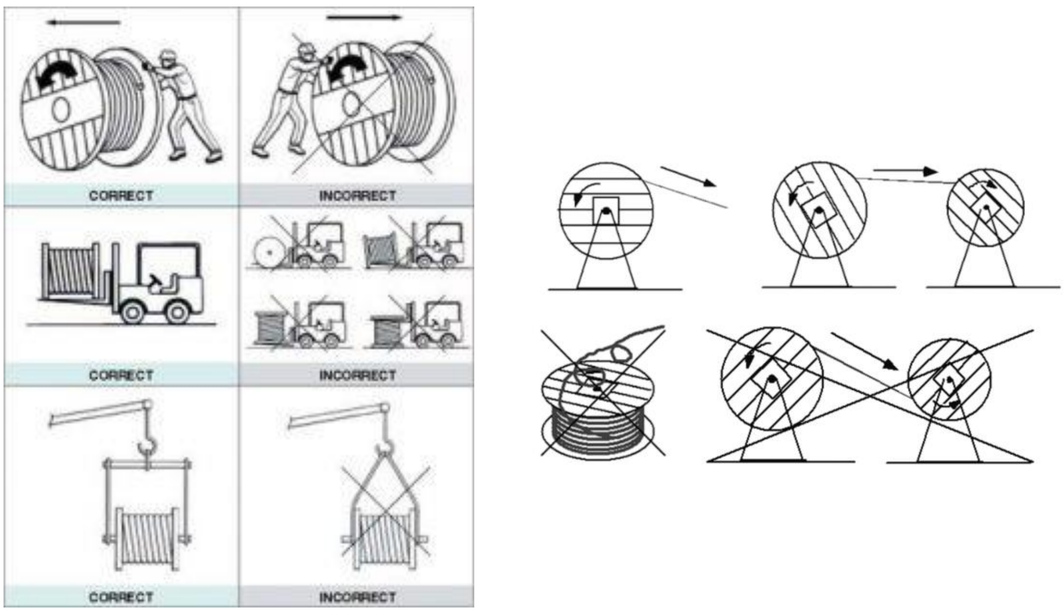


Fig 2.4.13: Handling OFC

Pre Installation - Drum Inspection

Check the drums for the following:

- Before shifting drums from storage space to sites all the drum should be check and verified by continuity breakage and damage inspections.
- The important drum parameters or specifications like fiber count & type, meter marking, cable length, manufactures details etc. Should be marked on the drum flanges.
- All these verifications should be done before taking it to shift from one place to another.

Cable Inspection

Check the cable for any damage:

- In case of doubt, remove lagging & examine cable thoroughly.

- Continuity test should be done for every cable.
- Total length and the total attenuation should be measures and marked
- At the time of shipping itself, check the damages and inform suppliers.
- Inner and Outer ends should be located for every cable drum.
- Pulling grips and end caps should be removed from the cable before taking it to sites.

Apart from making sure that the correct type and quantity of cable was shipped from factory, it is necessary to inspect each drum for damage. Before installing cable, test all fibers for their optical continuity, attenuation and length; if any deviation is found inform the supplier immediately.

Opening Drum

Open the drum carefully keeping the following in mind:

- Optical Fiber cables are protected by enclosing it with wooden batten nailing on the flanges of drum with aluminum or iron strip .It can avoid damage of fibers when it transporting from one location to another. For laying the cable at the installation site, it has to open without damaging the fiber.
- Strip cutters can be used to cut the aluminum or iron strip safely.
- Wooden batten should be taken out safely with hammers.
- Nails also should be removed or bend it to avoid injuries while handling the drum.
- Remove thermal wrapper applied over cable.

Preparation of Drum

- The reel or drum mounted on a shaft which can roller payoff. For the easy roll of action, the pulling direction and the payoff orientation should be same and take out the cable from the roller from top to avoid cable contact with platform.

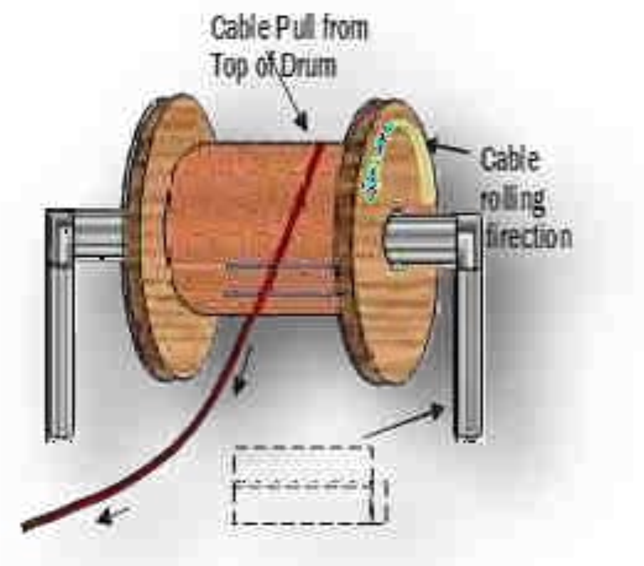


Fig. 2.4.14: Preparation

2.4.11 Installation of OFC

The actual installation process basically involves pulling cable, terminating and testing it. Pre-requisites to do the same are to:

- Keep the cable pulling plan handy.
- Keep copy of all the permits handy.
- Keep all the tools & equipment & emergency plan handy.
- Share the cable pulling plan with all the relevant stakeholders/installation team.
- The location of intermediate access points, splice locations and the specific responsibilities of each member of the installation team.

Steps OFC Installation

Work to convert the designed system to operating communication system. A contractor comes in between user and the network owner to establish the real connection. The main roles of contractor are design, installation, testing, trouble shooting, documentation, and restoration. The contractor must have the experience on the network installation and should have the same like reference works to submit.

Following are the steps for installing optical fiber cable:

Step 1– Installation through

(a) Trenching or (b) Aerial.

Step 2– Ducting process.

Step 3– Conduct figure 8'ing'. Step 4– Cable pulling and blowing. Step 3– Cable termination.

Step 1(a)- Trenching

Trenching is a process of making a narrow excavation on earth along a short distance. It involves digging, placing cables and refilling. Trenches can be made by several methods like manually by hand tools, excavation machineries etc. After digging, it should be visually inspected and verify that there should not be any rocks, debris or sharp objects to damage the cable. This process need more man power and time to establish and it is the most effective installation method/Laying method for shorter distance applications. Most normally after dug trench a conduit made up of concrete or plastic will laid throughout the trench to make the fiber lay quite smoothly and also it can avoid the repetitive trenching to pull again cable between access points in future.

Ploughing is also used for the cable lay, where dig a narrow channel, place fiber cable on it and cover it with the soil. There are some machineries to plough and directly reel off the cable and the same system can cover it with mud. This system is quite fast on their work, will reduce the manpower and time. That's why, ploughing is used for the long distance application and it is less catastrophic to soil. The cable which laying after plough is directly buried and so the depth of channel should be more compare to trench to providing more protection. But again the actual depth will be varying according to the application and characteristics of cable which using. So the direct buried process is more beneficial when it comes with cost and time.

- Trenches are done where the excavation will be hard because of more obstacles are present and normally at urban and sub urban areas to laying optical fiber cables.
- Trenching is a process of excavating, placing cable and refilling. Trenching is conducted by using machinery or manually. Trench dimension will vary according to the applications. Every cable termination point will be sealed and protected by protective caps.

- Route markers and warning tape will be used to protect the underground cables from future excavation. Underground cable will be buried under a standard depth to avoid the accidental damages by being dug up.
- The normal depth at which the trenches are made is 3-4 feet from the ground.
- The first process is digging a narrow channel and duct placement along the distance with pulling tape will be provided inside for the actual pulling process of cable in future.
- There are various types of ducts are available in market and the duct selection will be depends on characteristic of soil where we are installing. If the dielectric duct is using, normally a conductive marker will be placed on the ground level to get noticed by workers and pedestrians to avoid the dangers.
- Trenching conducted normally by machineries and in some areas manual trenching is also done by using hand tools. But the manual trenching will take more manpower and time. To complete the trenching in maximum speed, trenching width and depth will not goes over requirement.

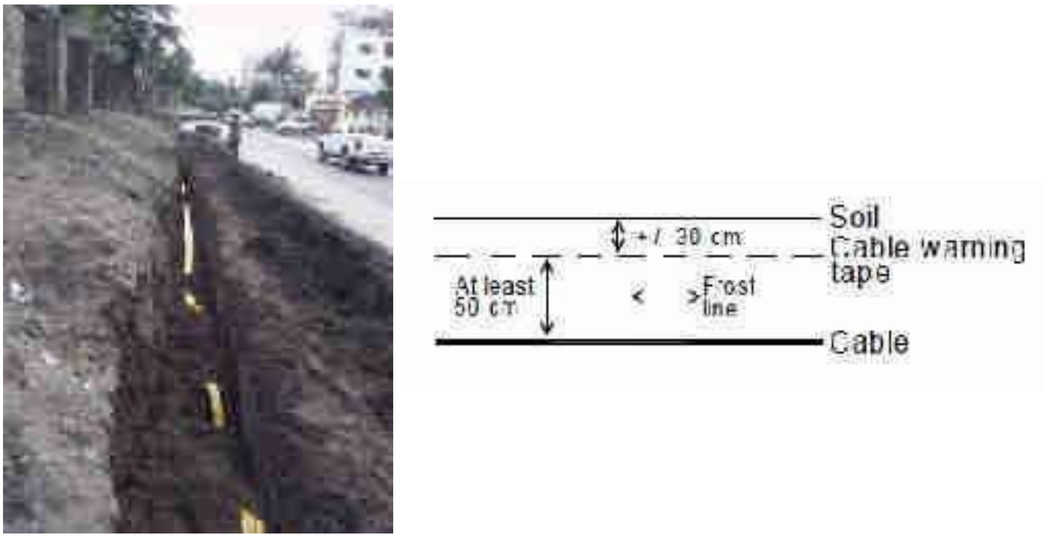


Fig. 2.4.15: Trenching

Precautions of Trenching - While using 'trenching' for installing the OFC following precautions must be taken:

- Buried cable to be located in a manner that it is not moved
- Trench route should be select by considering the future development planning in those areas. Road widening should not disturb the installed fiber cable.
- Route selection of cable trench should consider the natural drainage holes on the particular location.
- Need to use a route marker and should be placed on the surface where underground cable is laid.

Step 1(b)- Aerial Cabling

There is another type of cable laying which is generally using in outdoor sites like direct buried is Aerial installation. Specialized Aerial cables are using for this pole- to - p o l e installation. The installation of aerial cable is executed by specialized companies. Aerial installation needs sophisticated equipments for the long-distance applications. Optical fibers are lightweight and flexible but the cables which designed to install outdoors are made with high tensile strength. Aerial cables may be subjected to high pulling force because of wind, ice, and other environmental factors. These factors can cause the cables to pull on the cable or sag. To avoid the damage of cables because of this sag force, normally aerial cables will be supported by a specialized messenger cable made of steel with strong tensile force capability along the route. So, the aerial cable will be laid along with messenger wire and at every particular length they will be tied or lashed together. To avoid any kind of dangers due to electrical conductivity between the conductive cables and messenger wire, they will utilize dielectric threads to lash. According to requirements of support on messenger wire, they will select the number of threads in particular distance. Generally, there should be at least one lash/tie per foot. According to the application, cable laying distance, type of cable using the type of messenger wire also will vary. There is one method that cables can be tied or lashed on the existing.

It is an armor buffered tube fiber cable with the following key features as depicted in the picture. Aerial cable is:

- Supported by poles (Telephone/electrical towers) (is tough for the same reason) - is used where outdoor conditions prevent OFC burial or where aerial infrastructure is present– telephone poles or electrical towers.
- There are two types of cable installation that self-supported (no need of messenger wire) and tied/lashed.
- Susceptible to – load, wear & tear etc. as it stands exposed.
- Messenger wires & hangers are used to prevent it from sagging.

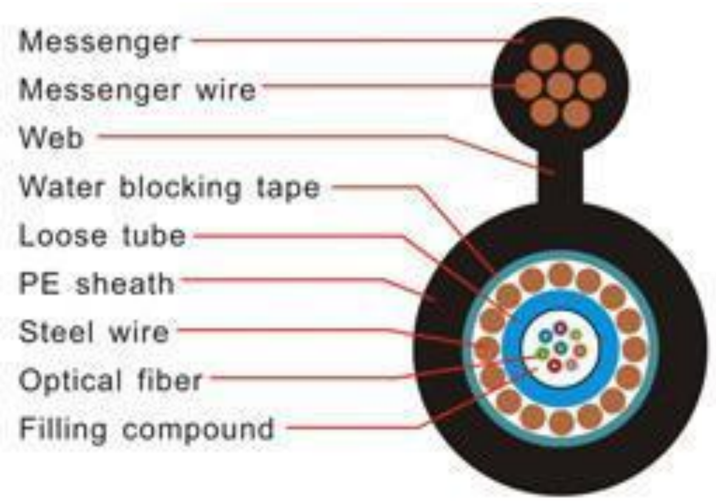


Fig. 2.4.16: Step – aerial cable

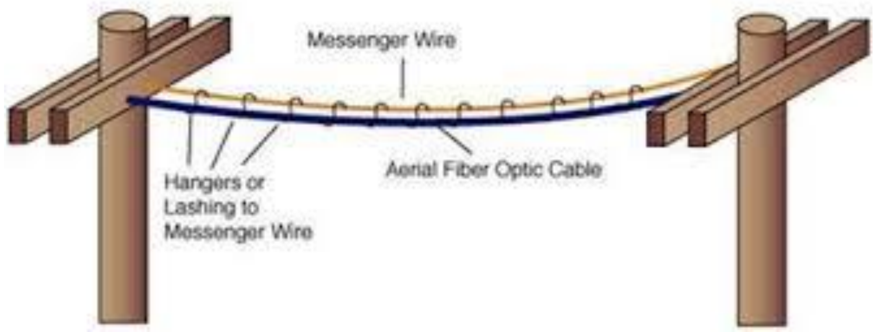


Fig. 2.4.17: Step – aerial cable

Step 2– Ducting Process

The duct used in outdoor applications is providing an extra protection to the optical fiber cables from rodent penetration and other damages. Also these ducts are providing an extra easiness in the cable laying and pulling. Ducts are made up of rigid, abrasion resistant material. These conduits are buried directly and cables are laying through it. By using series of ducts and conduits under the cities, where they lagging the physical spaces to accommodate fiber plant, they are utilizing underground plant and accessing it through manholes or access holes. Once a duct laid, it will provide a new route for new cables and it is very easy to remove old cable without damaging the optical fiber cables. It will also avoid making further disturbance to streets, footpaths and other public constructions. Mostly these ducts will have a pull tape or rope to make the future run easy. Sometimes the duct will be placed without any cables inside and it will be used in future for the upgradation. Inner ducts will also play major roles in the optical fiber cable laying. It will be in a physical condition that, it can easily place inside outer big ducts. The inner ducts colors are using for the identification purpose in maintenance and it will be clear and clean for the new fiber installation.

- Ducting is done either manually or through machine.
- It is made of PVC (Poly Vinyl Chloride).
- Duct diameter must be at least twice the OFC.
- Duct should have pull ropes or tapes to ease future runs.
- Ducts have inner ducts or lining to avoid damage to OFC due to rubbing; in various colors they assist in cable identification and maintenance.
- Required length of duct is measured by the installer.
- Length of duct is properly unwound & put in position.
- Duct is fed through the path after which refilling is done and path is restored with grass or tiles as may be the case.
- Ensure ducts are clean, without twists, collapsed portions, with ends sealed - using end plugs (to avoid – mud, water or dust).
- Ensure duct joints are airtight.

Fig. 2.4.18: Ducting process

Following is the underground duct – advantages

- Duct is providing an extra protection to the optical fiber cables from rodent penetration and other damages, but it can provide following advantages
- Conduits are excellent for installing tight buffered cables.
- Duct can avoid the rodent penetration.
- Duct is an economic way of installing optical fibers where the repeated ploughing and refilling is difficult or impossible to carry out.
- Bundle of Ducts/conduits are laying under the street to create underground plant and also can access it by manholes.
- It will also avoid making further disturbance to streets, footpaths, and other properties.
- Duct will have a pull tape or rope to make the future run easy.
- Sometimes the duct will be placed without any cables inside and it will be used in future for the upgradation.
- Inner ducts will also play major roles in the optical fiber cable laying. It will be in a physical condition that, it can easily place inside big ducts.
- The inner ducts colors are using for the identification purpose in maintenance, and it will be clear and clean for the new fiber installation.
- Inner duct will make sure that the inner path is clear and clean for smooth laying and pulling where if ducts are already filled with multiple cables.
- Ducts can avoid the further disturbance on soil by the ploughing and refilling.
- Duct without any cable inside will also establish in certain areas. It can be utilized for the future run.

Step 3 – Figure 8'ing'

Following steps to be taken for figure 8ing:

- Draw two adjacent circles to create a figure 8 pattern with a diameter of 1.5 to 2 meters.
- If require, use cardboard sheets between layers.
- Create one above other layers of figure 8 loops by taking the cable from drum or payoff trailer and Put it on the circle marks.
- To create figure 8 pattern loop by heavy optical fiber cables, required at least 3 people, one at center and one each on end of both circles.
- Figure 8 pattern is particularly advantages for heavy and lengthy optical fiber pulling in opposite direction.
- Avoid free running and jerking of cable while winging by using cable drum brake

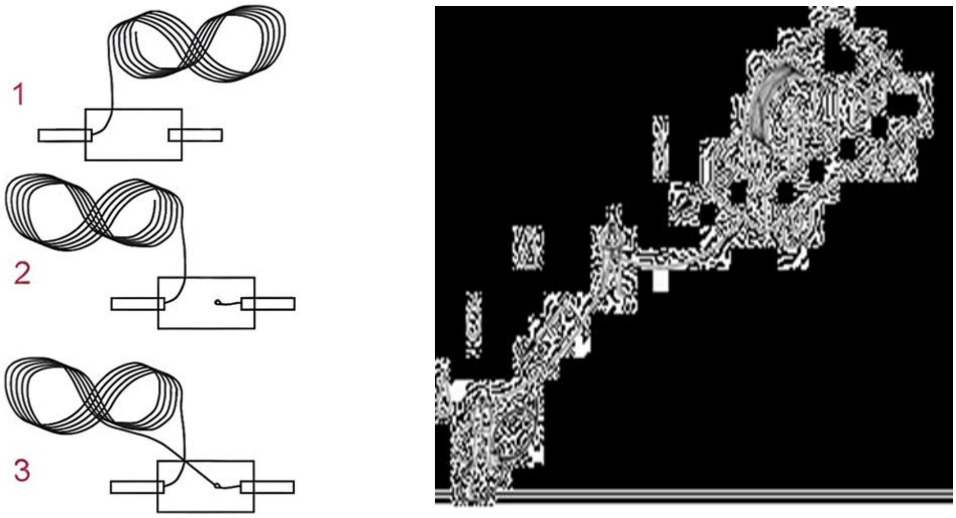


Fig. 2.4.19: Figure

Step – Cable Pulling & Blowing

Cable pulling

In many situations where the optical fiber cable is laying in short straight enough paths, without using any sophisticated equipment, the cables can be pulled in by hand. In optical fiber cable the entire load has to be subjected to strengthen members. To make it, at the end of the cable, strengthen member will be tied to the pulling rope and the same has to be attached/clamped with the whole cable units to distribute the force. If it is not connected the entire cable components, there is a chance of elongation of the cable sheaths, and this will result damage on optical fibers inside. There are so many standard equipment are available to apply additional mechanical force to pull. With this equipment there are number of pulling grips available to lock pulling rope with the entire cable units. Pulling grips are tightening around the cable and which will be attached with the pulling to distribute the tensile force.

Pulling grip is the attaching point of cable to the pulling rope so to make the attachment in proper way and to avoid the fiber damage at the pulling contact point grip has to be fixed on the aramid strengthen member inside the outer jacket around the core of fiber optic cable. The jacket length which has to be removed will depend on the length of pulling grip. The rope should be attached with core part of the cable with the strengthen member inside cable to avoid the elongation of cable sheath due to heavy tensile force. To fix the rope with core strengthen member a tape or tying mechanism has to utilize. In order to avoid the twisting of fiber, need to use swivel at the joining point of cable and rope. It will avoid the chance of twisting of fiber cable by keep away transferring the twisting motion of pulling rope to cable. The total load which is applied on to the cable has to be measured and analyzed continuously to avoid the excess force acting on the fiber. As per the permissible value of tensile strength of the cable it is better to cut the cable 10 feet from pulling side. It will avoid the generation of large tensile force on cable.

Even if the optical fiber cable is pulled over along the trench length, it is not ready to terminate or connectorization. Before doing any connectorization or termination the cable has to pull over an extra length for the future works on either side of the route ends or in between manholes. In outdoor application the connectorization or the termination work will not take place on the trench end, for this purpose the cable will be laid to a special clean area or a tent. So, the total length should be considered at the time of link design including all extra cable length to the workplace and for the future upgrades.

- OFC's maximum tensile strength varies from 600 pound to less than 1000 pounds; lubricants are used to reduce pulling tension.
- Pulling forced should be kept less than the designated limit.
- At the time of pulling optical fiber cables, especially when using high power equipments are using to pull the tension monitoring equipments should be used. To avoid the twisting in optical fiber swivels should be used when pulling cable. Duct should have pull ropes or tapes to ease future runs.
- During OFC de-spooling avoid– twisting or sharp bending. Pay off cable form the top of the reel during cable pulling.
- If the cable has to lay long distance, pulling should be completed in number of stages at least two. Attach pulling eyed to the cable's strength member.
- Adequate cable is stored on ground in the shape of figure 8. The cable pulling should be started at the middle pulling location and get going towards end.
- Once it reached at one end of the cable run, the same process started at the center again in opposite direction. After the entire pull is complete, Rack the optical fiber cable.
- Maximum pulling speed to be 3 feet / sec if pulling rope is used; it can be tripled for mule tape.

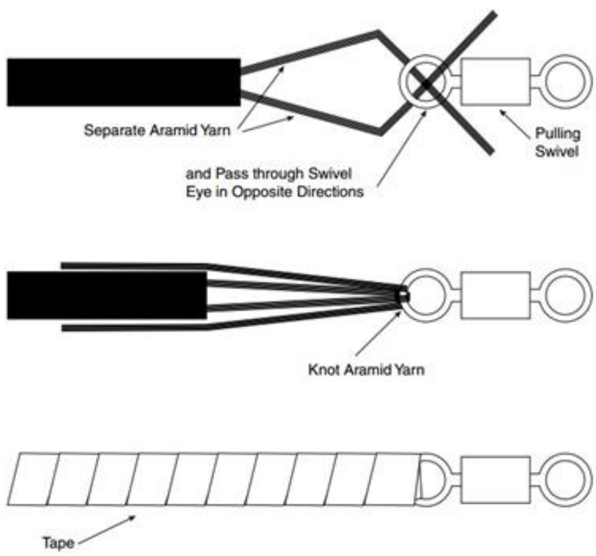


Fig. 2.4.20: Duct with pull ropes, tapes

Cable Blowing:

Following steps are to be taken for cable blowing:

- Cable is inserted in the motorized blower head with a duct and a one way valve.
- The optical fiber cable will pushed through the duct by using high-speed airflow from a source.
- High speed air current pushes the cable along the length.
- High air drag & low friction causes the cable to move forward.
- It provides high installation speeds, with less cable tension and reduced chances of damage; it requires less manpower

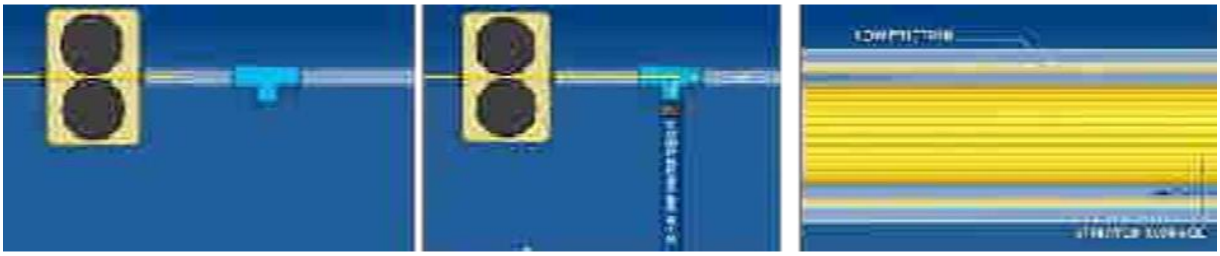


Fig. 2.4.21: Cable blowing

Step 5: OFC Termination Method

There are 2 methods for terminating the fibre: The first is through the use of connectors that form a temporary joint, and the other is through splicing, which is actually connecting two bare fibre ends directly. The most common termination methods are:

- No-epoxy/no-polish
- Epoxy-and-polish
- Pigtail splicing

Steps to terminate OFC using fibre boot:

 Put on a fibre boot	 Measure 14 cm for striping as per specifications	 Strip the fibre using a wire stripper
 Use alcohol wipes to clean any residue	 Give the fibre a very slight bend	 Put the fibre in a cleaver holder at the 10.5 cm mark (as per specs) and cleave the fibre
 Put the fibre in the connector & squeeze the holder	 Slide the boot, and the connection is complete	

Fig. 2.4.22: Steps to terminate OFC using fibre boot

2.4.12 Testing and Closing Activities

After installation, splicing and termination of optical fiber it must be tested for the following:

- Polarity testing
- Total insertion loss
- If there is any problem, troubleshoot it
- Ensure marking for identification of route for future maintenance and troubleshooting.
- Appropriate cable marking should be done as per the recommended guidelines.
- Backfill and remove debris and rock to clean the site.

Fig. 2.4.24: Testing equipment

2.4.13 Reporting and Documentation

Documentation is absolutely necessary for future references and troubleshooting therefore we should ensure a proper reporting and documentation. The whole plant of optical fiber cable has to be documented in design part for the installation and future upgradation.

It helps in:

- The loss of time & cost can be reduced by the process planning at the time of installation
- Upgradation process will be more
- The cable laying process will be faster, including cable pulling and installation
- Tracing links & finding faults
- Speed up the pulling process if the routing and terminations are already documented
- The test data should be documented with the previous information to get the acceptance from end user
- After the installation, if there is any repositioning of equipment the documentation will helps to rerouting to the exact end points

Information record about the cable, splice, fiber, paths, etc. is a must and should be captured as follows:

- Cable: manufacturer, type, ID, length, and drum number
- The distance at which the Splices and termination point has done
- Optical fiber type & size, splice and connectors position, losses
- Rote of cable lay
- Optical fiber cable route, loss and test results on cable plant should be noted
- All these data should be kept with the documents of Component, connection, and the test results
- OTDR test results will be stored separately for the troubleshooting purpose in future. It can be printouts or in digital format. The digital data file should be stored in database in an arranged manner
- All the cable spool should be marked with type, installation method has to be followed, total number of fibers inside, and the total length.
- Special requirements should be specified (type of application and installation requirements) to estimate the total manpower and cost required.
- Record test data on each individual fiber run.
- It will reduce the complexity of troubleshooting.
- Documentation will tell you about everything that required for a cable installation, like where cable go, distance between access points, the areas in which where installation take more time etc. Testing information gives the way to find out the degradation over time.

Merely recording is not enough record storage is also an essential ingredient:

- Documentation of data's in plant location is very essential.
- Databases has to be stored in different data formats , paper printouts or digital files, should have multiple copies stored in several locations and make sure that the data is accessible for every teams to review.
- Ensure it is available to all the authorities for review.

Following reports have to be filed regularly so as to regularly update status:

- Report on the status update
- Pending issues
- Challenges
- Faults & Serviceability
- NOC for cable integration
- Final Closure of the job

2.4.14 Installation Procedures for Ultra-Low Loss (ULL) Optical Fiber Cables and Their Significance

Ultra-Low Loss (ULL) optical fiber cables are designed to minimize signal attenuation, which is critical for high-performance, long-distance, or high-bandwidth networks. Proper installation is essential to maintain their performance characteristics.

1. Installation Procedures for ULL Cables

Step 1: Planning and Route Survey

- Review the route plan provided by the planning team.
- Ensure compliance with bend radius, tension limits, and environmental conditions.
- Identify obstacles, existing infrastructure, and clearances required.

Step 2: Handling and Preparation

- Transport cables carefully to avoid physical stress or bending.
- Store cables in a clean, dry area to prevent contamination.
- Use specialized drum dispensers to prevent twisting or kinking.

Step 3: Trenching and Duct Placement

- Supervise trenching to follow depth and alignment standards.
- Place ducts using proper dispensers and check for uniform depth.
- Ensure ducts are clean and sealed with end plugs to prevent dust or moisture.

Step 4: Cable Laying

- Maintain the minimum bend radius throughout the installation.
- Avoid sharp bends, pulling stresses, or compressive loads that could damage fibers.
- Use tension monitors during pulling to avoid exceeding recommended limits.

Step 5: Cable Blowing/Jetting (if applicable)

- Use cable blowing machines for micro duct installations.
- Ensure proper alignment of ducts and adequate lubrication to reduce friction.
- Monitor the process to maintain tension within safe limits.

Step 6: Splicing and Jointing

- Use fusion splicing for minimal loss joints.
- Protect joints with heat-shrink, mechanical, or multi-diameter seals.
- Ensure sufficient slack or loop at joint locations for future maintenance.

Step 7: Testing and Documentation

- Test optical continuity and signal loss using OTDR or power meter.
- Record as-built diagrams, cable lengths, and joint locations.
- Document compliance with industry standards and manufacturer specifications.

2. Significance of Ultra-Low Loss Cables in Network Performance

1. Reduced Signal Attenuation
    - Lower loss per kilometer allows longer transmission distances without repeaters.
2. High Bandwidth Capacity
    - Supports higher data rates over long distances, making it ideal for backbone networks.
3. Improved Reliability
    - Minimizes the risk of signal degradation, reducing network downtime.
4. Cost Efficiency
    - Fewer repeaters or amplifiers required due to lower signal loss.
    - Reduced maintenance and operational costs.
5. Future-Proofing
    - Suitable for emerging high-speed applications such as 400G/800G networks, 5G backhaul, and data centers.

Notes

Scan the QR Code to watch the related videos

https://youtu.be/46JAjiQfCkg

10 tips for installing fiber optic cables

UNIT 2.5: Safety, Quality, and Environmental Compliance in Optical Fiber Installation

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the importance of OHS and environmental regulations in optical fiber projects.
2. Discuss quality assurance, Acceptance Testing (AT) standards, and key signal quality KPIs.
3. Identify and use relevant PPE correctly for fiber optic work.
4. Recognize and manage electrical, chemical, and environmental hazards.
5. Demonstrate proper use of fire safety equipment and first aid procedures.
6. Follow standard procedures for disposal of fiber waste and hazardous materials.
7. Comply with site-specific risk controls, OHS guidelines, and environmental regulations.
8. Document cable IDs, drum numbers, test results, and obtain sign-offs for audits and NOC updates.

2.5.1 Occupational Health and Safety (OHS) in Fiber Installation

Occupational Health and Safety (OHS) refers to a structured approach to protecting the health, safety, and well-being of workers on-site. In optical fiber installation, OHS considerations include:

1. Risk Assessment and Site Safety Planning
    - Before starting any installation, a comprehensive risk assessment must be conducted. This includes identifying potential hazards such as uneven terrain, open trenches, live electrical lines, and chemical exposure.
    - Site safety planning ensures that work areas are clearly marked, access is restricted to authorized personnel, and emergency exits are identified.
2. Personal Protective Equipment (PPE)
    - Technicians must use appropriate PPE at all times. This includes helmets for head protection, safety boots to prevent foot injuries, knee pads for ground-level work, gloves for fiber handling, and trench guards to protect against excavation hazards.
    - PPE selection should consider the type of installation (underground vs. aerial), environmental conditions, and potential exposure to chemicals or electrical hazards.
3. Electrical and Environmental Hazards
    - Electrical hazards include contact with high-voltage lines or Earth Potential Rise (EPR) areas. Technicians should maintain safe distances, use insulated tools, and follow grounding protocols.
    - Environmental hazards include exposure to extreme temperatures, rain, or unstable soil. Proper precautions, such as weather monitoring and trench reinforcement, reduce the risk of accidents.
4. Fire Safety and First Aid
    - Fire safety equipment, including extinguishers, blankets, and alarms, must be available on-site. All personnel should be trained in their usage.
    - First aid training is essential for managing injuries such as cuts, burns, eye punctures, and electric shocks. Immediate response can prevent severe outcomes.

2.5.2 Environmental Regulations and Waste Management

Fiber optic installation impacts the environment in several ways, especially during trenching, duct placement, and cable laying. Compliance with environmental regulations ensures sustainability and legal adherence:

1. Permits and Approvals
    - Municipal approvals and statutory permissions are required before excavation or installation. This includes clearance from local authorities, utility providers, and environmental agencies.
    - Approvals may cover soil disturbance, watercourse crossings, tree or vegetation removal, and access to public property.
2. Managing Environmental Impact
    - Installation teams must minimize soil erosion, avoid contaminating water sources, and protect natural habitats. Temporary barriers, sediment control, and careful route planning mitigate environmental damage.
3. Waste Disposal
    - Cut fibers, chemical residues, packaging materials, and other waste must be disposed of safely. Sharp fiber scraps should be placed in puncture-proof containers.
    - Environmental compliance requires adherence to guidelines for waste segregation, recycling where possible, and safe disposal in designated facilities.

2.5.3 Quality Assurance and Acceptance Testing (AT)

Quality assurance ensures that fiber optic networks perform reliably and meet contractual and technical specifications. Key considerations include:

1. Acceptance Testing Standards
    - Optical fibers are tested using OTDR (Optical Time Domain Reflectometer) to measure signal loss, reflectance, and continuity.
    - Acceptance Testing (AT) validates that fibers meet project requirements, including attenuation limits, optical return loss (ORL), and signal-to-noise ratio (SNR).
2. Key Performance Indicators (KPIs)
    - Insertion Loss: Measures signal attenuation across a fiber segment.
    - Optical Return Loss (ORL): Indicates signal reflections that can degrade performance.
    - Bandwidth: Confirms the fiber can carry the required data rate.
    - Continuity and Fault Localization: Identifies breaks or faults within the fiber link.
3. Documentation and Reporting
    - All test results must be accurately recorded and submitted to project teams and the Network Operations Center (NOC).
    - Cable IDs, drum numbers, and joint locations must be logged to enable future fault localization and maintenance.
    - As-built diagrams reflecting the installed route, duct placement, and splicing points provide a reference for operational and auditing purposes.

2.5.4 Handling and Installation of Optical Fibers

Proper handling of optical fibers is crucial to prevent damage, contamination, and performance degradation:

1. Cable Handling
    - Fibers should be uncoiled carefully, avoiding twists, sharp bends, or excessive pulling tension.
    - Special dispensers and tension monitoring tools ensure smooth deployment without exceeding manufacturer-specified limits.
2. Duct and Trench Management
    - Ducts must be placed at proper depths and aligned correctly to comply with installation standards. Collapsed or twisted ducts should be rectified promptly.
    - Protective materials such as GI (galvanized iron) or RCC (reinforced cement concrete) pipes are used where environmental or mechanical protection is required.
    - End plugs prevent dirt or moisture from entering ducts, maintaining fiber cleanliness.
3. Managing Earth Potential Rise (EPR)
    - EPR hazards can occur near high-voltage installations. Technicians should use insulated tools, maintain safe distances, and implement grounding measures to prevent electrical shocks.
4. Fiber Splicing and Jointing
    - Fusion splicing ensures low-loss joints. Protective closures, such as heat-shrink or mechanical seals, maintain the integrity of spliced fibers.
    - Adequate slack or loop at joint locations allows for future maintenance or network expansion.

2.5.5 Emergency Protocols and Incident Management

Workplace incidents can occur despite preventive measures. Adherence to emergency protocols ensures safety and rapid response:

1. Emergency Response
    - In case of accidents, personnel should follow pre-defined evacuation routes and communicate with supervisors immediately.
    - Fire incidents, chemical exposure, or electrical hazards must be reported and managed according to site protocols.
2. First Aid
    - Injuries such as cuts, burns, eye punctures, or electrical shocks must be addressed immediately using available first aid kits.
    - Proper first aid reduces the severity of injuries and prevents complications.

2.5.6 Maintenance of Cleanliness and Documentation

Maintaining cleanliness and accurate records supports both quality assurance and regulatory compliance:

1. Clean Handling
    - Optical fibers must be kept free from dust, moisture, and other contaminants during installation.
    - Site cleanliness ensures fibers remain in optimal condition for network performance.
2. Documentation
    - Cable IDs, drum numbers, test results, and joint locations should be meticulously recorded.
    - OTDR test reports, acceptance certificates, and as-built diagrams must be submitted to project teams and updated in the NOC.
    - Obtaining sign-offs from supervisors and maintaining all documents ensures accountability and compliance during audits.

Exercise

Short Questions:

1. Explain the importance of reviewing an OFC route plan before beginning installation.
2. What are the key differences between Single Mode and Multi-Mode optical fiber, and when would you use each?
3. Describe the steps involved in supervising trenching to ensure compliance with site terrain and route plans.
4. Why is adherence to manufacturer-specified bend ratios critical during cable installation?
5. List the statutory permissions and municipal approvals commonly required for optical fiber installation work.

Fill in the Blanks:

1. The __________ of an optical fiber must be maintained according to manufacturer specifications to avoid signal loss.
2. __________ fiber is typically used for long-distance, high-bandwidth applications.
3. Before beginning installation, all required statutory permissions and __________ must be obtained.
4. Patch panels help in organizing network connections and facilitate easier __________ and maintenance.
5. During trenching, ducts must be checked for proper depth, alignment, and be free of __________ to ensure cable integrity.

Multiple Choice Questions (MCQs):

1. Which of the following is a key benefit of using ultra-low loss optical fiber cables?
   a) Reduced installation cost
   b) Enhanced network performance with minimal signal loss
   c) Easier trenching
   d) Less documentation required
2. What is the primary purpose of a patch panel in a network?
   a) Store cable drums
   b) Organize and manage network connections for easy maintenance
   c) Measure cable depth
   d) Provide power to network devices
3. When inspecting ducts in trenches, what is a key compliance check?
   a) Duct color
   b) Pipe/duct depth and alignment as per laying standards
   c) Cable manufacturer
   d) Contractor name

4. Which tool is specifically used for checking optical continuity in cables on the drum?
   a) Splice tray
   b) Optical Time Domain Reflectometer (OTDR)
   c) Cable cutter
   d) Multimeter
5. What is a common method to seal fiber optic joints?
   a) Heat shrinking
   b) Wrapping with cloth
   c) Painting with epoxy
   d) Tying with cable ties

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=mkwScwUVyuM

Fiber Optic Safety Introduction

3. Undertake Condition Based Maintenance and Planned Repair Activities

Unit 3.1 - Carry Out Testing of Optical Fiber

Unit 3.2 - Optical Fiber Testing, Documentation, and Predictive Maintenance

TEL/N6403

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain how advanced tools are used to test the effectiveness of a fiber splice.
2. Describe the process of recording test results for traceability and performance analysis in fiber splicing.

UNIT 3.1: Carry Out Testing of Optical Fiber

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the principles of optical transport media and OFC communication.
2. Elucidate the characteristics of optical fibers, including refraction, polarization, attenuation, and dispersion.
3. Discuss the impact of different wavelength bands on signal transmission in optical fiber networks.
4. Explain the working principles of optical test equipment like OTDR, power meters, and light meters.
5. Determine the optimal values for OTDR, power meter, and light meter test results to ensure network efficiency.
6. Discuss the importance of spare part management and the repair/return processes for faulty optical fiber equipment.
7. Show how to use advanced testing tools like OTDR, power meters, and light meters to validate optical fiber installations.
8. Demonstrate how to identify and eliminate cross-fiber issues using power source and power meter tests.
9. Demonstrate how to perform final transmission loss tests and rectify any issues exceeding manufacturer specifications.

3.1.1 Testing Optical Fiber Visual Fault Locator

We start the testing with a visual inspection tool called visual fault locator. This is a very helpful tool to trace a path of a fiber, if the fibers are not broken from one end to another with many connections, duplex connector polarity verifying for example. It looks like a pen-like instrument or a flashlight with a LED or light bulb, source that mates to a fiber optic connector. Connect the fiber to be tested to the visual tracer and check at the other end of the fiber to identify the light transmitted through the core of the fiber. If there's no light at the end, return to intermediate connections to seek out the bad section of the cable.

Fig. 3.1.1: Visual fault locator

A handheld optical test device is to inject a highly visible laser light into a fiber to identify faults, bends, continuity, or port identification.

Fig. 3.1.2: VFL general specifications

Continuity check with the help of the visual fault locator (VFL):

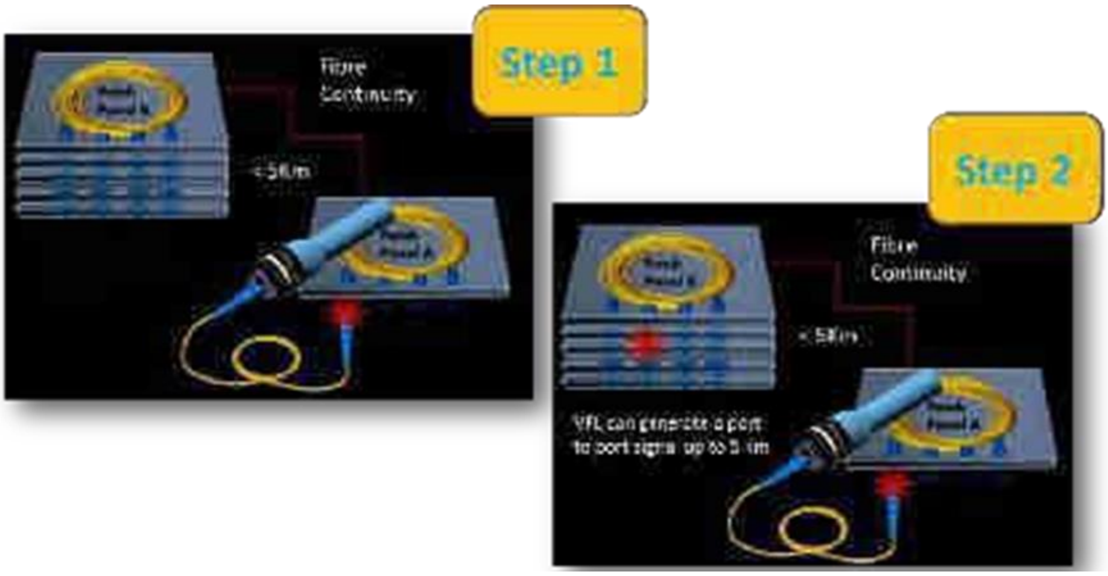


Fig. 3.1.3: Checking continuity through VFL

It can be used to identify fault location. A highly visible laser light is injected on to a fiber; for identification of faults, bends, continuity or port identification.

You can easily see the loss of light at fiber damage by the bright red light from the VFL through many yellow or orange simplex jacket cables (except black or grey jackets). It's most important function is finding faults near the connectors or in short cables where OTDRs cannot find them. You can also utilize this gadget to visually test and optimize mechanical splices or pre polished -splice type connectors. By visually reducing the light lost you can get the lowest splice loss. In fact- no ways to think of doing one of those pre-polished -splice type connectors. No option will assure you of high yield with such connectors.

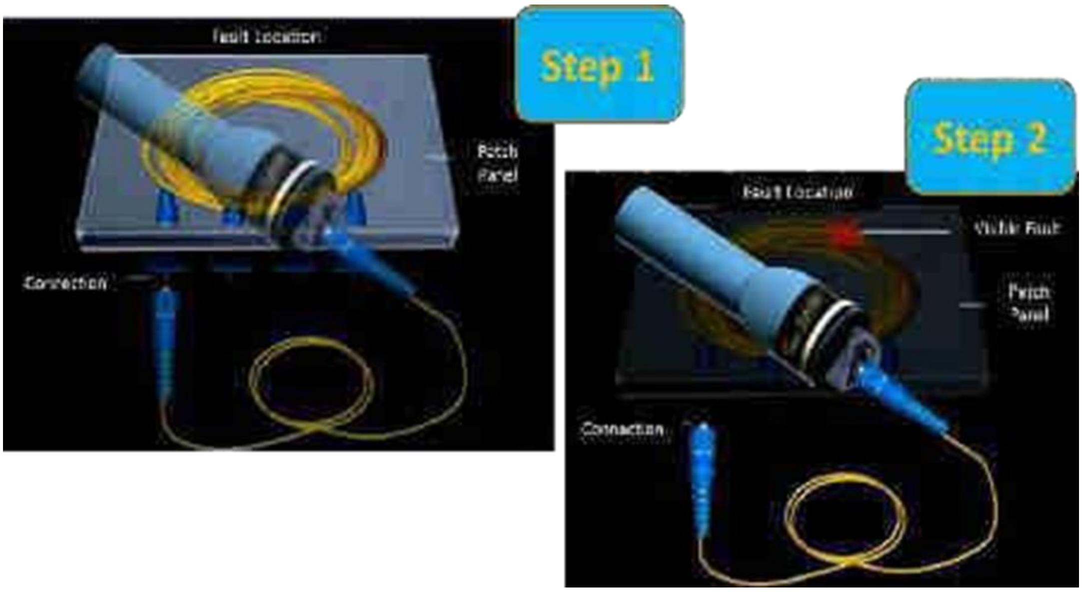


Fig. 3.1.4: Testing fault location through VFL

Light Source

In fiber optics, a light source (such as a laser or LED) is used to generate electromagnetic radiation in order to carry out a specific duty, such as identifying link loss or certifying LAN/WANs or detecting faults, breakage, and microbends. For the purpose of testing a fiber optic cable, light is injected into the wire using a fiber light source. Laser diodes and light emitting diodes are the two main types of them. The wavelength they produce and the kind of cable they test help to further distinguish them from one another

Fig. 3.1.5: Lighting Source

Power Meter

The power of fiber optic equipment or the strength of an optical signal transmitted through a fiber cable can be precisely measured using an optical power metre (OPM), a testing tool. It aids in calculating the power loss the optical signal experiences as it travels through the optical media.

An optical time-domain reflectometer (OTDR), on the other hand, provides length and loss by exploiting backscatter reflection, while an optical power metre measures the incoming optical power

A cheap method of certifying optical fiber is with a power metre and light source. These two test tools are used to gauge the optical signal's actual power as well as the fiber optic light's continuity and loss.

Fig. 3.1.6: Power Meter

3.1.2 Testing OFC – Inspection Microscope

Testing OFC – Inspection Microscope Visual connector inspection with the help of microscope. To inspect connectors fiber optic inspection microscopes are used so as to confirm proper polishing; find problems like scratches, polishing defects and dust and also check termination quality procedure and diagnose problems. A good connector will have a smooth, scratch free, polished finish and the fiber will not show any signs of cracks; chips or areas where the fiber is either protruding from the end or pulling back into it.

1. The amplification for survey connectors can be 30 to 400 power units, however it is best to utilize a medium amplification.
2. The best Microscope instruments enable you to investigate the connector. From a few edges, either by tilting the connector or having point light to get the best picture of what's happening.
3. Check to ensure the magnifying instrument has a simple to-utilize connector to append the connectors important to the microscope.
4. Make sure to watch that no power is available in the link before you take a gander at it in a microscope to secure your eyes. The microscope will focus and concentrate, any power introduce in the fiber, into your eye with possibly dangerous outcomes. A few magnifying instruments have channels which expel infrared light from sources to be protected.

Fig. 3.1.7: Inspection microscope

Following tools are required for 'Visual Connector Inspection':

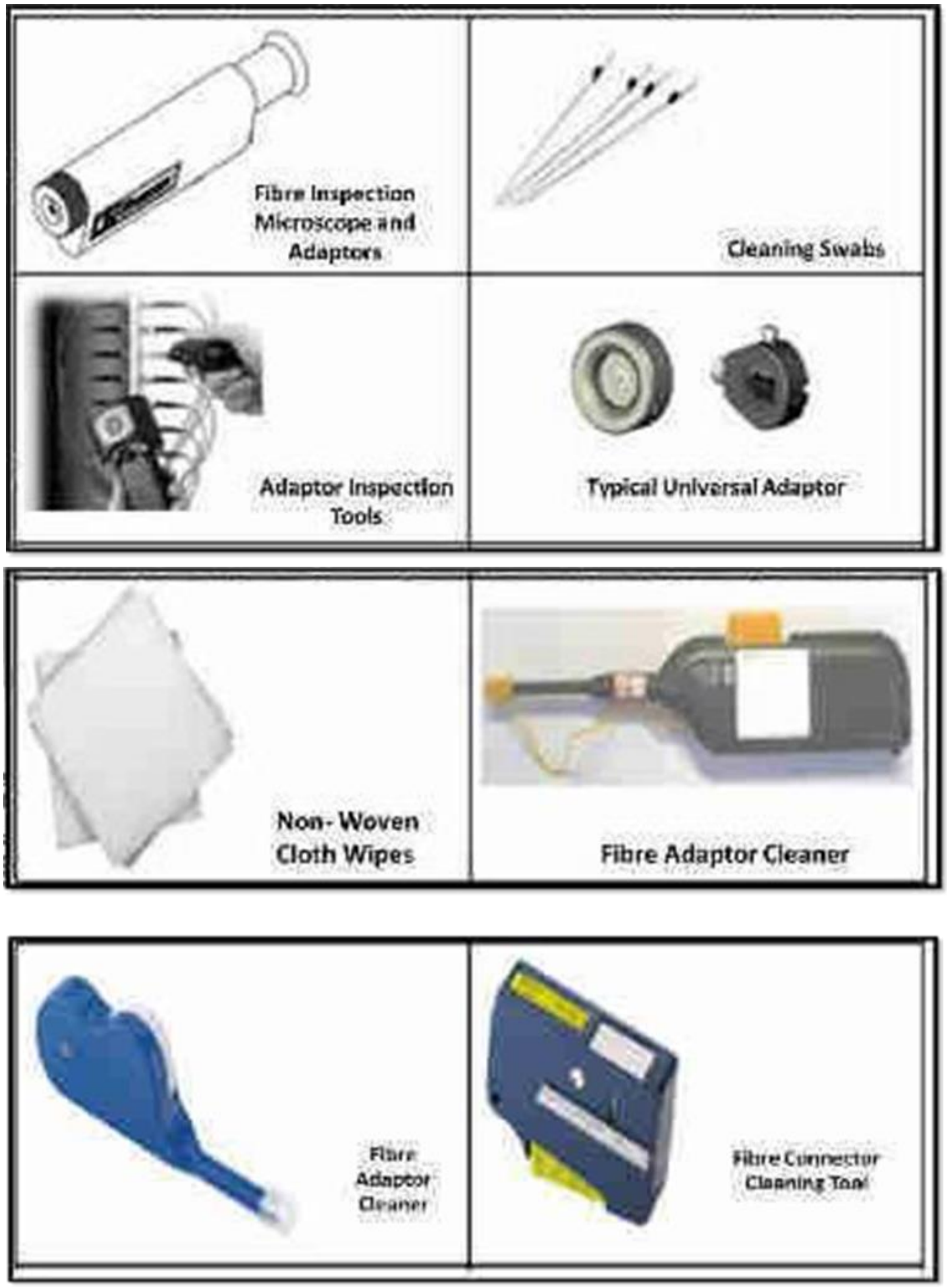


Fig. 3.1.8: Tools required for visual connector inspection

3.1.3 Steps - Visual Connector Inspection

Following are the steps to be followed for visual connector inspection:

Fig. 3.1.9: Steps for visual connector inspection

Connector end views as observed by microscope:

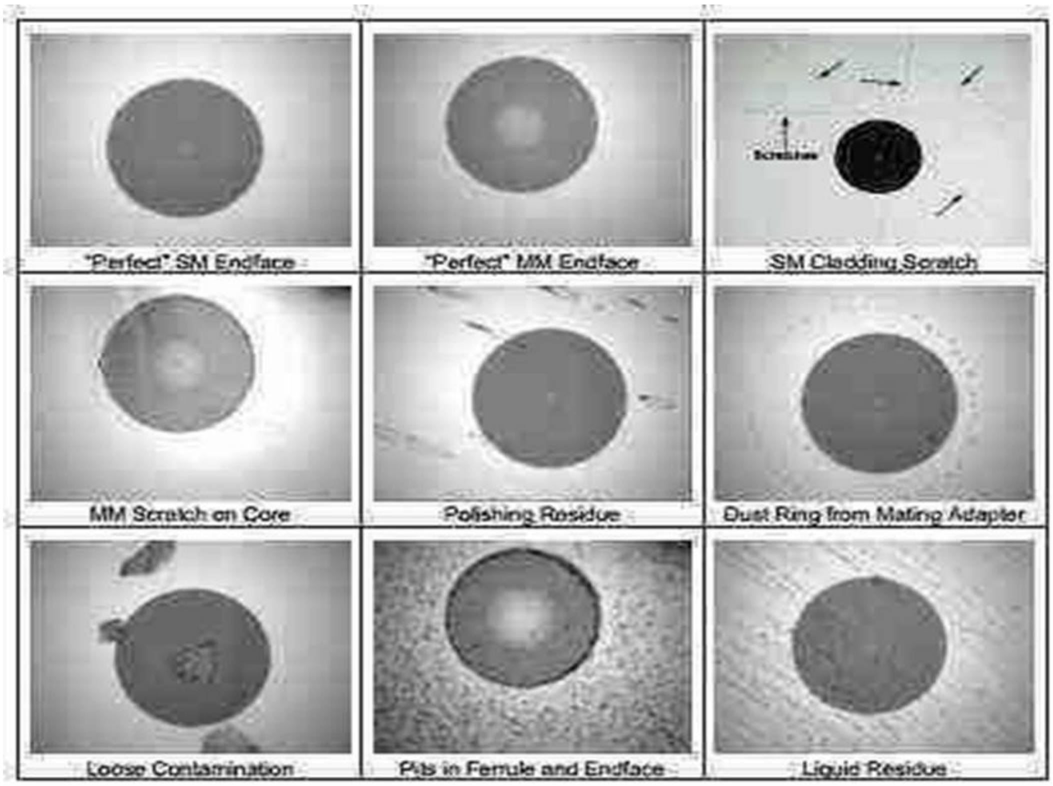


Fig. 3.1.10: Connector end views

3.1.4 Testing OFC – Connector End Cleaning Procedure

We need to learn the connector end cleaning procedure.

1. We need to learn the connector end cleaning procedure. Continuously keep clean tops on connectors, bulkhead grafts, fix boards, or anything that will have an association made with it.
2. Utilize build up free cushions and isopropyl liquor to clean the connectors. A few solvents may assault epoxy, so just liquor ought to be utilized. Cotton swabs and material desert strings. Some optical cleaners leave buildups. Buildups as a rule pull in soil and make it stick.
3. All "canned air" now has a fluid force. Quite a while back, you could purchase a jar of plain dry nitrogen to blow things out with, yet not any more. The present airborne cleaners utilize non-CFC force and will leave a buildup unless you hold them at consummate level when splashing. Splash for three to five seconds before utilizing to guarantee that any flui d fuel is ousted from the spout. These jars can be utilized to blow tidy out of bulkheads with a connector in the opposite side or a dynamic gadget mount. Never utilize packed air from a hose (This radiates a fine splash of oil from the compressor or blow on connectors. Try not to utilize your breath, your breath is loaded with moisture, also each one of those germs.)
4. A superior approach to clean these bulkheads is to remove the two connectors and clean with alcohol pads, at that point utilize a swab made of a similar material with liquor on it to wipe out the bulkhead.
5. Indicators on fiber optics control meters should be cleaned with the alcohol pads sometimes to remove dirt. Take the connector off and wipe the surface, at that point air dry.
6. Ferrules on the connectors/links utilized for testing will get messy because they scrap off the material of the arrangement sleeve in the splice bushing. Some of these sleeves are formed glass-filled thermoplastic and sold for multimode applications. These will give you a filthy connector ferrule in 10 inclusions. You can see the front edge of the connector ferrule getting dark. The arrangement sleeve will develop an inner edge and make a hole between the mating ferrules (a 1–2 dB attenuator). Utilize the metal or fired arrangement sleeve bulkheads just in the event that you are expecting rehashed additions. Cleaning the above requires aggressives crubbing on the ferrules with the liquor cushion and hurling the bulkhead away.
7. Few companies sell fiber optics cleaning kit. These are better solutions but perhaps not as cost-effective as making your own to meet your needs.

Fig. 3.1.11: Connector end cleaning procedure

3.1.5 Tools Required for Bare Fiber Test

- Knife
- Armor stripper
- Kevlar shears
- Alcohol and wipes
- Fiber stripper
- Fiber cleaver
- Bare fiber adapter
- OTDR
- Heat shrink & cable ties

Steps for Bare Fiber Test

Two reasons we may want to test bare fiber i.e., fiber that has not been terminated in connectors but is simply plain optical fiber:

To ensure the fiber or cable we make meets its specifications.

To test cable on the reel to ensure it is in good condition before we install it (or even purchase it or accept it on delivery).

Following steps are needed to perform the tests:

Step 1 – Check the cable and record any visible signs of damages.

Step 2 – Strip cable end at least of 2 ft, strip and clean the fibers.

Step 3 – Connect the fiber using a bare fiber adapter to an OTDR through a patch cord.

Step 4 – Switch on the OTDR and select the proper wavelength and refractive index for the test. Record and print the OTDR traces on disk. Mention direction of measurement and loose tube - fiber color.

Step 5 – Compare the test records to the specifications of manufacturer's

Step 6 – Take out bare fiber adapter and Remove excess fiber from the cable end.

Step 7 – Install heat shrink / protective covering sleeve to the link end to keep the section of dampness or different contaminants.

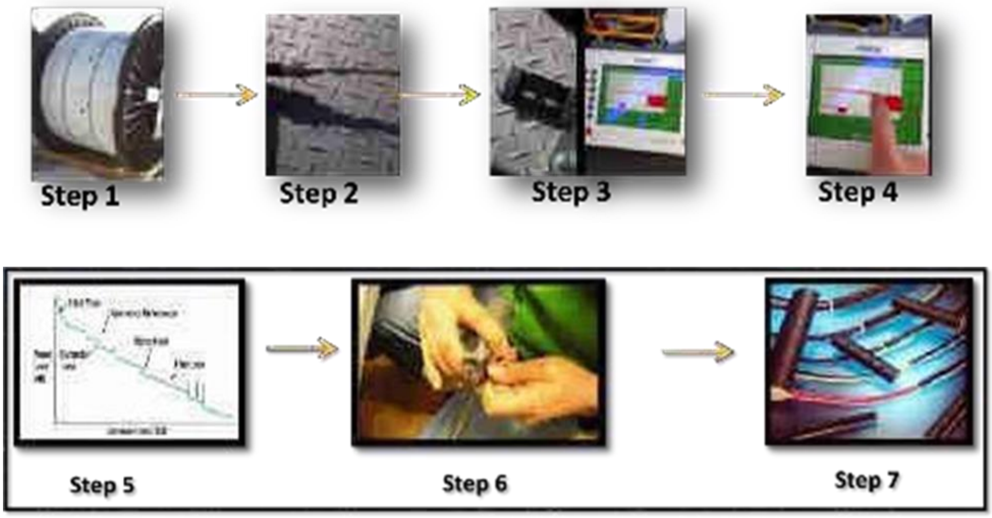


Fig. 3.1.12: Steps for bare fiber tests

3.1.6 About OTDR

Telecommunication characterization of optical networks can tested by fiber optic tester called OTDR; it acts like a one-dimensional radar system. The use of an OTDR is to detect, locate, and measure elements at any location on a fiber optic cable Only one end access is need by OTDR for the link and acts like a one-dimensional radar system. By providing pictorial trace signatures of the fibers under test, graphical representation also possible in the entire fiber optic link.

What an OTDR Measures?

OTDR measures optical distance to:

- Elements: splices, connectors, splitters, multiplexers Faults
- End of fiber

OTDR also measures:

Loss of splices and connectors.

What an OTDR Measures?

- OTDR measures optical distance to:
- Elements: splices, connectors, splitters, multiplexers Faults
- End of fiber

OTDR also measures:

- Loss of splices and connectors.
- ORL (optical return loss) of link or section Reflectance of connectors
- Total fiber attenuation

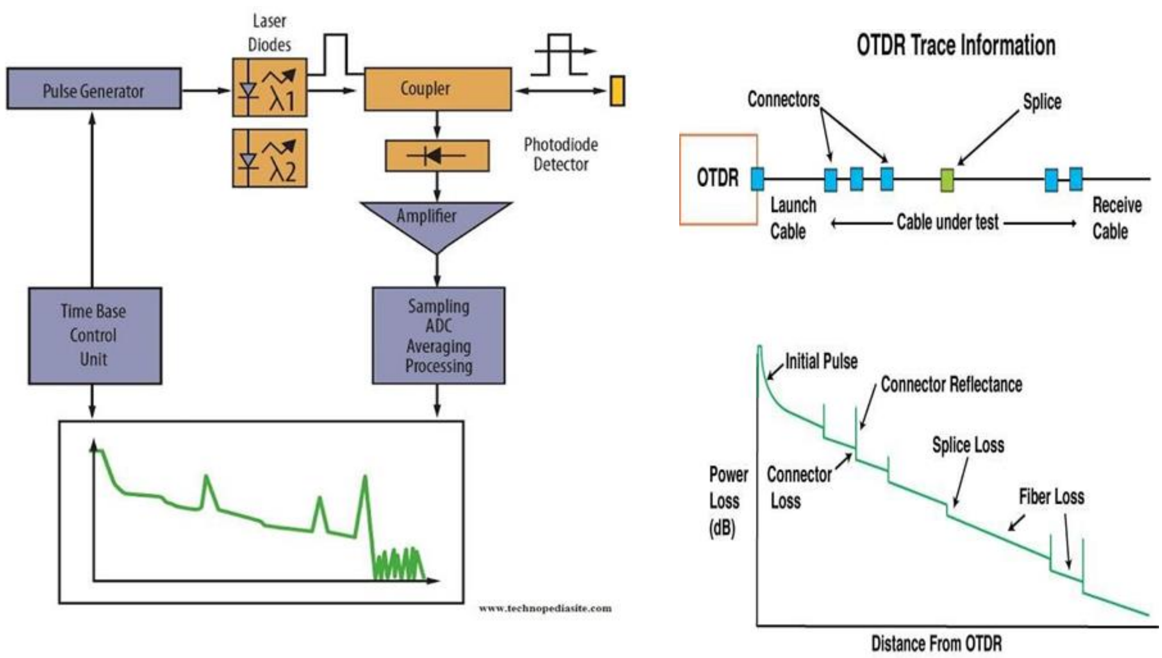


Fig. 3.1.13: OTDR block diagram and OTDR trace

Why do I need an OTDR?

Fiber testing is essential to provide confidence that the network is optimized to deliver reliable and robust services without fault.

Telecom, video, and data wireless service providers and network operators want to ensure that their investments into fiber networks are protected. In outside fiber optic plant, each cable will be tested for end-to-end loss and with an OTDR to ensure the installation was properly made. Installers will be asked to use loss test sets (source and power meters) as well as OTDRs, performing bi-directional tests and providing accurate cable documentation to certify their work. Later, OTDRs can be used for troubleshooting problems such as break locations due to dig-ups.

Many contractors and network owners question whether they should perform OTDR testing for premises cabling. They also want to know if OTDR testing could replace the traditional loss testing with a power meter and a light source. Premises fiber networks have tight loss budgets and less room for error. Installers should test the overall loss budget with a light source and power meter (Tier 1 certification required by TIA-568C standards).

OTDR testing (Tier 2 certification) is a best practice that can identify the causes for excess loss and check that splices and connections are within appropriate tolerances. It is also the only way to know the exact location of a fault or a break. Testing a fiber link with an OTDR also helps document the system for future verification.

Understanding key OTDR specifications:

Wavelengths

In generic, The same wavelength is used to test the fiber which is used for transmission that is used for transmission.

- 850 nm and 1300 nm wavelengths for multimode fiber links.
- 1310 nm and/or 1550 nm and/or 1625 nm wavelengths for single mode fiber links.
- Filtered 1625 nm or 1650 nm for in-service troubleshooting of single mode fiber links.
- CWDM wavelengths (from 1271 nm to 1611 nm with a channel spacing of 20 nm) for commissioning and troubleshooting single-mode fiber links carrying CWDM transmission.
- 1490 nm wavelength for FTTH systems (optional — test can be performed at 1490 nm, but a common recommendation is to test at 1550 nm to minimize additional investments).

Testing at a single wavelength will only allow fault location. Testing at dual wavelengths is recommended during the installation phase and troubleshooting as it detects fiber bends.

Dynamic Range

The dynamic range is an important characteristic since it determines how far the OTDR can measure. The dynamic range specified by OTDR vendors is achieved at the longest pulse width and is expressed in decibels (dB). The distance range or display range sometimes specified is usually misleading as this represents the maximum distance the OTDR can display, not what it can measure.

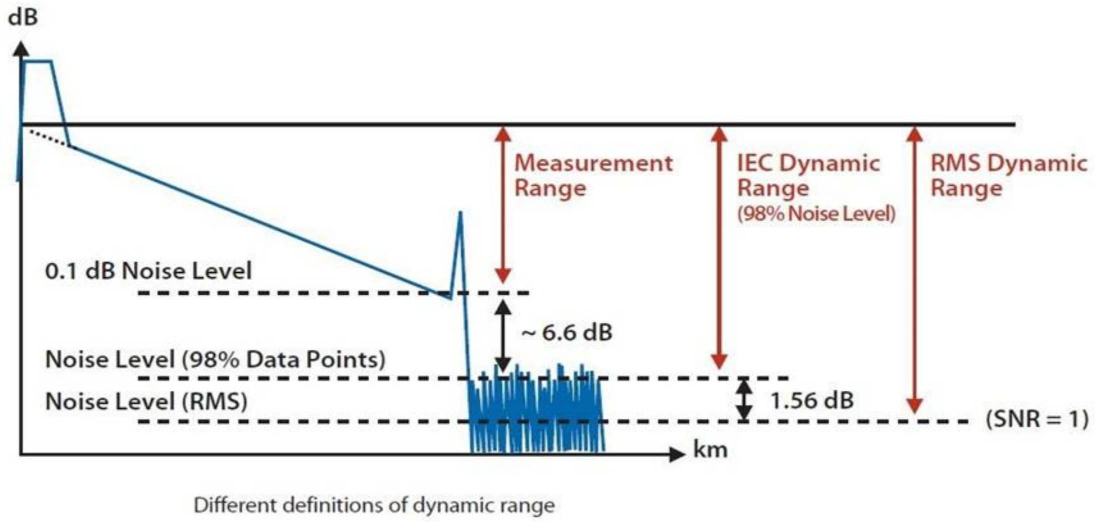


Fig. 3.1.14: Key OTDR specification table

Dead Zone

Dead zones are important characteristics since they determine the OTDR's ability to detect and measure two closely spaced events on fiber links. Dead zones are specified by OTDR vendors at the shortest pulse width and are expressed in meters (m).

- The event dead zone (EDZ)is the two consecutive reflective events of minimum distance (such as two pairs of connectors) can be distinguished by the OTDR.
- The attenuation dead zone (ADZ) is the minimum distance after a reflective event (for instance, a pair of connectors) that a non-reflective event (for instance, a splice) can be measured.

Pulse Width

The relationship between dynamic range and a dead zone is directly proportional. To test long fibers, more dynamic range is needed so a wide pulse of light is required. As dynamic range increases, the pulse width increases and the dead zone increases (close events won't be detected by the OTDR). For short distances, short pulse widths should be used to reduce the dead zones. The pulse width is specified in nanoseconds (ns) or microseconds (µs).

Fig. 3.1.15: A typical OTDR

Choose your OTDR as per your applications:

Wide range of OTDR models available in the market, addressing different measurement needs and test. A solid understanding of key OTDR specifications as well as the application will useful for buyers make right choice for their specific needs.

These are the questions to answer before looking for an OTDR:

- Which kind of networks will you be testing? LAN, metro, long haul?
- Which type of fiber will you be testing? Multimode or single-mode?
- What is the maximum distance you could test? 500 m, 20 km, 125 km?
- Which kind of measurements will you perform? Construction (acceptance testing), troubleshooting, in-service?

Choose your OTDR asper your applications.

Premises, LAN/WAN, Data Centers, Enterprise

Type of Fiber	Multimode	Single-mode	Single-mode and Multimode
Wavelengths	850/1300 nm	1310/1550 nm	850/1300/ 1310/1550 nm
Key specifications	Shortest possible dead zones to locate and characterize events that are closely spaced		

FTTA, DAS, and Cloud RAN

Type of Fiber	Multimode	Single-mode	Single-mode and Multimode
Wavelengths	850/1300 nm	1310/1550 nm	850/1300/ 1310/1550 nm
Key specifications	Shortest possible dead zones to locate and characterize events that are closely spaced		

Point-to-Point Access/Backhaul

Type of Fiber	Single-mode
Wavelengths	1310/1550 nm
Key specifications	Dynamic range ≤35 dB at 1550 nm
	Shortest possible dead zones to locate and characterize events that are closely spaced

Point-to-Multipoint Access/FTTH/PON

Type of Test	Installation — Before and After Splitter(s)	Installation with one or cascaded Splitter(s)	In-Service Trouble-shooting
Wavelengths	1310/1550 nm	1310/1550 nm	Filtered 1625 nm or 1650 nm
Key specifications	Dynamic range ≤35 dB at 1550 nm	Dynamic range ≥35 dB at 1550 nm to test through 1/32 splitter type	Dynamic range not relevant
		Dynamic range ≥40 dB at 1550 nm to test fibers with 1/64 splitter type	
	Shortest possible dead zones to locate and characterize events that are closely spaced	Shortest possible PON/splitter dead zones + automatic multi-pulses acquisition	Shortest possible dead zones to locate and characterize events that are closely spaced + automatic multi-pulses acquisition

CWDM & DWDM

Type of Test	Installation, Wavelength Provisioning, or Troubleshooting
CWDM Wavelengths	From 1271 nm to 1611 nm with a channel spacing of 20 nm
DWDM Wavelengths	C-band tuning – C62 to C12 (1527.99nm –1567.95nm)
Key specifications	Dynamic range ≥35 dB to test through mux, optical add/drop multiplexer (OADM), and demux
	Shortest possible dead zones to locate and characterize events that are closely spaced
	Integrated continuous-wave light source capability to verify end-to-end continuity

Metro/Long/Ultra Long Haul

Type of Network	Metropolitan/ Long Haul	Very Long Haul	Ultra Long Haul
Wavelengths	1310/1550/ 1625 nm	1310/1550/ 1625 nm	1550nm/ 1625 nm
Key specifications	Dynamic range ≥40 dB at 1550 nm	Dynamic range ≥45 dB at 1550 nm	Dynamic range ≥50 dB
	Shortest possible dead zones to locate and characterize events that are closely spaced		

Multiple Applications

Type of Network	Premises/Access	Metro to Very Long Haul
Wavelengths	850/1300/1310/1550 nm (1625 nm optional)	1310/1550/1625 nm (adding an external filter on the 1625 nm wavelength makes OTDR suitable for FTTH/PON network troubleshooting)
Key specifications	Dynamic range: Not relevant for multimode; ≤35 dB at 1550 nm for single-mode	Highest dynamic range
	Shortest possible dead zones	
	Modular platform that evolves according to testing needs and provides the most flexibility	

Fig. 3.1.16: Choosing OTDR as per application

Fig. 3.1.17: Various OTDR

Other Important Product Specifications

Operating an OTDR is not difficult, but it does require familiarity with fiber testing best practices in order to measure correctly. OTDR traces can only be analyzed and correctly interpreted by trained and experienced technicians. It's difficult for a less-qualified technician to operate an OTDR and make sense out of the results.

An intelligent software application, integrated into the instrument, can help technicians use an OTDR more effectively, without the need to understand or interpret OTDR traces. It schematically shows the fiber link tested and automatically recognizes and interprets each OTDR event and represents it as a simple icon for easy understanding. However, it is mandatory to be able to correlate the results to the original OTDR trace if needed.

Fig. 3.1.18: OTDR trace

Factors to consider when choosing an OTDR include:

- Size and Weight: vital on the off chance that you need to scale a cell tower or work inside a building.
- Show Size: 5" ought to be the base prerequisite for a show estimate. OTDRs with littler showcases cost less yet make OTDR follow examination more troublesome.
- Battery Life: an OTDR ought to be usable for a day in the field; 8 hours ought to be the base.
- Follow or results stockpiling: 128 MB ought to be the base inward memory with alternatives for outside capacity, for example, outer USB memory sticks.
- Bluetooth and additionally Wi-Fi Wireless Technology: remote network empowers effortlessly sending out test results to PCs/portable workstations/tablets.
- Measured quality/Upgradability: a particular/upgradable stage wills all the more effortlessly coordinate the development of your test needs; this may be costlier at the season of procurement yet is more affordable in the long haul.
- Post-Processing Software Availability: in spite of the fact that it is conceivable to alter and record your strands from the test instrument, it is significantly less demanding and more advantageous to examine and archive test comes about utilizing post-handling programming.

Acceptance testing of fiber optic cable with the help of OTDR

Fiber optic acceptance testing guarantees that any new link coordinates the optical and physical necessities of the arranged application. This testing ought to be endless supply of the link, preceding its establishment.

Always carefully examine the cable reel for physical signs of shipping damage. Look for evidenc e that indicates the cable has been subject to unacceptable amounts of stress. The reel will include some form of cable documentation. A copy of this information should be attached to the acceptance test form. These documents generally contain traceability information, as well as optical test data difficult to acquire in the field. For example, a multimode fiber reel's documentation would include information on the fiber's bandwidth, while a single-mode fiber reel would provide test data related to the various types of optical dispersion.

This documentation form also lists the fiber's index of refraction, as documented by the fiber's manufacturer. This number should not be used for the index of refraction in the OTDR because it does not include the cable's helix factor, which is a measure of the difference in fiber versus cable sheath length. The technician must compensate for the extra fiber slack by adjusting the OTDR's refractive index setting so that OTDR distance readings match the sequential markings on the cable jacket. The test of acceptance is the best opportunity to make these adjustments prior to cable installation. One important consideration in testing is to ensure a good launch condition that couples the maximum amount of light from the OTDR into the fiber. Poor launch conditions result in greatly reduced distance to measurement capability, and possible measurement errors. Before any tests can be made with the OTDR, it must be properly terminated to the fiber to be tested. For installed spans, linking the OTDR to the span under test requires a hybrid patch cord. Most OTDRs have an internal ultra-physical contact (UPC) spherical polish, but some reflection-sensitive systems use the angled physical contact (APC) polish. The hybrid patch cord addresses both connector type and connector polish issues. Always clean the end face of the plug prior to mating to the OTDR.

There are two strategies for ending a fiber. The primary technique utilizes an exposed fiber connector, which comprises of an attachment body that holds the fiber to be tried. The outline of the exposed fiber connector is with the end goal that the fiber can go totally through the connector body and harm the optical port. Along these lines, the exposed fiber connector should never be associated straightforwardly to the OTDR. Rather, the connector ought to be utilized with a short fix rope and mating connector sleeve to disconnect harm from OTDR's port.

The second technique utilizes a ponytail with a reusable mechanical graft, which enables simple mating of the filaments to be tried with the OTDR. The Norland reusable mechanical graft has been utilized for a considerable length of time for testing exposed strands. It highlights a glass body that inside holds and adjusts two filaments. The join is loaded with a refractive list coordinating liquid to decrease reflections.

To make the association, strip and sever both strands to be tried, at that point embed and focus both into the mechanical join to finish the end. For the link to be tried, set up the finish of the link by stripping ceaselessly the external coats, reinforcement (if present), and cradle tubes to a separation of roughly one meter. Clean the greater part of the strands and sort out them considering the business standard shading code. Strip, clean, and separate the principal test fiber and embed it into the other side of the mechanical join.

We will utilize the manual technique for OTDR operation. Begin the OTDR and select the right wavelength and refractive list for the test. Set the OTDR's estimation mode to "Two Point Attenuation". In this mode, the OTDR enables you to set markers at any two focuses on the backscatter follow and show the constriction of the locale between the markers in either dB or dB per kilometre. For an acknowledgment test, set the primary marker toward the start of the follow the underlying tail of the no man's land and the second marker toward the finish of the follow. The outcomes will show as dB/km at a wavelength being tried. Set the OTDR to "Constant Mode" and alter its range, beat width, and zoom settings so the whole fiber traverse is noticeable on the screen.

For this situation, alter the filaments in the brief mechanical graft. Make certain that the divide length is right and that the filaments are focused in the join.

In real-time mode, the trace may appear noisy. Start the OTDR's averaging mode to reduce noise and clean up the trace. After averaging is complete, the event table will show reflective events at the OTDR port and at the end of the fiber. The trace should appear linear with no abrupt interruptions that would indicate a break or other fault in the fiber. After the dead zone, the straight line will have a very gentle slope indicating the attenuation of the fiber span.

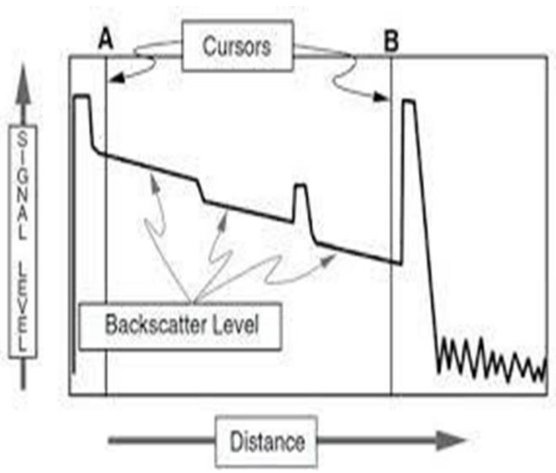


Fig 3.1.19: An OTDR trace showing a linear attenuation/

Marker placement is extremely important when making any OTDR measurement. Select the “A” marker and use the arrow keys to place it immediately following the dead zone at the OTDR’s connector. The tail of the dead zone is shaped somewhat like a ski slope. The exact point where this slope becomes a straight line is the point where the marker will be placed. The far Fiber end could be a spike representation, or less commonly, by a roll-off. In either case, the “B” marker must be placed at the exact point where the backscatter trace ceases to be a straight line. To correctly place the second marker, use the zoom controls on the OTDR for increased resolution.

The OTDR will display the distance from the OTDR connector to the end of the fiber as well as the complete loss of span in dB or the loss per kilometer. Use data storage features of the OTDR to save the trace using a unique file name. If using a dead-zone box, the length must be subtracted from the length measurement. When measuring the other fibers in the cable, the end reflection should be located at the roughly same point. The presence of shorter fibers implies that the fiber is damaged or stressed within the cable structure and will require further investigation. It could also be caused by cable structures with inner and outer rows of buffer tubes. The inner buffer tubes would have a shorter fiber length than those in the outer rows. In this case, an index of refraction adjustment must be made for both inner and outer rows and the adjustment documented.

For each fiber, make a note of the total length and dB per kilometer for each test wavelength on the acceptance test form. It is also important to test each fiber at the wavelengths designed for the fiber type. For multimode fiber, this is 850 and 1300 nanometers, and for single-mode fibers, both 1310 and 1550 nanometers. Refer to the testing specifications and note if they pass or fail. In addit ion, make note of the sequential markings at both ends of the cable, as well as the adjusted value of refractive index.

After each fiber has been tested, trim back 50 percent of the exposed length. This indicates that it has been tested, but allows re-testing if necessary. When all fibers go under testing, fibre traces must be counted in the OTDR’s memory to ensure that all fibers have been documented. Then, cut back the left over lengths of showcased fiber and correctly reseal the cable ends. All users will depend on the OTDR’s automatic measurement functions which displays length, losses and reflection values for the fiber span very quickly. In case of an acceptance test, the key points to document

are the total length of the fiber, the total loss of the fiber in dB, and the loss of the span for each test wavelength in dB per kilometer.

OTDR best practices

Several best practices ensure reliable OTDR testing.

Use of Launch/Receive Cables

Launch and get cables, which has spools of fiber with specific distances, must be connected to it ends of the fiber link under test to qualify the front end and the far end connectors using an OTDR. The length of the launch and receive cables depends on the link being tested, but it’s generally between 300 m and 500 m for multimode testing and between 1000 m and 2000 m for single-mode testing. For very long haul, 4000 m of cable may be used. The fiber length highly depends on the OTDR attenuation dead zone, which is function of the pulse width. The larger the pulse width, the longer the launch cable and receive cables. Launch/receive cables must be of the same type as the fiber under test.

Proactive Connector Inspection

A single dirty fiber connection can affect overall signal performance. Proactively inspecting each fiber connection with a fiber microscope probe will significantly reduce network down time and troubleshooting. Always use it in practice to ensure fiber end terminals are clean before making connections. A dirty OTDR port or a dirty launch/receive cable connector will impact the OTDR measurement. It needs to be inspected and cleaned before the launch cable is connected.

An optimized fiber optic network's infrastructure delivers reliable and robust services to customers. Positive customer experience drives loyalty, enabling a fast return on investment and sustained profitability. An OTDR is a key field tester for maintaining and troubleshooting fiber optic infrastructures. Before finalizing an OTDR, relook into the applications that the instrument will be utilized and check the OTDR's specifications to ensure that they are suited to your applications.

3.1.7 Insertion Loss Test

All measurement in fiber optics brings notice to optical power measured in dB. The power output of a transmitter or the input to receiver is "absolute" optical power measurements, that is, you measure the actual value of the power. Loss is a "relative" power measurement, the difference between the power coupled into a component like a cable, splice or a connector and the power that is transmitted through it. This difference in power level before and after the component is what we call optical loss and defines the performance of a cable, connector, splice, etc.

Insertion Loss Test: An insertion loss verification conducted by light source and power meter is a easy test that resembles the principle of fiber optic link operation. A light is kept on one terminal of the cable and a power meter measures loss at end terminal, as like a link transmitter and receiver use the fiber for communications.

Tools – Insertion Loss Test

Following are the tools required for measuring 'Insertion Loss':

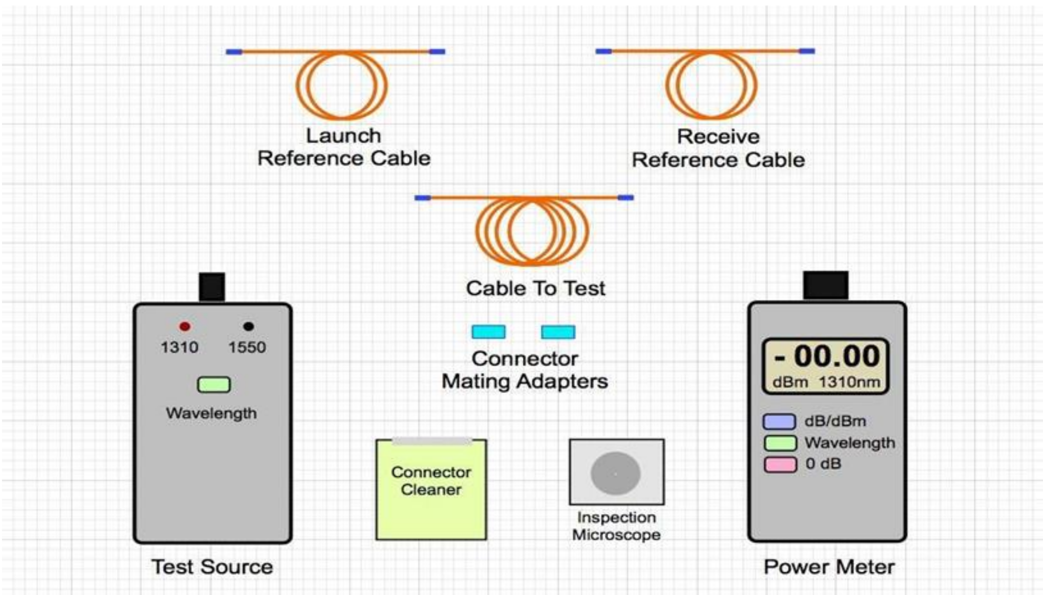


Fig 3.1.20: Tools for testing insertion loss

Steps - Insertion Loss Test

Following are steps to test the insertion loss:

Step 1 - Connector end-faces are to be verified and cleaned (alcohol wipes) before mating via adapters

Step 2 - Set-up light source, power meter e.g., adapters, power supply, data entry, etc.

Note: given list of entities need warm up period to stabilize.

Step 3 - Setup “launch cable” for calibration before actual tests.

Step 4 - Connect actual leads to the “launch cable” in order check loss at one end.

Step 5 - Connect the third lead to the ”launch cable” and the actual lead to check the loss at the other end.

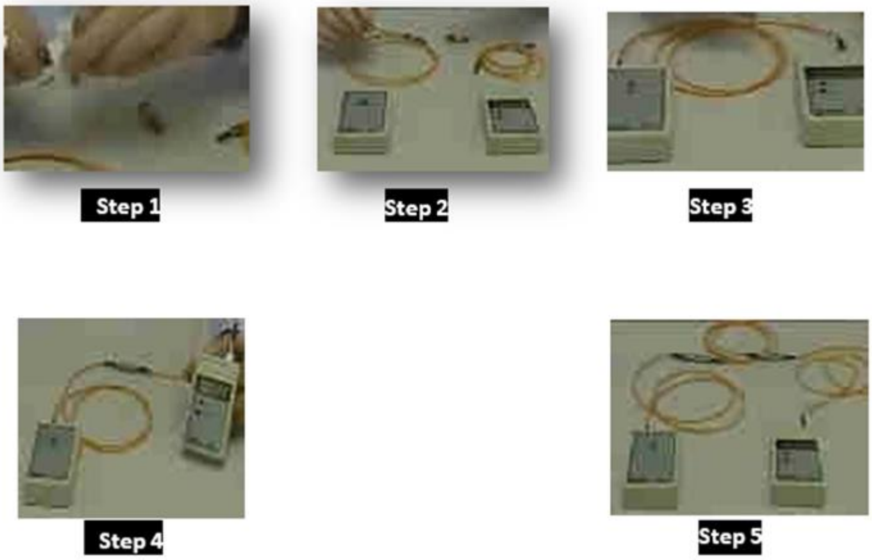


Fig 3.1.21: Steps for testing insertion loss

3.1.8 Optical Return Loss

Reflectance or optical return loss (also called "back reflection") of a connection is the amount of light that is reflected back up the fiber toward the source, by light reflections off the interface of the polished end surface of the mated connectors and air. It is also called Fresnel reflection and is caused by the light going through the change in index of refraction at the interface between the fiber (n=~1.5) and air (n=~1). Reflectance is primarily a problem with connectors but may also affect mechanical splices which contain an index matching gel to prevent reflectance.

Fig 3.1.22: (a) Return (b) Return Loss

Steps – Optical Return Loss Test

Following are steps to test the insertion loss:

Step 1- Optical Reference Loss (ORL); referencing: count the output power level at the fiber jumper with help of power meter

Step 2- Measure the ORL of the front connector (jumper to test equipment connection). Requires use of connectors

Step 3 - Connect to the fiber under test:

- ORL is measured in dB and is a positive value.
- Higher the number, smaller the reflection – yielding the desired result.
- ORL is most commonly measured at 1310, 1550 and 1625nm single-mode wavelength.

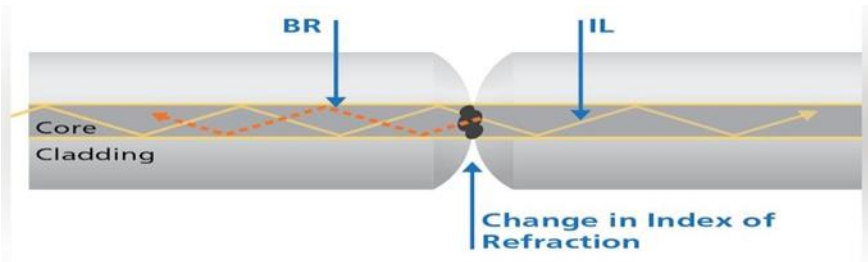


Fig 3.1.23: Optical return loss test

3.1.9 Miscellaneous Test

Following are the other checks that should be done:

- Verify the fiber joint by OTDR to assured conformance to design needs.
- Sealing off joint closure via heat shrinking/ multi-diameter seals/ mechanical seals as appropriate.
- FRP- Fiber Reinforced Plastic is utilized to strengthen the joint as needed.
- Verify the fiber at both terminals for instances of cross fiber using power source and power meter tests and ensure their elimination

We need to make sure that:

- Joint is kept properly in chamber properly
- Additional cable (loop) is coiled as needed & kept inside the joint
- Sand is filled in the chamber to the brim and the chamber covers are placed properly Connected indicator must be placed right 1 m behind the chamber location (away from road)
- A specific color used for painting indicator (for e.g., yellow for joint)

3.1.10 Identifying and Eliminating Cross-Fiber Issues and Performing Final Transmission Loss Tests in Optical Fiber Networks

Ensuring the integrity of optical fiber networks involves more than just proper cable laying and splicing. Testing the fiber after installation is critical to detect faults such as cross-fiber connections and signal loss that could compromise network performance. This chapter explains how to identify and eliminate cross-fiber issues using power source and power meter tests and how to conduct final transmission loss tests to ensure compliance with manufacturer specifications.

Identifying Cross-Fiber Issues

What are Cross-Fiber Issues?

Cross-fiber issues occur when signals intended for one fiber path unintentionally couple into another fiber. This can lead to poor signal quality, increased error rates, and even complete failure in communication between endpoints. Cross-fiber interference is often caused by:

- Improper splicing or connector insertion
- Physical damage to the cable
- Loose connections at patch panels
- Faulty or dirty connectors
- Incorrect routing or labeling

Identifying these issues early ensures the network operates at peak efficiency.

Using Power Source and Power Meter Tests to Detect Cross-Fiber Issues

1. Equipment Overview
   - Power Source: A device that generates a known optical signal, typically at a specific wavelength.
   - Power Meter: A measurement tool that detects the strength of the optical signal in a fiber.
2. Setting Up the Test
   - Connect the power source to one end of the fiber link, ensuring a stable and calibrated light output.
   - Connect the power meter at the receiving end of the fiber link.
   - Confirm that both devices are set to the correct wavelength (typically 1310 nm or 1550 nm, depending on the fiber type and project specifications).
3. Performing the Test
   - Send the test signal from the power source through the intended fiber.
   - Measure the received signal using the power meter.
   - Compare the measurement to the expected output.
4. Identifying Cross-Fiber Interference
   - If the power meter reads signals on unintended fibers, this is a sign of cross-fiber issues.
   - Multiple unexpected readings across different fibers indicate coupling or leakage.
   - A sudden drop or rise in signal strength may also suggest splicing errors or connector faults.
5. Eliminating Cross-Fiber Issues
   1. Visual Inspection
      - Check connectors for dirt, dust, or misalignment.
      - Inspect patch panels to ensure correct fiber labeling and port usage.
   2. Re-Splicing
      - If the issue arises from poor splicing, carefully remove the damaged section and perform fusion splicing again, ensuring precise fiber alignment.
   3. Cleaning Connectors
      - Use fiber optic cleaning tools to remove contaminants from connectors and ensure proper mating.
   4. Re-routing
      - Ensure cables are correctly routed according to the documented layout to prevent accidental coupling.
   5. Retesting
      - After adjustments, perform another power source and meter test to confirm that cross-fiber interference has been resolved.

3.1.11 Performing Final Transmission Loss Tests

Understanding Transmission Loss

Transmission loss refers to the reduction in signal strength as light travels through a fiber. Every fiber has an acceptable loss threshold, defined by manufacturer specifications, which ensures signals can travel long distances without degradation.

Common causes of transmission loss include:

- Poor splicing
- Bending or stress on the fiber
- Dirty or faulty connectors
- Incorrect installation depth or duct placement

Steps to Perform Final Transmission Loss Tests

1. Calibration
   - Ensure the power source and meter are calibrated before testing.
   - Set the appropriate test wavelength according to fiber type.
2. Test Procedure
   1. Connect the power source to the transmitter side of the fiber link.
   2. Connect the power meter to the receiver side.
   3. Measure the input power at the source end and the output power at the receiving end.
   4. Calculate transmission loss by subtracting the received power from the transmitted power.

Formula:

Transmission Loss (dB) = Input Power (dBm) – Output Power (dBm)

Interpreting Results

- Compare the measured loss against manufacturer specifications.
- A typical single-mode fiber loss at 1550 nm is less than 0.35 dB/km.
- If the measured loss exceeds the threshold, corrective actions must be taken.

Rectifying Issues That Exceed Specifications

Common Causes and Solutions

1. Excessive Bending
   - Check for sharp bends near splices or connectors.
   - Ensure the fiber bend radius is not less than the recommended limit (usually 30 mm or greater).
2. Connector Contamination
   - Inspect connectors using a fiber inspection scope.
   - Clean connectors with lint-free wipes and approved cleaning solutions.
3. Splice Errors
   - Review splicing procedures and repeat fusion splicing with better alignment.
4. Improper Patch Panel Termination
   - Confirm fiber routing and proper port usage.
   - Reinsert connectors and secure them to prevent movement.
5. Environmental Damage
   - Check ducts for crushing, water ingress, or physical damage.
   - Replace damaged sections and ensure proper protective materials like GI or RCC pipes are in place.

Documentation After Rectification

- Record initial and final transmission loss measurements.
- Document any corrective steps taken (re-splicing, cleaning, re-routing).
- Update cable IDs, joint locations, and test reports.
- Obtain sign-off from the project team before commissioning the fiber link.

Importance of These Tests

1. Ensures Network Integrity
   - Detecting cross-fiber issues prevents data loss and network failures.
2. Improves Signal Quality
   - Accurate transmission loss measurement guarantees the network meets performance requirements.
3. Reduces Downtime and Maintenance Costs
   - Early detection and resolution prevent future disruptions.
4. Complies with Standards
   - Adhering to manufacturer guidelines and industry best practices ensures regulatory compliance and long-term network reliability.

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=wnCOnzGc0iU

VFL(visual Fault Locator)

https://www.youtube.com/watch?v=jML7kgQ-MjA

How to test the insertion loss of Fiber Optic Cable

UNIT 3.2: Optical Fiber Testing, Documentation, and Predictive Maintenance

Unit Objectives

By the end of this unit, the participants will be able to:

1. Describe the compatibility requirements for advanced connectors and protection sleeves in OFC installations.
2. Explain the different types of OFC connectors based on equipment specifications and their applications.
3. Determine the functionality and usage of optical equipment like cleavers, fusion splicers, and mechanical splicing kits.
4. Discuss the operation and importance of fiber strippers, protection sleeves, and fiber-reinforced plaster in fiber optic installation.
5. Describe the use of advanced tools like multi-joiner fusion splicers and cable blowing machines in optical fiber deployment.
6. Demonstrate how to verify the availability and proper operation of advanced multi-joiner fusion splicers.
7. Show how to supervise multi-fiber splicing to ensure proper alignment and minimal signal loss.
8. Demonstrate how to use advanced protection sleeves and connectors during fiber termination.
9. Show how to follow step-by-step splicing and termination techniques to maintain quality standards.
10. Show how to ensure splice quality meets established quality assurance standards.
11. Show how to check for proper backfilling, crowning, and the installation of route/joint markers.
12. Demonstrate how to update as-built documentation with accurate joint locations and installed fiber routes.
13. Show how to ensure site cleanup and proper disposal of debris after fiber optic installation.

3.2.1 Splicing of OFC

It is a process of connecting two optical fibres permanently.

It is commonly used in long cable runs, which need more than one cable connection. This can connect different cables and can interlink various locations. It is used to terminate the single Fibres. It is commonly used in OSP applications because cables are pulled and terminated. There are two types of splicing:

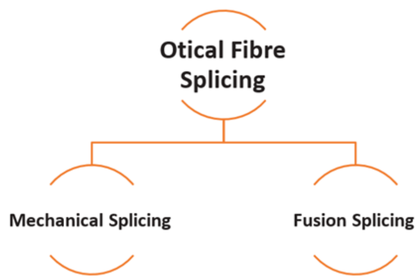


Fig. 3.2.1: Types of splicing of OFC

Why do we need to splice optical fibres?

Following are the reasons for carrying out 'Splicing':

- It is used when a long fibre cable is required
- It is used to connect two or more small fibre cables, which are bound to make a single connection using small cables
- Cut-off fibre links may need splicing to join them
- It is used in terminating the optical fibre to network and fibre panels

3.2.2 Types of Optical Fibre Splicing

As already discussed above, optical fibre splicing is of two types – Mechanical and Fusion. Let us discuss both types in detail.

Mechanical Splicing

This splicing technique comprises the precise alignment of two fibre optic cables, held in place by a self-contained assembly rather than a permanent bond. A mechanical splice is used to hold two fibre optic cables, allowing the light to pass through seamlessly, with a typical loss of around 10% (or 0.3 dB).

In this process, you must use an alignment device along with an index matching gel. The gel used must have a similar refractive index to enhance the light transmission across the joint, with minimal back reflection.

Steps to perform mechanical splicing:

Step 1: Prepare the fibres

The first step is to precisely strip the fibres of their protective coatings, jackets, tubes and strength.

Fig. 3.2.2: Preparing fibre for mechanical splicing

Step 2: Cleave the fibres

After stripping, the next step is to break your cables using a fibre cleaver. Now, use the cleaver to create a small, clean cut on the cables with ends perpendicular to the fibre axis.

Step 3: Mechanical joining of fibres

In this step, you just have to place the fibre accurately ends together in the mechanical splice unit. The index matching gel inside the equipment will do the rest, like linking the light to the ends of your cables. If using an older unit, you may have to use epoxy instead of the index matching gel to align the fibres correctly.

Step 4: Securing united fibres

Once done with these steps, place the fibres in a splice tray and then inside a splice closure. Now the completed mechanical splice renders its own protection for the splice. Ensure to seal the cables carefully, as this will prevent your cables from experiencing moisture damage.

Fig. 3.2.3: Mechanical Splicing

Types of mechanical splicing

V-Grooved Splicing

This technique takes a V-shaped substrate, and the two fibre ends are butted in the groove. Once the two are properly placed inside the groove, they are bonded by an index matching gel. This index matching gel provides proper grip to the connection. The V substrate can be composed of ceramic, plastic, silicon, or any metal.

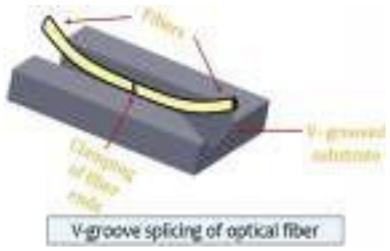


Fig. 3.2.4: Mechanical Splicing (V-Groove Splicing)

However, the fibre losses are more in this technique as compared to the fusion technique. These losses are due to the core and cladding diameter and core position with respect to the centre. Here, the two fibres do not form a continuous smooth connection as the joint is semi-permanent.

Elastic-Tube Splicing

It is a technique of splicing the fibre with the help of the elastic tube, which majorly finds its application in the case of multi-mode optical fibre. Here the fibre loss is similar to that of the fusion technique. However, the need for the equipment and skill is slightly less than the fusion splicing technique.

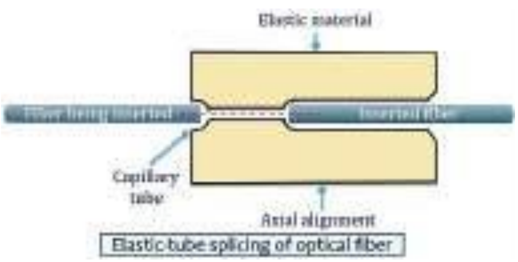


Fig. 3.2.5: Mechanical Splicing (Elastic-tube splicing)

Here, the elastic material is rubber, inside which a small hole is present. The diameter of this hole is less than the diameter of the fibre to be spliced. Tapering is done at the ends of both the fibres to allow easy insertion inside the tube.

When the fibre with a slightly larger diameter than the hole is inserted inside the hole, then it ultimately gets expanded. Due to this symmetricity, a proper alignment between the two fibres is achieved.

Fusion Splicing

Another method to join fibre optic cables together to form a permanent connection is fusion splicing. Here, a machine or an electric arc is used to produce heat and fuse/weld glass ends that are precisely aligned together for seamless transmission of light. It has a much lower attenuation of around 0.1 dB.

Fig. 3.2.5: Fusion Splicing

Overview of Fusion Splicing
Stripping the Fibre:

- It is a process of removing the protective layer, which is a polymer, from around the fibre.
- This process of splicing begins by fusing the two ends together.
- It is done by passing the fibre via a mechanical stripping device. We can also use a special procedure for stripping, which can be done using sulphuric acid.
- Sometimes, hot air is also used to remove the coating.
- There is also a method which uses chemicals under a defined time. It is called as solvent capture method.
- This procedure also helps to get rid of coatings and claddings.
- Tools used in cleaning the stripping and cleaving are very important.

Cleaning the Fibre:

- It is a process of cleaning the Fibres with alcohol and wipes like alcopad.
- Use of IPA is not advisable, as it attracts impurities.
- IPA is hygroscopic in nature, which is why it absorbs moisture.
- So, most aqueous-based cleaners are used in cleaning.

Cleaving the Fibre:

- The fibre is cleaved using the score and break method to make it flat and perpendicular to its axis.
- A microscope is used to analyse the quality of the fibre.

Splicing the Fibre

- Using core or cladding alignment, the fusion splicer automatically aligns the two cleaved fibres in the x,y,z plane; then, the fibres are fused together.
- Proof-test is done to confirm that the splice is firm enough to tolerate handling, packaging and prolonged use. Then, it is removed from the fusion splicer.
- Recoating is done, or a splice protector (heat shrinkable tube with strength membrane) is used to safeguard the bare fibre area.

Optical splicing procedure

- Placement of splicing process. Inspecting fibre optic splice closure content and the supplementary kits.

- Cable installation in the oval outlet.
- Cable preparation.
- Organisation of the fibres within the tray.
- Installing heat shrinkable sleeve and testing it.

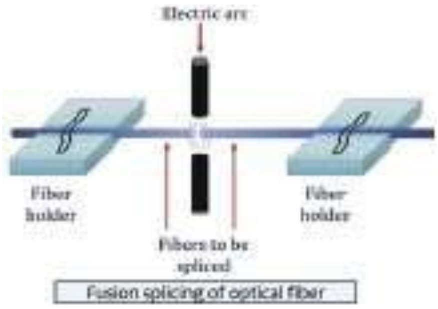


Fig. 3.2.7: Fusion splicing process

Fibre Spliced Still Unprotected

- The basic fusion splicing apparatus has two fixtures (sheath clamps) for mounting the fibres and two electrodes
- An inspection microscope is used to place ready fibre ends into the fusion-splicing apparatus. The fibres are then aligned and fused together
- Nichrome wire was used earlier in fusion splicing as the heating element to fuse fibres together
- Carbon dioxide (CO2) lasers, electric arcs, or gas flames are used to fuse the fibres.
- Electric arc fusion (arc fusion) has become a popular technique for splicing due to small-sized and automatic fusion splicers.
- Optical fibre connectors or mechanical splices can be used but have higher insertion losses, lower reliability and higher return losses than fusion splicing.

Fig. 3.2.8: Basic splicing instrument

Cable Preparation for Splicing

Following are the checks to prepare OFC for splicing:

- Check the installed cable and whether it has all the parameters as per the plan.
- Look for the damage or any issues
- Make sure those bend ratios are as per the measurement.
- Make sure that the cable is placed on a stable joining pit.
- Secure the cable properly to avoid damage.
- Check that the fibres are joined as per the colour coding and sequence.

Material and Equipment Used for Splicing

 Fibre optic cable	 Pig tail (2 in number)	 Stripper
 Mechanical splice	 Fusion splicer	 IPA cleaner & wipes
	 Cleaver	

Table 3.2.1: Equipment Used for Splicing

Steps for fusion splicing

Step 1: Prepare the fibres

The first step is to strip the fibres of their protective coatings precisely.

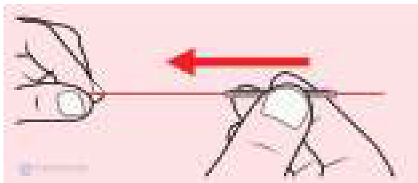


Fig. 3.2.9: Prepare the fibres

Then, similar to mechanical splicing, strip the protective coating around the optical fibre using a mechanical fibre stripper until you reach the bare fibre cores. Clean the stripping tools before starting the process.

Step 2: Clean and cleave the fibres

Clean the bare fibre using an Isopropyl Alcohol wipe. Do it twice using a different part of the wipe.

Once cleaned, avoid touching or contaminating the surface.

Now, use the cleaver to create a small, clean cut on the cables with ends perpendicular to the fibre axis.

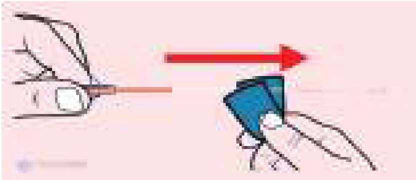


Fig. 3.2.10: Clean and cleave the fibres

Step 3: Fuse the fibres

The fibre is now ready to fuse using the fusion splicer. It involves the alignment of the fibres and heating to melt the fibre ends and fuse them.

Alignment can be manual or automatic, depending on the fusion splicer you are using. Once the end faces of the fibre are flawlessly aligned and centred on the electrodes, the splicer unit uses an electric arc to melt the two fibre ends and fuse them together.

Fig. 3.2.11: Fusion of fibres

If the fusion splicer stops the process in between, it may be due to the following issues:

- Poor alignment of the wires on their guides
- Fibres are not cleaved at a perfect 90-degree angle
- Due to the presence of some residual plastic cover or dirt on the end of the fibre

Step 4: Protect the fibre

A fusion splice usually has a tensile strength between 0.5 and 1.5 lbs and will not break during normal handling. Even then, it is advisable to provide protection from bending and pulling forces and ensure the fibre doesn't break during routine use.

After the fibres are successfully fused together, it's time to either re-apply a coating or use a splice protector.

You can use silicone gel, heat shrink plastic, or mechanical crimp protectors to secure the splice from external damage and breakage.

3.2.3 Tips for Better Splices

1. **Tips 1:** Thoroughly and frequently clean your splicing tools. When working with fibre, keep in mind that particles not visible to the naked eye could cause tremendous problems when working with fibre optics. Excessive cleaning of your fibre and tools will save you time and money.
2. **Tips 2:** Properly maintain and operate your cleaver. The cleaver is your most valuable tool in fibre splicing. Within mechanical splicing you need the proper angle to insure proper end faces or too much light escaping into the air gaps between the two fibres will occur. The index matching gel will eliminate most of the light escape but cannot overcome a low quality cleave
3. **Tips 3:** For Fusion splicing, you need an even more precise cleaver to achieve the exceptional low loss (0.05 dB and less). If you have a poor cleave the fibre ends might not melt together properly causing light loss and high reflection problems. Maintaining your cleaver by following manufacturer instructions for cleaning as well as using the tool properly will provide you with a long lasting piece of equipment and ensuring the job is done right the first time.
4. **Tips 4:** Fusion parameters must be adjusted minimally and methodically. If you start changing the fusion parameters on the splicer as soon as there is a hint of a problem you might lose your desired setting. Fusion time and fusion current are the two key factors for splicing. High time and low current result in the same outcome as high current and low time. Make sure to change one variable at a time and keep checking until you have found the right fusion parameters for your fibre type.

3.2.4 Evaluating Splices

Good Splices

You can look at the splice after the installation using both X and Y views. Some of the damage does not have any effect on the optical transmission. These are acceptable, and the examples for good splices are shown in the image given below. Some Fibres can cause white and black lines in the splice but are not considered faults. These are shown in the following figure:

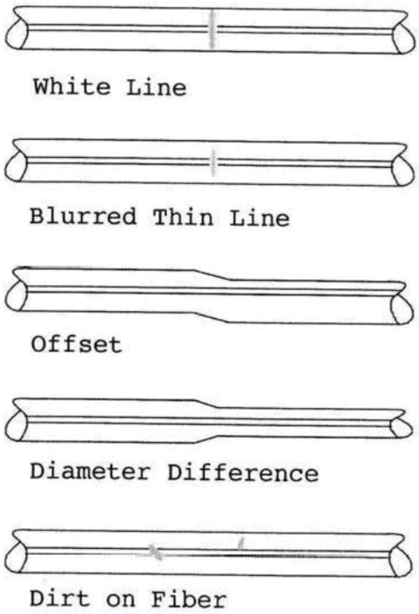


Fig. 3.2.12: These flaws do not affect optical transmission

Bad Splices

Splicing black spots or lines are known as bad splices, and these can be corrected. But they cannot be corrected more than twice. Other bad splices' identities are core offsets, bubbles and bulging splices.

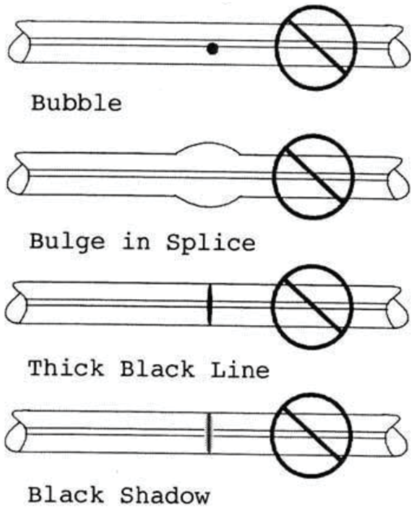
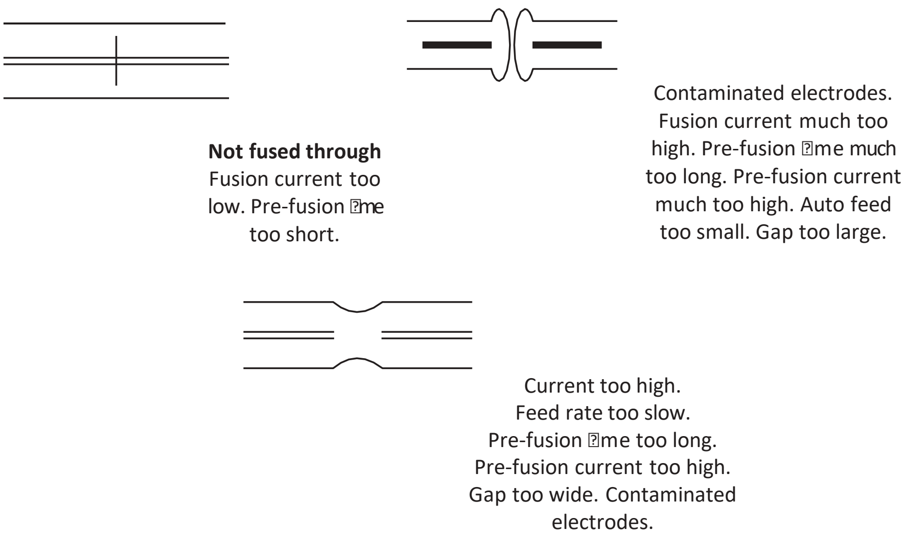
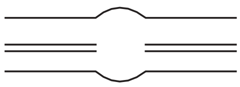


Fig. 3.2.13: These flaws require a redo

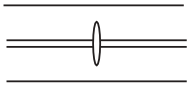
Splice Problem Troubleshooting

Some common problems and their likely causes are shown in the following figure:





Enlargement
Auto-feed too fast.
Incorrect current.



Bubble or Inclusion
Contaminated fiber end faces. Poor cleave. Fusion current too high.. Pre-fusion current or time too low.

Additional problems

Fusion splicers generally have stored programs for most fibers and the user can modity those program parameters or create new ones. Refer to the instruction manual or ask the manufacturer is there is any question about using the splicer with the fiber you are installing.

It is sometimes necessary to splice older fibers, either in restoration or modifying networks. Older fibers may become brittle and hard to strip.

Fig. 3.2.14: Splice Problem Troubleshooting

3.2.5 Optical Fibre Safety Overview

Keep all food and beverages out of the work area. If fiber particles are ingested they can cause internal hemorrhaging

Wear disposable aprons to minimize fiber particles on your clothing, Fiber particles on your clothing can later get into food, drinks, and/or be ingested by other means.

Always wear safety glasses with side shields and protective gloves. Treat fiber optic splinters the same as you would glass splinters.

Never look directly into the end of fiber cables until you are positive that there is no light source at the other end. Use a fiber optic power meter to make certain the fiber is dark. When using an optical tracer or continuity checker, look at the fiber from an angle at least 6 inches away from your eye to determine if the visible light is present.

Only work in well ventilated areas.

Contact wearers must not handle their lenses until they have thoroughly washed their hands.

Do not touch your eyes while working with fiber optic systems until they have been thoroughly washed.

Keep all combustible materials safely away from the curing ovens.

Put all cut fiber pieces in a safe place.

Thoroughly clean your work area when you are done.

Do not smoke while working with fiber optic systems.

Fig. 3.2.15: Safety rules

3.2.6 Splicing Safety – Norms and Rules

During splicing following safety rules must be followed:

- It is advised to wear safety goggles at all times of installation and other exercises and activities. You must insist the person working without a glass wear it
- Dispose of the bi-products at the proper disposal area. Make sure they are removed carefully, and no one gets harmed because of the waste
- Cover the tools before storing
- Clean the tools properly for the next use
- Always make use of FDU. You can replace FDU with the use of water or soda
- Always have scraps which can be used to pick the diffused products into the skin
- The objects and wastes are very tiny and can diffuse into the skin, which is very difficult to remove with bare hands. So, make sure to wear protective clothing
- Make use of scotch tape to pick the small pieces of fibre
- Use dark colour paper while working, because these can help show the small particles that are emitted while working
- Always use IPA, epoxy and anaerobic adhesive while working
- Always wipe the tool with alcohol
- Remember that epoxy cannot be removed from clothes
- Never touch any Fibre with bare hands or fingers
- Terminators are very hot from the curing ovens. So be cautious while handling them
- Be careful while handling a glass piece as it can cut the skin

3.2.7 Safe Handling Procedures for Optical Fibre Splicing

Objective:

Ensure all personnel follow proper safety protocols to prevent injuries, equipment damage, and network reliability issues during fibre optic splicing activities.

Key Safety Guidelines:

1. **Personal Protective Equipment (PPE):**
   - Always wear safety goggles to protect eyes from tiny fibre shards.
   - Use protective clothing (gloves, lab coats, or long sleeves) to prevent skin contact with fibre fragments or chemical adhesives.
2. **Handling Fibre Scraps:**
   - Collect fibre scraps immediately to avoid accidental embedding in skin.
   - Use scotch tape or tweezers to safely pick up tiny pieces of fibre.
   - Work over dark-colored surfaces to easily spot stray fibre fragments.
3. **Chemical Safety:**
   - Handle epoxy, anaerobic adhesives, and IPA carefully; avoid direct contact with skin and clothing.
   - Clean any spills immediately using proper disposal methods.
   - Avoid using IPA excessively as it attracts moisture; prefer aqueous-based cleaning solutions.
4. **Tool Safety and Maintenance:**
   - Always cover tools when not in use.
   - Clean all tools, cleavers, and strippers after each session to remove residue.
   - Inspect fusion splicers and mechanical splicing units before use.
5. **Splice Closure and Environmental Safety:**
   - Use Fiber Distribution Units (FDU) or water/soda alternatives to safely handle diffused particles.
   - Ensure proper sealing of splice closures to prevent moisture ingress.
   - Properly coil and secure spare fibres inside the joint closure to prevent bending or breakage.
6. **General Precautions:**
   - Never touch bare fibre ends with bare hands.
   - Dispose of all by-products and scraps in designated disposal areas.
   - Be aware of potential long-term hazards if safety procedures are ignored.

Exercise

Short Questions:

1. Explain how refraction and dispersion affect signal transmission in optical fibers.
2. What are the differences between fusion splicing and mechanical splicing in fiber optic networks?
3. Describe how the choice of wavelength band influences the performance of an optical fiber network.
4. Why is it important to use compatible connectors and protection sleeves in fiber optic installations?
5. How do OTDR and power meters help in identifying faults in an optical fiber network?

Fill in the Blanks:

1. The bending of light inside the optical fiber core due to differences in refractive index is called ___________.
2. A ___________ is used to remove the outer coating of a fiber before splicing.
3. Excessive signal loss due to scattering or absorption in the fiber is referred to as ___________.
4. The device that helps locate faults and measure distance along a fiber cable is called an ___________.
5. After installation, accurate ___________ must be recorded to ensure proper network operation and troubleshooting.

Multiple Choice Questions (MCQs):

1. Which property of optical fiber is responsible for light bending inside the core?
   a) Attenuation
   b) Refraction
   c) Polarization
   d) Dispersion
2. Which of the following tools is used to ensure proper alignment during fiber splicing?
   a) Fiber stripper
   b) Cable blowing machine
   c) Fusion splicer
   d) Light meter
3. What is the typical reason for using protection sleeves during fiber termination?
   a) To enhance signal speed
   b) To prevent dust contamination
   c) To protect the fiber from mechanical stress
   d) To reduce light reflection

4. Which test instrument helps measure the power loss between two points in a fiber link?
    a) OTDR
    b) Power meter
    c) Fusion splicer
    d) Cable blower
5. What is the main purpose of updating as-built documentation after installation?
    a) To prepare for warranty claims only
    b) To improve signal strength automatically
    c) To keep accurate records for maintenance and troubleshooting
    d) To increase fiber count

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=A-190m4LvEg

Optical Fiber Splicing Safety

4. Perform Corrective Maintenance/ Restoration of Optical Fiber Faults

Unit 4.1 - Fault Notification

Unit 4.2 - Fault Localization and Restoration

Unit 4.3 - Preventive and Corrective Maintenance

TEL/N6404

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Explain the process of handling fault notifications in an optical fiber network.
2. Describe the steps involved in rectifying faults at Points of Presence (POPs).
3. Discuss the importance of documenting and reporting fault rectification status.

UNIT 4.1: Fault Notification

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss signal strength and quality Key Performance Indicators (KPIs) used in optical fiber networks.
2. Describe network design principles and fiber optic system integration.
3. Discuss proper fiber cable termination techniques, including the use of advanced protection sleeves and connectors.
4. Describe the route and cable marking conventions for long-term maintenance and identification.
5. Demonstrate how to interpret fault notifications received from the Network Operation Center (NOC) or supervisors.
6. Show how to determine Turn Around Time (TAT) for fault rectification based on Service Level Agreements (SLAs).
7. Demonstrate how to access and interpret as-built drawings for fault location analysis.
8. Show how to verify the necessary tools and safety gear before heading to a fault location.

4.1.1 Fault Notification

Fault notifications are:

- Intimations received about fault in link, cable ends, connectors or tools & equipment from the customers, contractor or NOC (Network Operations Centre) are relayed to the network operations maintenance team and the same is rectified and the information is relayed back.
- The following picture indicates normal operation and what happens in case of a fault.

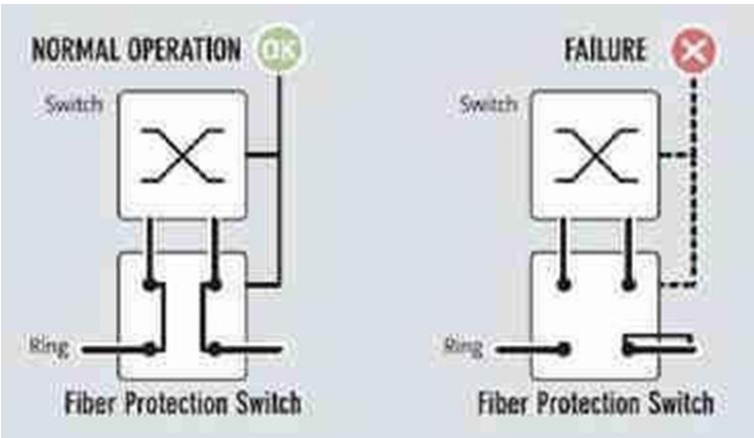


Fig. 4.1.1: Normal operation and failure

4.1.2 Steps Process of Receiving Fault Notification

A network operations center views the process of receiving the fault from the customer, contractor and the steps are as follows:

Step 1 - An operator zooms in from a macro view to the area of concern. Transceiver detects a fiber fault between a hub and one of the points (sometimes called a spoke).

Step 2 -The operator is immediately notified about the fault's approximate location as depicted in 'Red'. Operator acknowledges the fault and relays information to the network operations team of the area.

Step 3 -Once the fault has been fixed, information from the 'Network Team' is relayed back to the operator who then closes the issue.

Fig. 4.1.2: Step 1 - Fault Received

Fig. 4.1.3: Step 2 - Fault Acknowledged

Fig. 4.1.4: Step 3 - fault cleared

4.1.3 Fault Notification Guidelines

One should adhere to the following guidelines:

- Cross check the fault.
- Confirm the SLA's/ timelines.
- Set the priority with the team members.
- Get in touch with all stakeholders involved in fault rectification.
- Arrange for permits or approvals and equipment if needed.
- Document - fault, reasons and report; document resolution.

4.1.4 Fault Notification Process

One should adhere to the following fault notification process:

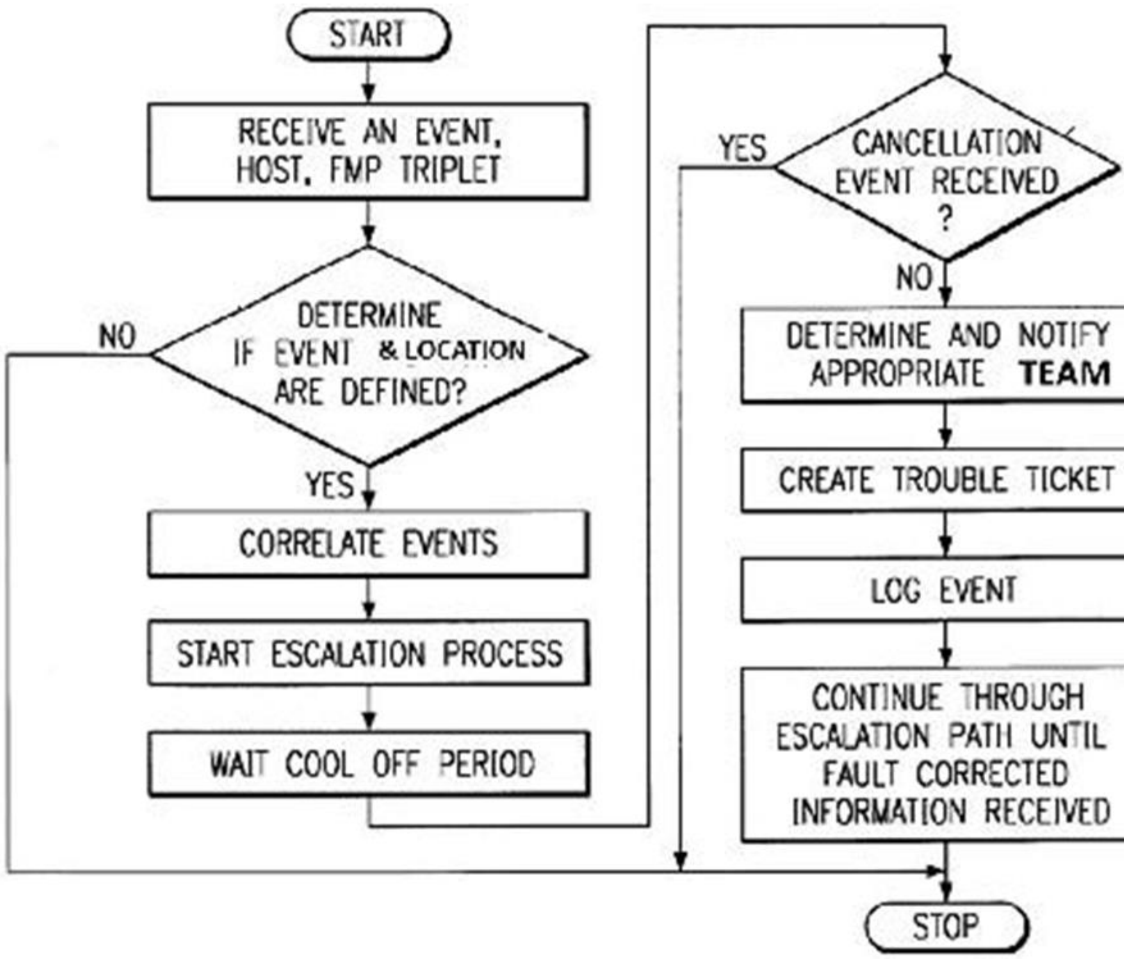


Fig. 4.1.5: Fault notification process

4.1.5 Fault Notification and Response in Optical Fiber Maintenance

In optical fiber communication networks, faults such as fiber cuts, signal degradation, connector failures, or splice errors can disrupt service and affect customer satisfaction. Rapid detection, accurate interpretation of fault alerts, and swift response are critical for minimizing downtime. This chapter explains how to interpret fault notifications from the Network Operations Center (NOC) or supervisors and how to estimate Turn Around Time (TAT) for fault rectification based on Service Level Agreements (SLAs).

Understanding Fault Notifications

Fault notifications are alerts that indicate a problem in the optical fiber network. These alerts can be generated by automated monitoring systems, NOC technicians, or supervisors based on network performance metrics, alarms, or customer complaints.

Sources of Fault Notifications

- Network Operation Center (NOC): NOCs continuously monitor network performance using real-time data from OTDRs, power meters, and traffic analysis tools. When an anomaly is detected, such as unexpected attenuation or signal loss, a fault alert is generated and communicated to field technicians.
- Supervisors or Field Reports: Technicians or supervisors at a location may report issues such as visible damage to cables, connector faults, or service disruptions.
- Customer Complaints: End users or clients may report slow internet speeds, intermittent signals, or total service outages, prompting fault verification.

Key Information in Fault Alerts

When a fault notification is received, it typically includes the following information:

1. Fault Location
    - GPS coordinates or site name
    - Route section or segment number
    - Nearest identifiable landmarks
2. Fault Type
    - Fiber cut
    - High attenuation
    - Connector or splice fault
    - Water ingress or corrosion
    - Cross-fiber interference
3. Time of Detection
    - When the fault was first detected
    - Whether it is intermittent or persistent
4. Impact Area
    - Number of users affected
    - Criticality of the fault (e.g., backbone vs. distribution line)
5. Priority Level
    - High, medium, or low priority based on SLA and network redundancy

b. Interpreting Fault Alerts

Accurate interpretation ensures that technicians respond appropriately:

1. Assess Fault Type and Impact
   - Determine if the fault is localized or widespread
   - Prioritize restoration for critical lines or high-paying customers
2. Verify the Data Source
   - Cross-check NOC-generated alarms with field reports
   - Confirm readings with OTDR or power meter tests before deploying resources
3. Evaluate Environmental or External Factors
   - Check for adverse weather conditions, construction work, or vandalism that may have caused the fault
4. Plan the Repair Approach
   - Identify required splicing, testing, or material replacement
   - Determine safety protocols before reaching the site

4.1.6 Estimating Turn Around Time (TAT) for Repair

Turn Around Time (TAT) is the expected duration from fault detection to fault resolution and service restoration. Accurate TAT estimation helps coordinate teams, set customer expectations, and comply with contractual obligations.

Understanding SLAs and Their Role in TAT

Service Level Agreements (SLAs) define the maximum allowed downtime, response time, and repair time commitments between service providers and clients. SLAs typically classify faults based on priority levels:

- Critical Faults: Must be resolved within 4–8 hours
- Major Faults: Should be resolved within 24 hours
- Minor Faults: Repairs may be scheduled within 48–72 hours

Failure to meet SLA commitments can lead to penalties, financial compensation, or reputational damage.

Factors Affecting TAT

1. Fault Complexity
   - A simple connector fault may be resolved within hours
   - A fiber cut requiring trench excavation and cable replacement could take days
2. Accessibility of the Site
   - Urban areas may allow quicker access
   - Remote or disaster-affected zones may extend repair time

3. Availability of Resources
    - Tools, spare parts, and trained personnel must be available on-site
    - Weather or logistics issues may delay deployment
4. Safety and Regulatory Constraints
    - Permits may be required before trenching or repair work
    - Environmental protocols must be followed, possibly extending repair schedules

Steps to Estimate TAT

1. Review the Fault Notification
    - Confirm location, fault type, and expected repair complexity
2. Assess Availability of Equipment and Personnel
    - Verify if fusion splicers, protection sleeves, and test meters are on-site
    - Confirm the presence of trained technicians and support staff
3. Check SLA Prioritization
    - Refer to contractual obligations to classify the fault as critical, major, or minor
4. Account for Environmental and Access Factors
    - Estimate potential delays due to weather, roadblocks, or safety concerns
5. Provide a Realistic Timeline
    - Communicate the estimated start and end time for repair
    - Include buffer time for unforeseen complications
6. Document the TAT
    - Record the estimated and actual repair times in maintenance logs
    - Use the data for future performance analysis and SLA compliance audits

4.1.7 Route and Cable Marking Conventions for Long-Term Maintenance and Identification

Accurate route and cable marking is essential for ensuring the safe, efficient, and sustainable operation of optical fiber networks. Well-documented markings assist maintenance teams, prevent accidental damage, simplify troubleshooting, and facilitate future expansions or upgrades. This section outlines the key principles, types of markings, and best practices used in optical fiber installations for long-term maintenance and identification.

Importance of Route and Cable Marking

- Quick Identification: Enables technicians to locate specific cables, splice joints, and distribution points without unnecessary digging or disruption.
- Safety: Prevents accidental cuts or damage during construction or routine maintenance.
- Compliance: Ensures adherence to industry standards, safety protocols, and regulatory requirements.
- Documentation and Troubleshooting: Helps map cable networks accurately, allowing faster fault isolation and repair.
- Future Upgrades: Simplifies installation of new lines, reduces downtime, and improves network scalability.

B. Types of Marking Conventions

a. Route Marking

Route marking refers to the identification of cable pathways, ducts, or trenches where optical fiber cables are installed.

1. Route Markers / Signage
    - Installed at regular intervals along the cable path (e.g., every 500 meters or as per site requirements).
    - Includes information such as:
        - Route name or ID
        - Cable type (e.g., Single-mode, Multi-mode)
        - Installation date
        - Safety warnings (e.g., "Optical Fiber – Do Not Dig")
2. GPS or Coordinate Marking
    - Precise mapping using GPS coordinates ensures that cable locations are recorded in digital asset management systems.
3. Color Coding
    - Routes are sometimes color-coded to distinguish between distribution lines, backbone cables, or temporary cables.

b. Cable Marking

Cable marking refers to the identification of individual fiber optic cables, splices, and joints for easy recognition and maintenance.

1. Cable Tags or Labels
    - Waterproof and UV-resistant tags are affixed near joints, cabinets, and termination points.
    - Information may include:
        - Cable number or ID
        - Type of fiber (SMF/MMF)
        - Length of cable
        - Manufacturer or batch number
2. Splice Closure Markings
    - Splice closures are labeled with:
        - Joint location ID
        - Date of splicing
        - Type of protection sleeve used
3. Marker Paint / Spray
    - Used for temporary markings along open trenches or construction sites.
    - Requires periodic renewal.
4. Panel Identification
    - Patch panels, distribution boxes, and termination cabinets are labeled to show incoming/outgoing cables.

5. Embedded Marking
    - In some cables, information is printed on the sheath at regular intervals (e.g., every meter) to aid in visual inspection.

C. Best Practices in Route and Cable Marking

1. Standardized Formats
    - Use consistent labeling across sites for easier cross-referencing.
    - Example: "RTE-C-DIST-045" could stand for Route C, Distribution Line 045.
2. Durable Materials
    - Labels and markers should withstand weather, sunlight, chemicals, and physical wear.
    - Use materials such as laminated tags, metal plaques, or industrial-grade plastics.
3. Documentation
    - Maintain detailed records in network management systems, including:
        - Map diagrams
        - Cable IDs
        - Splice locations
        - Installation history
4. Periodic Inspection
    - Schedule inspections to ensure markings remain visible and intact.
    - Replace faded or damaged labels during routine maintenance.
5. Safety Integration
    - Markings should include hazard warnings, safety protocols, and emergency contact information.
6. Future-Proofing
    - Use scalable numbering systems that allow for future expansions without confusion.

4.1.8 Accessing and Interpreting As-Built Drawings for Fault Location Analysis

Objective:

To train technicians on how to efficiently access, read, and interpret as-built drawings during fault diagnosis and maintenance tasks, ensuring faster and safer fault localization and repair.

Step 1 – Understanding the Purpose of As-Built Drawings

As-built drawings are detailed maps or schematics created after the installation of optical fiber infrastructure. They represent the exact location, layout, and specifications of cables, joints, splices, conduits, and network elements as they exist in the field.

Key Uses in Fault Location:

- Pinpointing cable routes and joints
- Identifying splice closures and patch panels
- Verifying depth and protection layers
- Locating nearby utilities or hazards
- Planning safe excavation paths

Step 2 – Accessing the As-Built Drawings

1. Locate the Digital or Physical Copy
   - Digital Access:
     - Log in to the network asset management portal or document repository.
     - Navigate to the project folder or site-specific documentation.
   - Physical Access:
     - Retrieve printed diagrams stored in the field office or maintenance van.
     - Verify that the copies are up to date and correspond to the fault location.
2. Verify Version and Revision
   - Check the version number and date to ensure that the drawing reflects the latest field changes.
   - Confirm that updates from previous maintenance activities are incorporated.
3. Confirm Permissions
   - Ensure access rights are granted if using a secured system.
   - Obtain supervisor approval if accessing sensitive infrastructure diagrams.

Step 3 – Interpreting the As-Built Drawings

A. Reading the Layout

1. Identify Key Elements
   - Cable routes (solid or dashed lines)
   - Joint locations (marked with dots or boxes)
   - Splice closures and patch panels
   - Distribution points and network nodes
2. Locate the Fault Area
   - Use the fault notification to match the reported segment with the map.
   - Example: "Fault reported between Joint 12 and Joint 13 → Trace this segment on the diagram."
3. Check Surrounding Infrastructure
   - Identify other utilities like electrical lines, water pipes, or gas lines.
   - Note potential excavation hazards or restricted zones.

B. Understanding Cable Specifications

1. Cable Type
   - Single-mode or multi-mode fiber cables indicated with labels or legends.
2. Cable Depth and Protection
   - Note trench depth, conduit types (GI or RCC pipes), or protective layers like sand bedding.
3. Splice and Joint Information
   - Types of splices used (fusion, mechanical)
   - Protection sleeves and sealing methods applied.

C. Using the Legend and Notes Section

- Review symbols for clarity (e.g., triangles for distribution points, circles for joints).
- Read annotations such as "maintain 1-meter clearance from power lines."
- Verify installation standards, testing checkpoints, and maintenance recommendations.

Step 4 – Applying As-Built Information in Fault Analysis

1. Mark the Fault Path
   - Highlight or annotate the segment on the drawing to plan access routes.
2. Estimate Repair Requirements
   - Identify required spare parts like splice kits, protective sleeves, or cables based on specifications.
3. Assess Safety Concerns
   - Check for nearby utilities and plan safe excavation or repair steps.
4. Coordinate with Teams
   - Share the drawing with supervisors or field teams for on-site alignment.

Step 5 – Documenting the Fault Investigation

1. Record Observations
   - Note discrepancies between the as-built layout and field conditions.
   - Document any required changes or updates.
2. Update As-Built Drawings Post Repair
   - Add notes on modifications made during fault rectification.
   - Ensure future maintenance teams have accurate data.

Notes

UNIT 4.2: Fault Localization and Restoration

Unit Objectives

By the end of this unit, the participants will be able to:

1. Discuss the functionalities of advanced OTDR and how to interpret OTDR traces for fault diagnosis.
2. Describe the techniques for diagnosing and rectifying faults in optical fiber systems using specialized tools.
3. Determine the testing procedures for duct integrity, including air-tightness and kink-free tests.
4. Explain Wavelength Division Multiplexing (WDM) fundamentals and troubleshooting techniques.
5. Demonstrate how to use advanced test equipment (OTDR, power meter, light sources, precision cutters, etc.) for fiber testing and troubleshooting.
6. Show how to identify fault locations using OTDR traces, signal loss patterns, and Wavelength Division Multiplexing (WDM) analysis.
7. Demonstrate how to interpret as-built drawings to locate physical sites and underground cable routes.
8. Show how to coordinate excavation, cable pulling, and preparation of jointing pits if required.
9. Demonstrate the proper technique for fiber splicing using advanced protection sleeves and connectors.
10. Show how to analyze OTDR and power meter test results to assess splicing effectiveness.
11. Demonstrate how to secure fiber joints using couplers, sleeves, and Fiber Reinforced Plastic (FRP).
12. Show how to evaluate the need for additional duct protection (e.g., RCC pipes, chambering) based on site conditions.
13. Demonstrate the correct procedure for back-filling trenches while ensuring structural integrity and environmental safety.
14. Show how to verify fault rectification by performing final OTDR tests and confirming network stability.
15. Demonstrate how to monitor and supervise fault rectification activities to ensure adherence to SLAs and minimize downtime.
16. Show how to escalate unresolved faults or significant delays according to organizational policies.

4.2.1 Fault Localization and Restoration

Fault Localization and Restoration:

To obtain best result from optical fiber, it would be essential to find out and make user adoptable and solve the fiber failures within allowed repair time. The methodology applied to find out and localize the failures of fiber is termed as localization. Merely detecting and locating the fault is not enough and hence the next step is to rectify the fault and close, this is known as rectification.

Fig. 4.2.1: Fault localization and restoration

4.2.2 Steps - Fault Localization and Restoration

Fault localization and restoration steps:

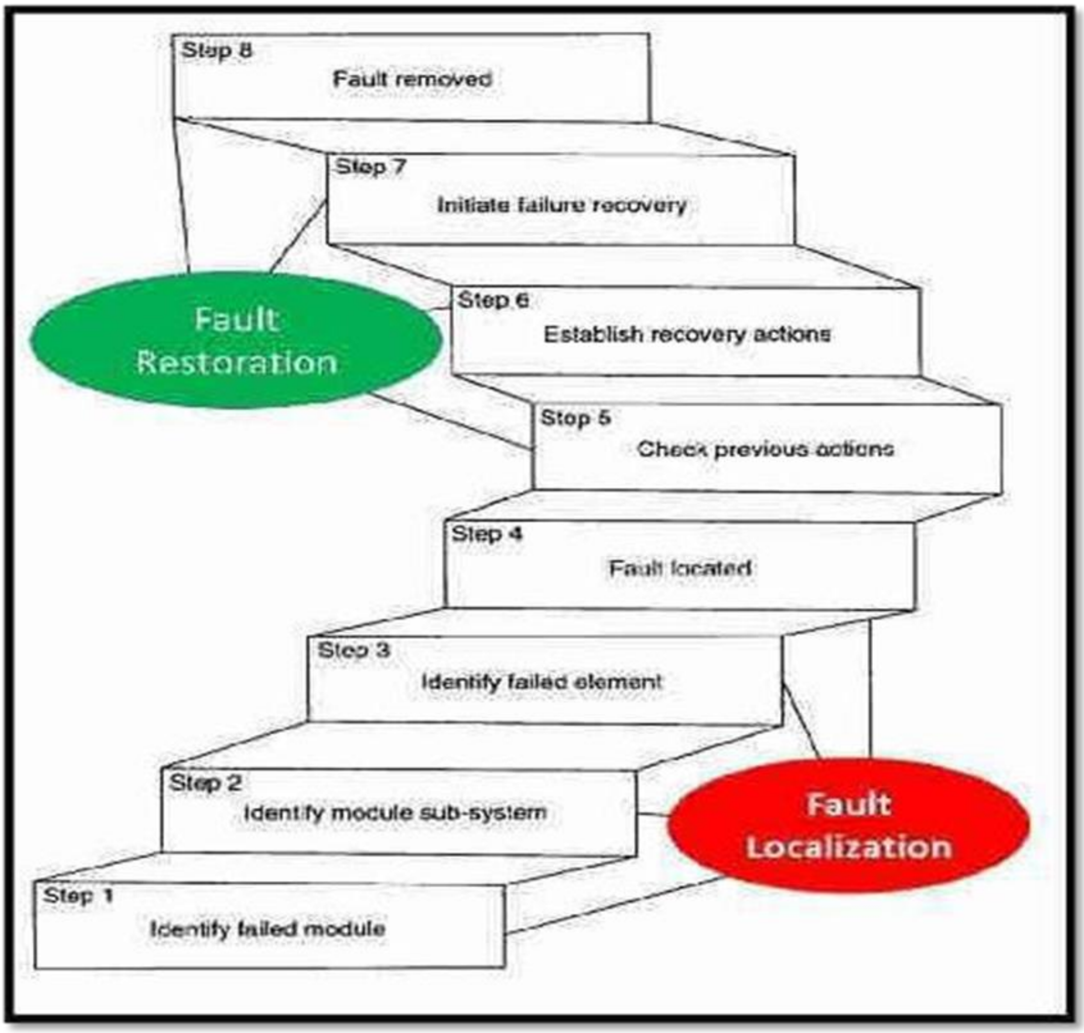


Fig. 4.2.2: Fault restoration steps

4.2.2 Cable System Faults

There are various cable system faults which must be rectified. The various faults , the root cause, equipment required for rectification and the remedy is depicted concisely in the following table:

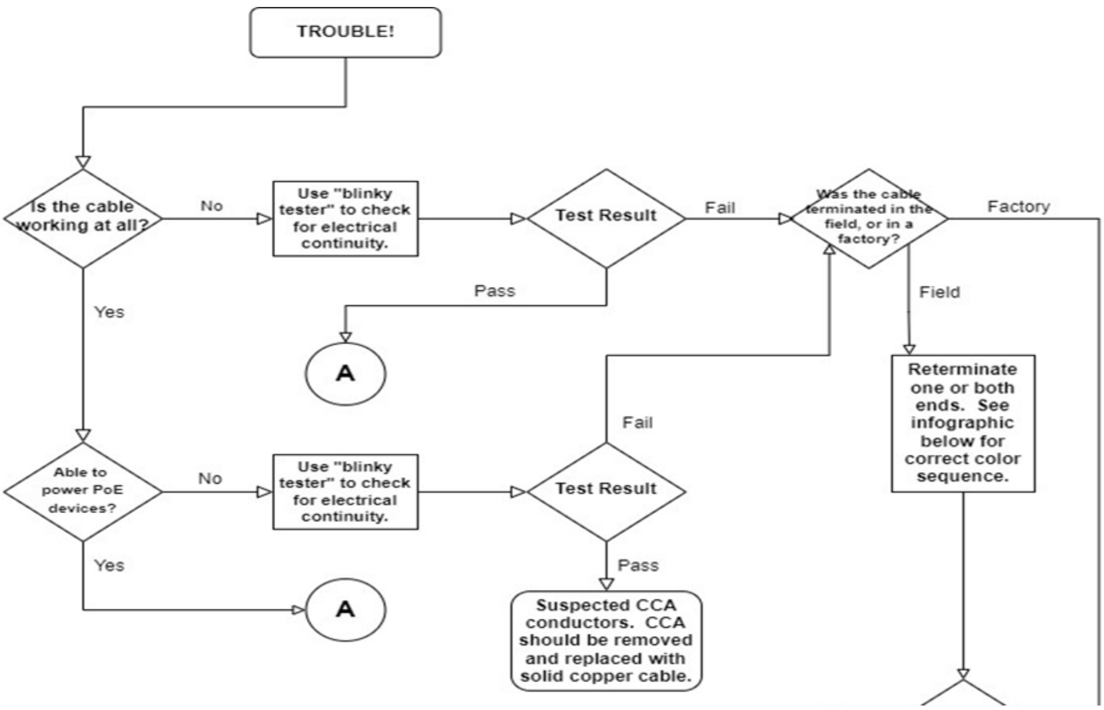
Typical Cable System Faults

Fault	Cause	Equipment	Remedy
Bad connector	Dirt or damage	Microscope	Cleaning/ polishing/ retermination
Bad pigtail	Pigtail kinked	Visual fault locator	Straighten kink
Localized cable attenuation	Kinked cable	OTDR	Straighten kink
Distributed increase in cable attenuation	Defective cable or installation specifications exceeded	OTDR	Reduce stress/ replace
Lossy splice	Increase in splice	OTDR	Open and redress
	Loss due to fiber stress in closure	Visual fault locator	
Fiber break	Cable damage	OTDR Visual fault locator	Repair/replace

Fig. 4.2.3: Cable system faults

4.2.3 Problem Identification Flowchart

Following is the problem identification flowchart:



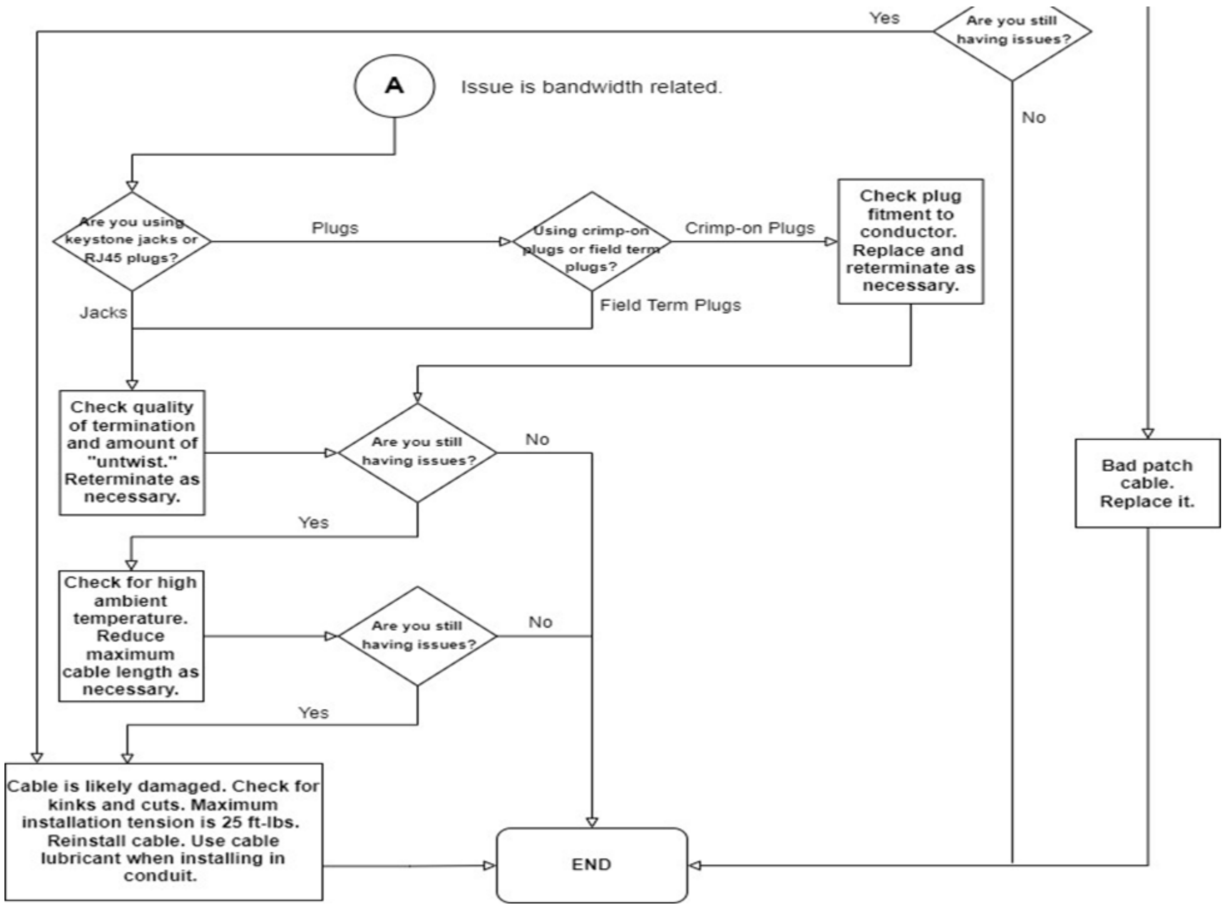


Fig. 4.2.4: Problem identification flow chart

4.2.4 Preparing for Fault Rectification

Understanding and adherence to the following is mandatory for fault rectification:

1. Following are important questions to be asked before embarking on fault rectification:
   - Fault could be one of the breaks interrupting service. It could be considered as loss point that could check/verifies and solved?
   - How long is the route- 100 m or 100 Km? Cabling type?
   - What sort of fault locator is readily available?
   - Who is available with which skills?
2. Following challenges are encountered during fault rectification:
   - Without link disruption, Transmission signal is difficult to measure and sometime it is impossible.
   - In case of locating, it's difficult to locate Non-metallic cables.
   - specific device/ instruments are brought in practice for localization/identification of optical fiber fault.
   - Route lengths can be very long e.g., 100 Km.
   - Unavailability of skilled staff.

3. Instruments used for locating faults:

Specific device/ instruments are brought in practice for localization/identification of optical fiber fault-

- Optical time-domain reflectometer (OTDR).
- Optical power meter (OPM).
- Pen-type visual fault locator (VFL).
- Optical microscope.

Fig. 4.2.5: Instruments used for locating faults

4.2.5 Steps - OFC Restoration Process

Process depends on the following for efficient fiber optic communication:

- Continuously facing the problem?
- Having information of fixing it?
- Having the correct spares and brings out the work done quickly and efficiently?
- In case of emergency, having clear guidelines/planning could reduce the issues encountered.

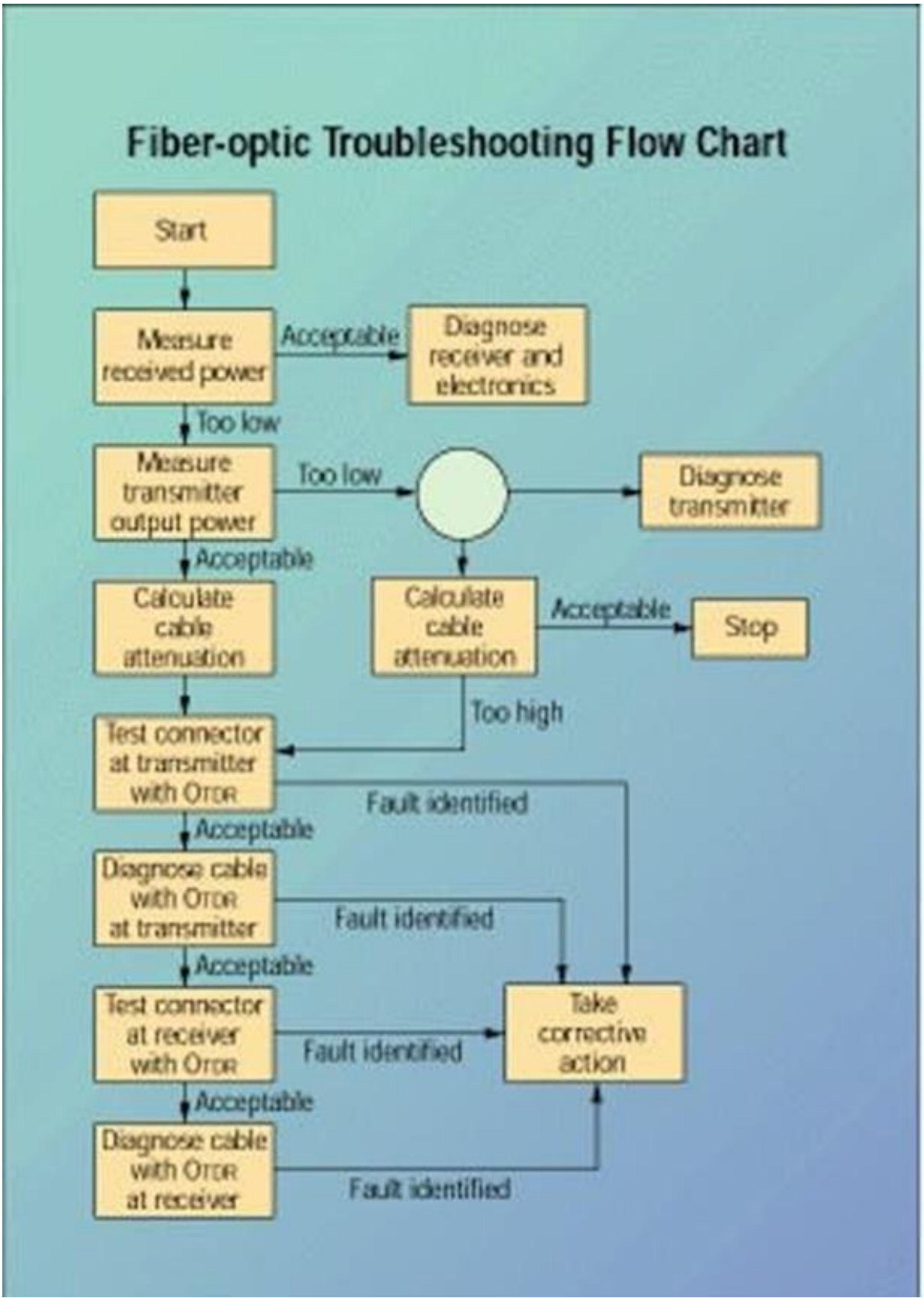


Fig. 4.2.6: 'OFC' restoration process

4.2.6 Identifying Fault Locations Using OTDR Traces, Signal Loss Patterns, and WDM Analysis

Objective:

To guide technicians on how to accurately pinpoint fault locations by analyzing OTDR traces, evaluating signal loss patterns, and interpreting Wavelength Division Multiplexing (WDM) data. These methods help diagnose issues such as fiber breaks, bends, splices, or wavelength-specific interference efficiently.

Step 1 – Preparing for Fault Location Analysis

1. Gather Necessary Equipment
    - Optical Time Domain Reflectometer (OTDR)
    - Power meter
    - Light source
    - WDM analysis tool or spectrum analyzer
    - As-built drawings and site documentation
2. Confirm Cable and Route Details
    - Verify the cable type (single-mode/multi-mode)
    - Refer to the as-built layout for joint locations, splice points, and lengths
3. Ensure Safety
    - Use appropriate PPE (helmets, gloves, safety boots)
    - Confirm that the fiber is not live with high-powered lasers before testing

Step 2 – Identifying Fault Locations Using OTDR Traces

A. Setting Up the OTDR Test

1. Connect the OTDR to one end of the fiber using a suitable patch cord.
2. Input parameters such as:
    - Wavelength (commonly 1310 nm or 1550 nm)
    - Test distance range covering the suspected fault area
    - Pulse width based on expected distance resolution
3. Initiate the trace scan and ensure that connectors and launch cables are calibrated.

B. Interpreting the OTDR Trace

1. Reflective Events (Peaks)
    - Large spikes indicate connectors, mechanical splices, or sharp faults like fiber breaks.
2. Loss Events (Slopes)
    - Gradual signal drop-offs signify attenuation due to bends, dirty connectors, or water ingress.
3. End-of-Fiber Marker
    - The end of the fiber is shown by a sharp drop → confirms the fiber length.

C. Locating the Fault

1. Identify unusual spikes or dips along the trace.
2. Use the distance markers provided by the OTDR to estimate where the fault is.
    - Example: A large reflection at 2.3 km → check joints or splices near that distance.
3. Compare the trace with expected data:
    - A clean trace should show minimal loss except at joints.
    - Unexpected loss patterns require inspection.
4. Mark the fault location on the as-built diagram and schedule repair.

Step 3 – Analyzing Signal Loss Patterns

1. Baseline Signal Check
    - Measure power levels at source and receiver with a power meter.
    - Compare with standard values based on cable type and length.
2. Attenuation Measurement
    - Calculate total link loss → If higher than expected, identify segments contributing to loss.
3. Segment Isolation
    - Test sections between joints individually.
    - Narrow down loss to a specific splice, connector, or segment.
4. Typical Fault Patterns
    - Sharp Spike + High Loss: Likely break or connector fault.
    - Gradual Loss: Dirty connectors, microbends, or fiber aging.
    - No Signal Beyond Point: Complete fiber cut or connector disconnection.

Step 4 – Identifying Faults Using WDM Analysis

WDM systems use multiple wavelengths to carry signals over a single fiber. Faults can be wavelength-specific.

1. Set Up the WDM Analyzer
    - Input expected wavelength bands (e.g., 1310 nm, 1490 nm, 1550 nm).
    - Run a spectrum scan along the link.
2. Interpret Spectrum Anomalies
    - Missing wavelengths → Possible attenuation or component failure.
    - Reflections at certain wavelengths → Fault in specific connectors or filters.
    - Crosstalk or interference patterns → Possible misalignment or damage.
3. Identify Fault Wavelength
    - Correlate the affected wavelength with known equipment or network segments.
    - Example: Loss at 1550 nm → Inspect optical amplifiers or filters at that frequency.

Step 5 – Correlating All Findings

1. Match OTDR Distance with Fault Location
    - Confirm if the reflective event aligns with known splices or joints.
2. Verify with Signal Loss Pattern
    - Ensure the segment identified by OTDR shows corresponding attenuation in power meter readings.
3. Confirm via WDM Spectrum
    - Check if wavelength-specific issues correlate with equipment in the same segment.
4. Document Findings
    - Mark fault location on diagrams
    - Record trace screenshots, attenuation values, and spectrum anomalies
    - Report to supervisors for repair planning

4.2.7 Securing Fiber Joints Using Couplers, Sleeves, and FRP

To train technicians on the correct procedures for securing fiber joints using couplers, protection sleeves, and Fiber Reinforced Plastic (FRP), ensuring mechanical stability, protection from environmental factors, and optimal signal performance.

Step 1 – Understanding the Components

1. Couplers
    - Devices that physically and optically join two fiber ends.
    - Types: mechanical couplers, fusion couplers, or connectors depending on installation requirements.
2. Protection Sleeves
    - Heat-shrink or mechanical sleeves that shield spliced fibers from stress, moisture, and external contaminants.
    - Used at splice points to provide insulation and strength.
3. Fiber Reinforced Plastic (FRP) Rods
    - Used to provide additional mechanical strength and flexibility.
    - Protects fibers from bending and external pressure in ducts or trenches.

Step 2 – Preparing the Fiber Ends

1. Clean and Inspect the Fiber Ends
    - Use lint-free wipes and cleaning solution to remove dust or oil.
    - Inspect for scratches or defects using a fiber microscope.
2. Strip the Fiber Coating
    - Carefully strip the protective coating without damaging the core.
    - Ensure that the stripped length matches the specifications of the coupler or splice sleeve.
3. Align the Fibers
    - Hold the two fiber ends with precision tools or holders.
    - Use a cleaver to create clean, flat ends for optimal signal transfer.

Step 3 – Splicing Using Couplers

1. Select the Appropriate Coupler
    - Mechanical coupler → used for temporary or quick repairs.
    - Fusion coupler → permanent solution with low signal loss.
2. Insert the Fibers into the Coupler
    - Carefully insert each fiber into the coupler channel.
    - Align the cores precisely to avoid signal reflection.
3. Secure the Coupler
    - For mechanical couplers → tighten locking screws or clamps.
    - For fusion splices → ensure alignment is correct before starting the fusion process.
4. Check Optical Continuity
    - Use an optical power meter to ensure signal is passing through without significant loss.

Step 4 – Applying Protection Sleeves

1. Select the Correct Sleeve Size
    - Choose sleeves that cover the entire splice area with some extra length on both sides.
2. Place the Sleeve Over the Joint
    - Slide the sleeve gently over the joined area.
    - Ensure that the fiber is not under tension before shrinking or locking the sleeve.
3. Shrink or Lock the Sleeve
    - Use a heat gun for heat-shrink sleeves → evenly heat to secure the sleeve without overheating.
    - For mechanical sleeves → lock into place as per manufacturer instructions.
4. Check for Proper Insulation
    - Ensure there are no air gaps or loose sections.
    - Confirm that the sleeve is firmly attached without putting undue pressure on the fiber.

Step 5 – Reinforcing with FRP

1. Cut the FRP Rod to Appropriate Length
    - Ensure it spans the joint area and extends into the cable for added strength.
2. Position the FRP
    - Place the FRP along the joint, ensuring it supports both fiber ends.
    - Avoid sharp bends; ensure the rod provides gradual curvature.
3. Secure the FRP to the Cable
    - Use cable ties, clamps, or adhesive tape to hold the FRP in place.
    - Do not over-tighten, as this could damage the fiber.
4. Check Mechanical Stability
    - Gently bend the cable to ensure the FRP absorbs stress without compromising the splice.
    - Confirm the joint area is protected from pressure or impact.

Step 6 – Final Inspection

1. Verify Signal Performance
   - Test the joint using an OTDR or power meter to ensure signal integrity.
   - Compare with pre-installation values to confirm minimal loss.
2. Inspect Physical Protection
   - Check that sleeves are fully covering the splice and FRP is properly aligned.
   - Look for signs of stress, overheating, or incomplete coverage.
3. Document the Joint
   - Record splice type, sleeve specifications, FRP length, and test results.
   - Update maintenance logs or as-built drawings for future reference.

4.2.8 Verifying Fault Rectification, Monitoring Activities, and Escalating Issues

1. Verifying Fault Rectification Using Final OTDR Tests and Confirming Network Stability

Ensure that the fault has been fully resolved, signal loss is within acceptable limits, and the network is operating normally before closing the maintenance activity.

Step-by-Step Process

1. Set Up the OTDR Test
   - Connect the OTDR at the source and, if needed, at the far end.
   - Select the appropriate wavelength (e.g., 1310 nm, 1550 nm).
   - Input the correct test range covering the repaired area.
2. Run the Trace Scan
   - Initiate the scan and allow the OTDR to capture the fiber profile.
   - Save the trace for documentation.
3. Analyze the Results
   - Look for the absence of reflective spikes or sudden attenuation near the repaired area.
   - Confirm that the signal loss is within manufacturer or network tolerance limits (typically <0.3 dB for splices depending on the specification).
4. Compare with Previous Data
   - Match the repaired trace with the baseline or pre-fault readings.
   - Ensure that the repaired section is performing equal to or better than before the fault.
5. Perform End-to-End Power Check
   - Use a power meter at the receiver end.
   - Verify that signal strength is stable, without significant drops or noise.
6. Confirm Network Stability
   - Run continuous ping or data tests to check packet loss and jitter.
   - Ensure that connected services are operating normally.
7. Document the Test Results
   - Save OTDR traces, attenuation values, and test reports.
   - Include time stamps, operator names, and equipment used.

2. Monitoring and Supervising Fault Rectification Activities

Ensure fault repair activities are performed correctly, efficiently, and according to Service Level Agreements (SLAs) while minimizing downtime.

Step-by-Step Process

1. Pre-Work Checklist
    - Confirm team readiness, tools, and safety equipment.
    - Verify that spares, connectors, and protective materials are available.
2. On-Site Supervision
    - Visit or remotely monitor the fault location.
    - Check that technicians follow safety protocols (PPE, trenching procedures, equipment handling).
    - Ensure correct splice methods and shielding are used.
3. Monitor Progress Against SLA
    - Track start time and compare against expected completion times.
    - Monitor key metrics:
        - Time to isolate fault
        - Time to repair
        - Time to restore service
4. Real-Time Feedback
    - Provide immediate guidance if technicians deviate from standards.
    - Offer suggestions for safety or technical improvement.
5. Check Documentation
    - Verify that all measurements, OTDR traces, and power readings are recorded properly.
    - Ensure that fault tags, cable IDs, and repair logs are updated.
6. Post-Repair Review
    - Ensure team tests the repaired section thoroughly.
    - Confirm that end users or network teams are notified of restoration.

3. Escalating Unresolved Faults or Significant Delays

Ensure that unresolved faults or delays beyond SLA thresholds are communicated appropriately to higher management for timely resolution.

Step-by-Step Process

1. Identify Escalation Conditions
    - Fault persists after troubleshooting attempts.
    - SLA timelines exceeded (e.g., repair time beyond agreed window).
    - Safety hazards or equipment shortages preventing timely restoration.
2. Document the Situation
    - Record fault description, attempted fixes, and test results.
    - Note the time and duration of delay or unresolved issues.
3. Follow Organizational Escalation Policy
    - Notify the supervisor or team lead immediately.
    - Fill escalation forms or digital reports as per protocol.
    - Share OTDR traces, test logs, and photographs if required.

4. Communicate Clearly
    - Provide essential details:
        - Fault location
        - Severity
        - Impact on services
        - Steps taken
        - Reason for escalation
5. Request Further Action
    - Ask for additional resources or specialized tools.
    - Seek approval for extended repair windows or alternate routing.
6. Ensure Follow-up
    - Confirm that escalation is acknowledged by management.
    - Track progress and provide updates to stakeholders.

4.2.9 Evaluating the Need for Additional Duct Protection Based on Site Conditions

Train technicians and supervisors to assess when additional protective measures such as RCC pipes or chambering are required to ensure the durability, safety, and performance of optical fiber cables in varying environmental and site conditions.

Step 1 – Understanding Why Additional Protection is Needed

Additional protection is necessary when environmental or operational risks could damage fiber cables. Proper evaluation prevents signal loss, cable breakage, or unnecessary downtime.

Common Risks That Require Extra Protection:

- Heavy traffic areas causing mechanical stress
- Areas prone to flooding or waterlogging
- Rocky or unstable soil conditions
- Construction or excavation activity nearby
- Areas with high rodent or pest activity
- Industrial zones with chemical or heat exposure
- Locations where accidental impacts are likely

Step 2 – Conducting the Site Assessment

1. Review Site Documents
    - Check the as-built drawings and planned route.
    - Identify segments passing through high-risk zones.
2. Visit the Site
    - Inspect the trench depth and soil type.
    - Check for nearby utilities such as water pipes, gas lines, or electrical cables.
    - Observe traffic patterns, nearby construction, or potential hazards.

3. Interview Local Stakeholders
   - Consult with site supervisors, construction workers, or residents.
   - Gather information about seasonal flooding, soil shifting, or other risks.
4. Perform Risk Mapping
   - Mark areas prone to hazards.
   - Identify segments requiring reinforcement.

Step 3 – Criteria for Additional Protection

Site Condition	Risk	Recommended Protection
Heavy vehicle movement	Mechanical stress	RCC pipes, reinforced ducts
Waterlogged/low-lying areas	Water infiltration	Elevated chambering, water-resistant ducts
Rocky or uneven soil	Abrasion, bending stress	RCC pipes, shock absorbers
High construction activity	Accidental impact	Chambering, protective barriers
Industrial chemicals/heat	Corrosion, insulation damage	FRP, protective coatings, sealed conduits
Rodent or pest prone areas	Chewing, cuts	Metal ducts, protective sleeves
Sharp bends or unstable terrain	Fiber breakage	Smooth bends with protective sleeves

Step 4 – Deciding on Protection Methods

1. Use RCC (Reinforced Cement Concrete) Pipes When:
   - The route crosses roads, vehicle paths, or industrial zones.
   - Soil is unstable or rocky.
   - There is risk of heavy loads or impacts.
2. Use Chambering (Manholes, Handholes) When:
   - Junction points need accessibility for maintenance.
   - Fiber sections require elevation or water protection.
   - Routing through dense infrastructure zones requires routing flexibility.
3. Use FRP Rods or Protective Sleeves When:
   - Bends need reinforcement.
   - Small segments need mechanical or environmental protection.
   - The cable needs added flexibility without increasing weight.
4. Use Sealed or Water-Resistant Ducts When:
   - Waterlogging or chemical exposure is expected.
   - Fiber crossings are in low-lying or flood-prone areas.

4.2.10 Work Instructions

It is essential to follow the following work instructions for better quality and enhanced efficiency:

1. Following are the 'Work Instructions' for mobilization:

- Driver shall be available for 24 Hrs (mostly).
- Driver to move only on instructions of the designated SPOC.
- On receiving information of a cut in cable, technician will move to the site.
- Driver to prepare the van with all the technical tools/equipment and also should check breaks, fuel in the van.
- At the site if the cut is measured, technician to conduct OTDR measurement and a visual inspection.
- Labor from the nearest location is picked if the cut is near the site else arrange labor.
- Two spare fibers must be patched at each site for measuring cut location quickly and easily.

2. Following is the 'Work Instructions' for travelling:

- Team will either rush to the place of the cut or to the place nearest to the same.
- Before leaving - driver/technician to note kilometer reading.
- Ensure minimum travel time, by taking alternate routes.
- Avoid routes with chances of traffic jam, bad-road, etc.
- Reach quickly with or without following the OFC route.

3. Following is the 'Work Instructions' for localization:

- Teams to move along the OFC route while locating the cut. Teams to move the exact distance as measured by the OTDR from the initial reading of the kilometer before moving.
- Teams should carry 'as-built drawings' with them & should have proper knowledge of the OFC route. Teams to look for any digging activity going on near the cut location as measured by the OTDR; if digging activity is found they will search for the cut.
- If cut is not found they will move on feet for locating the cut carrying torches with them (during the night). If cut is not visible teams to locate the nearest manhole and take traces again.
- Once the team reaches the location they should start digging. Digging should expose at least 5 meters of OFC on either side.

4. Following are the 'Work Instructions' for OTDR trace measurement:

- During OTDR trace measurement check live fibers first.
- 5 spare fibers should be checked besides the live fibers.
- Care should be taken while handling OTDR. Connector

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=7GL9nDCEJQk

Optical Fiber Cable (OFC) Splicing

UNIT 4.3: Preventive and Corrective Maintenance

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain the applicable reporting and documentation standards for optical fiber maintenance.
2. Describe the Standard Operating Procedures (SOPs) for OFC maintenance and fault rectification.
3. Elucidate the requirements for documentation management, including updating OTDR registers and as-built diagrams.
4. Explain the compliance requirements for safe excavation and installation in various terrains.
5. Discuss environmental safety and risk management practices in fiber network maintenance.
6. Elucidate emergency response protocols for handling optical fiber damage and minimizing downtime.

4.3.1 Maintenance

1. OFC Maintenance is keeping close watch on the cable routes to prevent OFC damage & disruptions. It means a periodic check on:
    - The cables.
    - Microscopic verification of spare parts/connectors and connecting adapters.
    - Insertion loss checking or obtaining OTDR traces.
2. Corrective Maintenance:
    - Corrective maintenance is executed on continuation of fault or issue upcoming, with the aim of bringing back operations of the links/cable.
    - In certain cases, it might be equal to expect or avoid a failure, making this type of maintenance is the only option.

E.g. damage occurring due to natural calamities like flood or earthquake.

3. Preventive Maintenance

The Service & care by qualified staff for the idea of maintaining devices and provisions in satisfactory operating situation by giving for systematic verification, finding out, and correction of early failures either before they happen or before.

4.3.2 Perform Corrective Maintenance Activities

Duct integrity tests, like air tightness and kink free tests:

- The DIT-Duct Integrity Test is a comprehensive set of tests carried out on the duct that will be buried beneath optical cable. It is the phase that comes after cable jetting within the duct but before duct laying.
- In addition to being useful for cleaning before installing O F C in Plb/silicore ducts of different diameters 32mm, 40mm, and 50mm in a safe environment, duct integrity test apparatus can be easily used for testing of various parameters like duct alignment, air tightness test, shuttle test, and more.
- The basic goal of a duct integrity test is to determine and confirm whether a duct is suitable for installing optical fiber cables using jetting, blowing, or cable pulling.

What is done in DIT?

- Verify that the duct is continuous.
- Remove any mud, stones, or water from the duct.
- Look for kinks, obstructions, and sharp turns.
- Inspect the duct for any leaks of any kind and fix the problems.

4.3.3 The 4 Duct Integrity

Test	Description	Purpose
Air Blowing	Complete Discharge from Compressor	Verify for duct continuity
Shuttle Blowing	Dia. 80% of duct I.D. and length 150mm for 40/33mm duct	Verify for kinks, dents and sharp bends
Sponge Blowing	Dia. Twice the duct I.D,4 inch in length then min. density 28gms/cft	Clean the duct of mud, stones, water, etc.
Air Pressure	Permit 5 bar for 30 minutes. Permissible drop consider 0.5 bar	Verify for leakage and punctures

4.3.4 Duct Integrity

Following is some of the faults which can occur while performing duct integrity test:

1. Improper duct laying
    - Bending radius not maintained while trenching
    - Uneven trench bottom/ faulty trenching
    - Decoiler not used while uncoiling.
2. Duct not continuous
    - Missing section of the duct
    - Coupler not installed.
3. Kink in the duct
    - Spiraling due to non-use of decoiler
    - Boulder used in back-filling the trench
    - Sharp bend could be occurred in duct at 900 crossings/ culvert, etc.
4. Mud & Water in duct
    - End plug not used while duct laying
    - Ends not coupled/ not sealed before back-filling
    - Duct laid in water-filled trench or laid on a rainy day.

5. Leakage in the duct
- Duct damaged while handling/ laying
- Duct not checked before laying
- Leakage at Couplers:
- Improper duct cut
- Improper sequencing of the coupler parts
- Coupler not sufficiently tightened.

Safety measures to be adopted
- When DIT is being done, avoid entering the pit.
- When DIT is being done, avoid standing in front of the ducts when:
- Air/ Shuttle/ Sponge/ Transmitter is blown.
- Suddenly, do not open couplers or PTE before pressure is completely released.
- Use caution tape and cones whenever

Concept and various elements of an as-build drawing for optic fiber cable

Since the AS-Built document for the fiber optic project is one of the most important ones that must be given to the fiber maintenance team, it is required to be more accurate than the suggested route drawing.

This diagram displays the fiber route and other important details. The text is split into two halves.
- THE LEFT PORTION: The project area is in THE LEFT PORTION. The drawing area on the left is where the line and point features are displayed.
- THE RIGHT PORTION: The section including project details. Information about the drawing is contained in the right portion.
- THE LOWER PORTION : The legend area is in the lower portion.

4.3.5 Standard Operating Procedure

As one of the key documents to be sent to the maintenance crew, the As-Built document is extremely important to the project. This document serves as the maintenance team's initial point of contact, helping them become familiar with the route; as a result, more accuracy is anticipated than in the proposed route drawing.

SOP Manual for Fiber Optic Cable

Standard Operating Procedures (SOPs) are written instructions with predetermined details designed for repeated use as a best practise.

The employee can find all the details they require in the manual to carry out a work accurately and consistently. After the initial investment is made to design the manual, a strategy for managing an update process for it and keeping it readily available to employees should be included. They work best when combined with staff training and performance reviews. Clarity, direction, effective communication, and work consistency are all provided by well- written SOPs.

The creation of SOPs must be collaborative. The participation of management and all staff levels ensures the most successful compilation while fostering a great teamwork environment. Success for the business becomes a definite shared objective at every level.

A crucial stage is assigning the right people the right tasks

SOPs are effective instruments that establish control over work processes. It finally creates a roadmap on the difference between success and failure by detailing every last element. Additionally, the SOP's successful communication increases staff engagement, motivation, and general satisfaction.

When done properly, the process requires a significant time commitment, but once a SOP is developed, the stages are logical and the time investment pays off.

Fig. 4.3.1 SOP Procedure

4.3.6 Corrective Maintenance Process

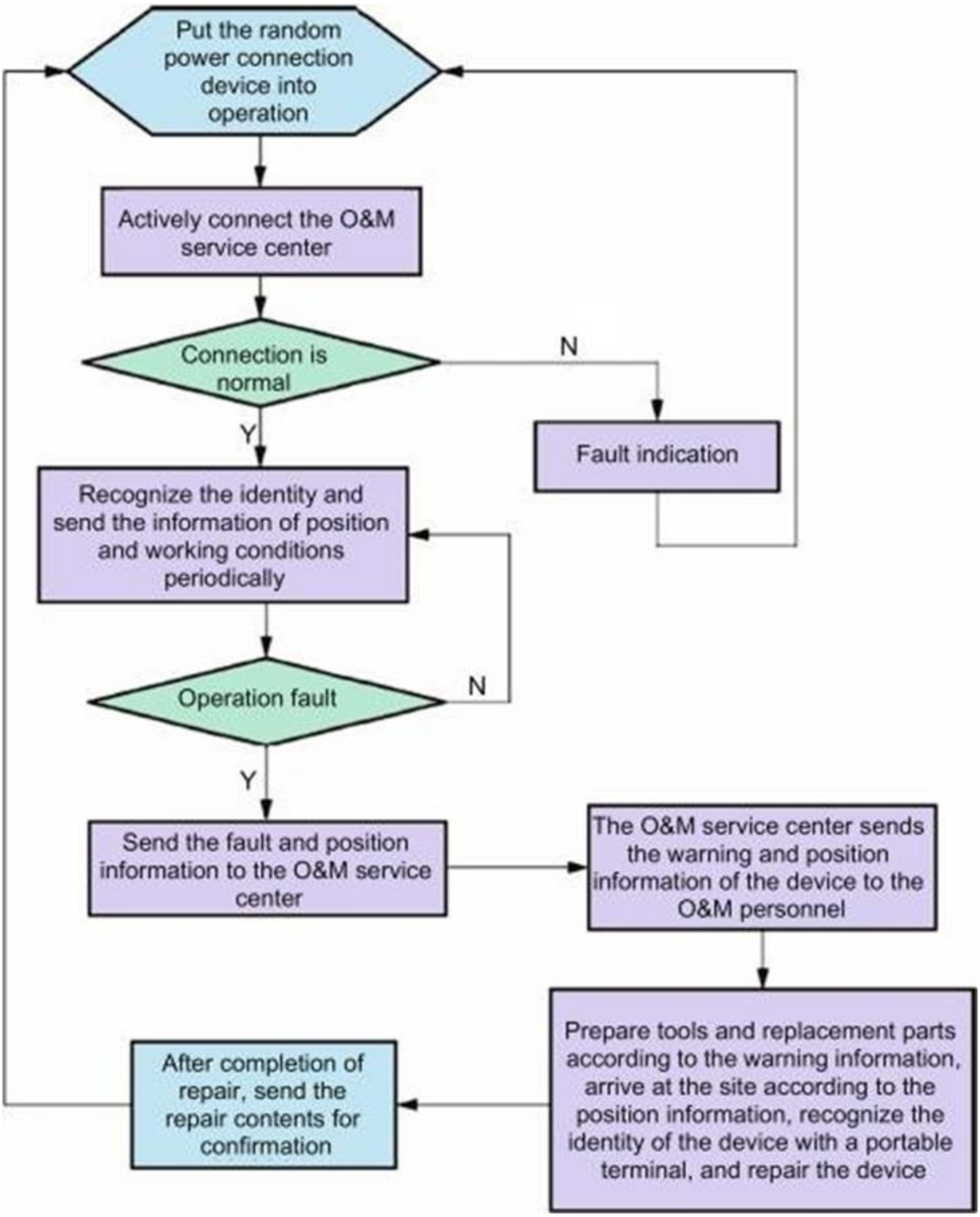


Fig 4.3.2: Corrective maintenance process

4.3.7 Preventive Maintenance Process

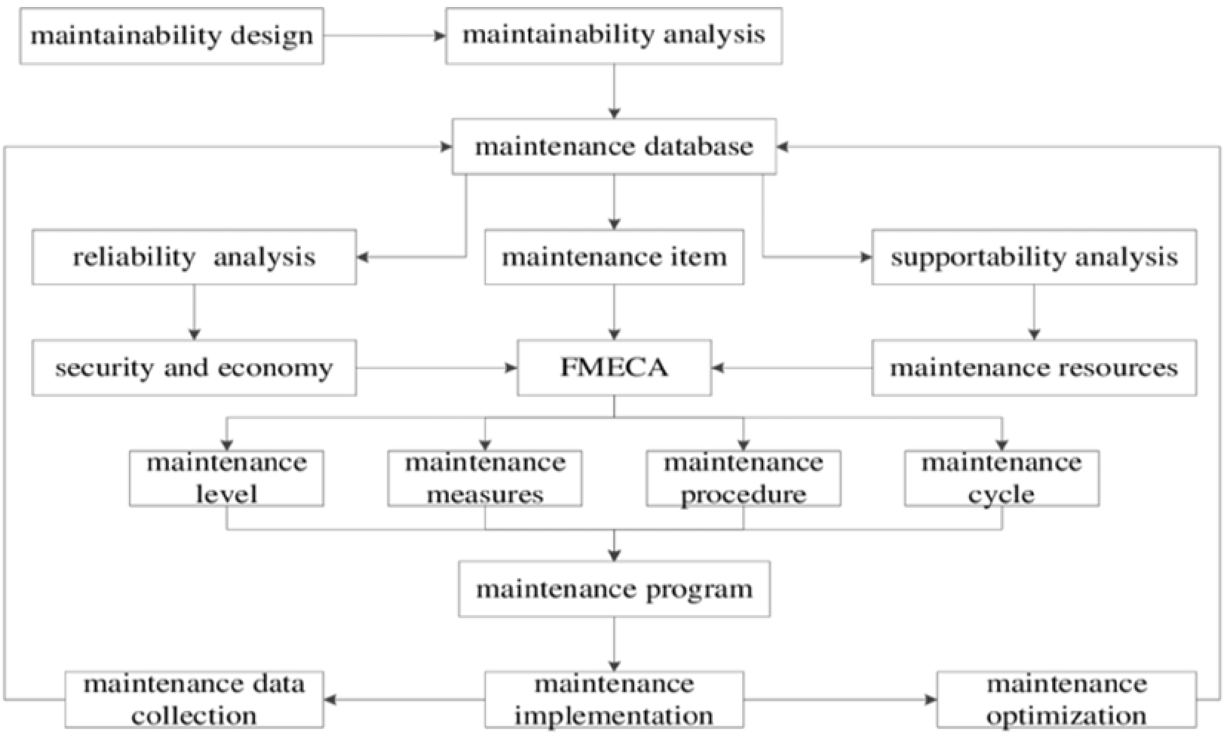


Fig. 4.3.3: Preventive maintenance process

4.3.8 Reporting - Preventive Maintenance Checklist

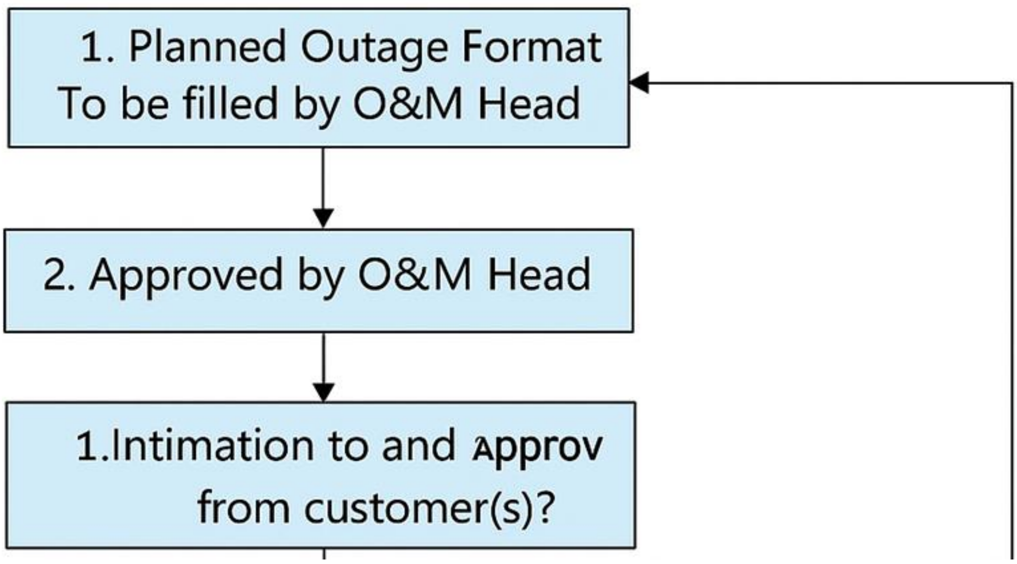
Environmental Tests	Optical Parameters	Optical Parameters (continued)	Mechanical Tests	Geometrical/Dimensional
Post life aging	Attenuation rate	Numerical aperture	Dynamic tensile strength	Core diameter
mechanical strippability	Attenuation uniformity	Polarization mode dispersion (lumped)	Mechanical strippability	Core ovality
Storage temperature	Bandwidth	Transient attenuation	Fiber curl	Cladding diameter
Temperature cycling	Chromatic dispersion		Tensile proof	Cladding ovality
Temperature life	Cut-off wavelength	Material Tests	Macrobending loss	Core-to-cladding eccentricity
Temperature/Humidity cycling	Macrobend attenuation	Fluid immersion aging	Microbending loss	Coating diameter
Thermal shock	Mode field diameter	Fungus resistance	Fatigue	Coating-to-cladding eccentricity
	Modal dispersion	Radiation resistance		Coating concentricity
		Salt spray	Visual Inspection	Coating uniformity
		Stress cracking factor	Fiber length	
			Fiber mass/unit length	

Table 2: Fiber Optic Cable Characteristics Checklist

Abrasion/scraping resistance	Corner bend	Flammability	Pressure withstand
Acid gas generation	Crosslink verification	Fluid immersion	Radial compression
Altitude cycling	Crosstalk	Freezing water immersion	Ribbon delamination
Attenuation rate	Crush	Fungus resistance	Shock
Bandwidth	Cyclic flexing	Halogen/toxicity content	Storage temperature
Cable-to-cable abrasion	Change in optical transmittance	Hosing	Temperature cycling
Cable jacket tear strength	Cold bend	Impact	Tensile loading and elongation
Cable element removability	Dripping	Jacket self adhesion/blocking	Thermal shock
Cable jacket material tensile strength & elongation	Dynamic bend	Knot	Toxicity index
Cable kinking	Electromagnetic effects	Life aging	Water absorption & Humidity
Cable shrinkage	Flame extinguishing	Marking Permanency	Weathering
Cable twist bending	Flame propagation	Operating tensile load	Weight
Color	Flaming smoke generation	Pressure (barometric)	Wicking

Fig 4.3.5: Monthly preventive checklist

4.3.9 Planned Outage Sub-Process



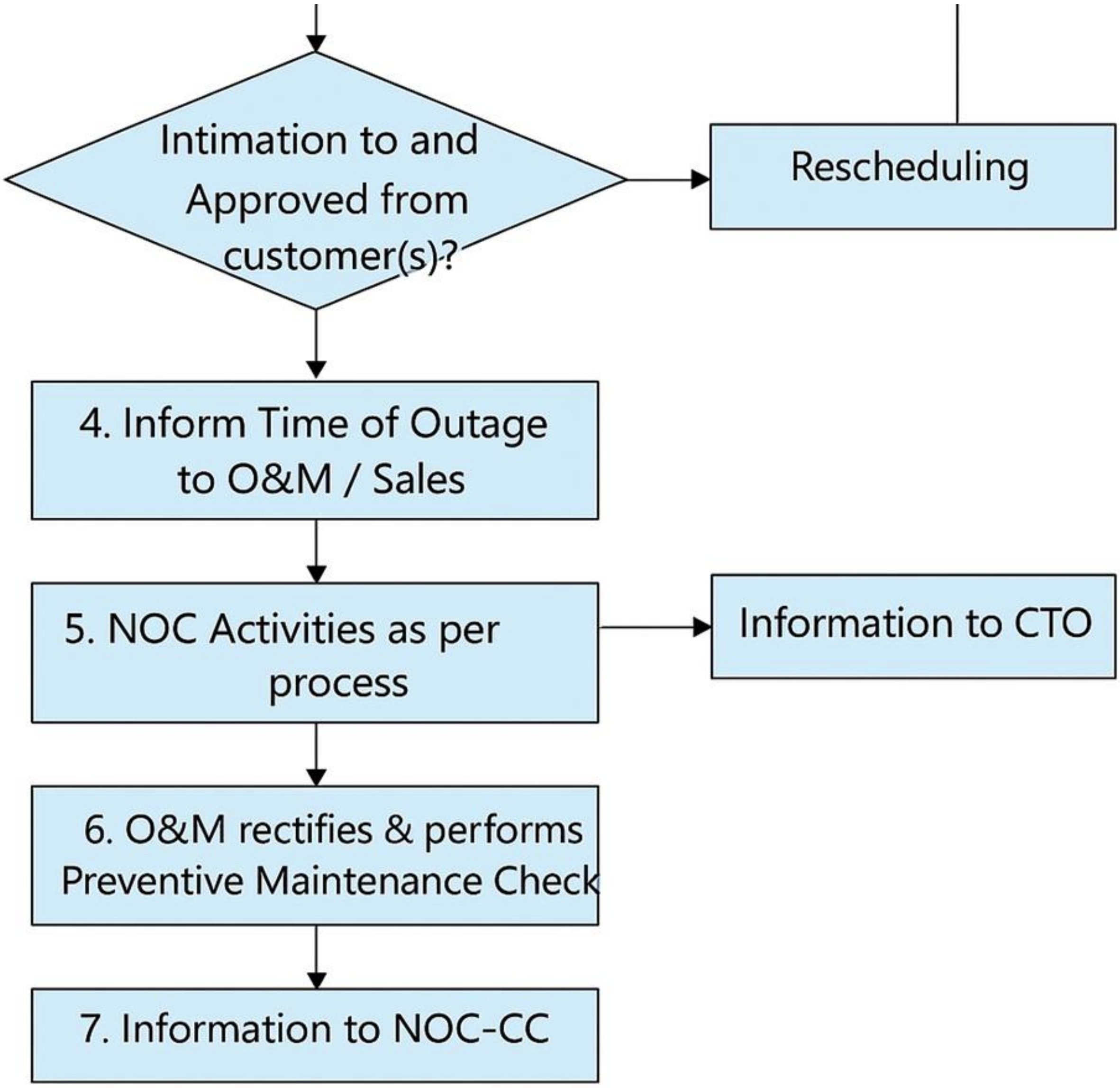


Fig 4.3.6: Planned outage sub process

4.3.10 Spare Management Process

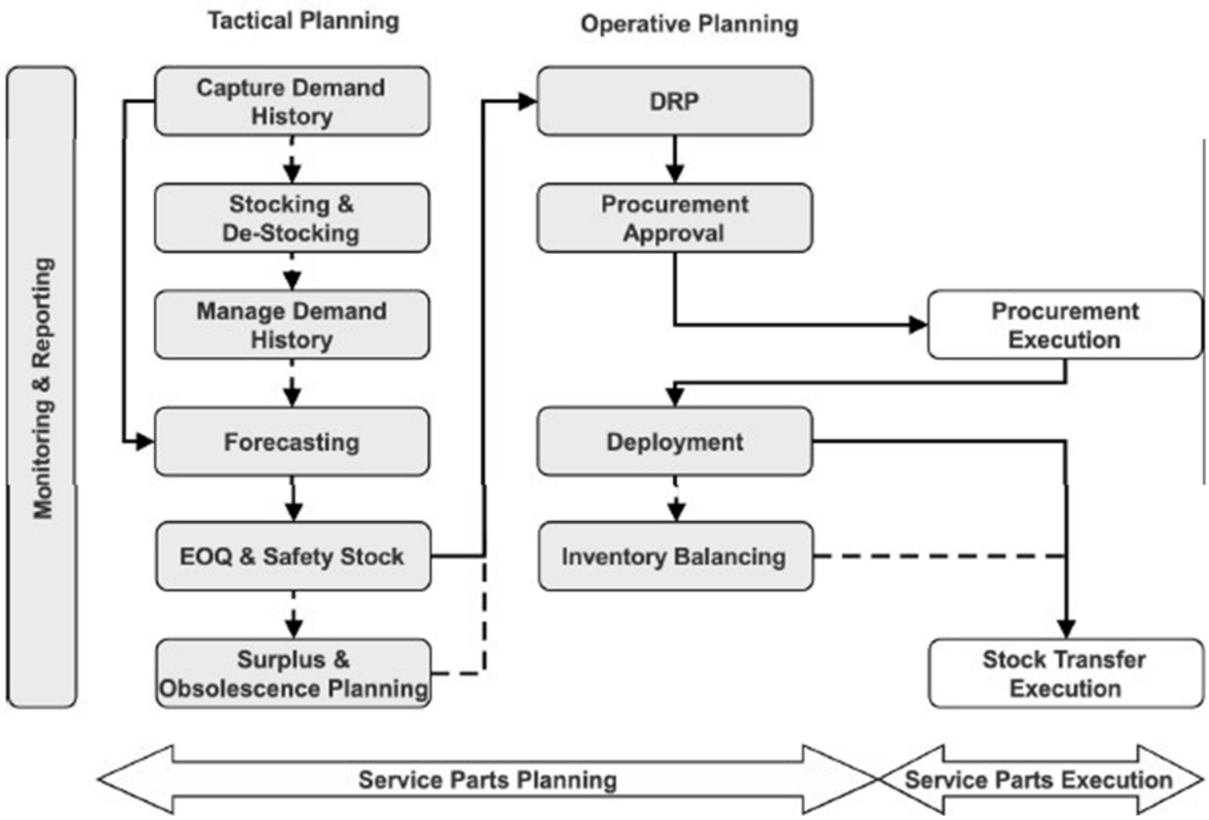


Fig. 4.3.7: Spare management process

4.3.11 Compliance Requirements for Safe Excavation and Installation in Various Terrains

1. Importance of Compliance in Excavation and Installation

Excavation and optical fiber installation involve significant risks such as trench collapse, electrical hazards, water ingress, and environmental damage. Compliance with safety standards ensures worker protection, project integrity, and environmental responsibility while minimizing downtime and legal liabilities.

A. General Compliance Requirements

1. **Pre-Excavation Planning**
   - Conduct a thorough site survey and risk assessment.
   - Review underground utilities maps (water, gas, electricity).
   - Obtain necessary permits from municipal and environmental authorities.
   - Mark excavation boundaries clearly using signage and barriers.
   - Prepare emergency response and communication plans.

2. Worker Safety

- Provide and enforce the use of Personal Protective Equipment (PPE), including helmets, safety boots, gloves, reflective jackets, and eye protection.
- Ensure proper supervision by trained personnel.
- Limit access to the excavation site to authorized workers only.
- Conduct toolbox talks before work begins to explain hazards and mitigation measures.

3. Trench Safety

- Maintain appropriate trench depth-to-width ratios to avoid collapse.
- Install shoring, trench boxes, or benching as required based on soil stability.
- Avoid working alone in trenches and ensure constant supervision.
- Inspect trenches regularly for signs of water seepage or wall movement.

4. Machinery and Equipment Safety

- Use machinery such as excavators and drilling rigs following manufacturer guidelines.
- Maintain equipment regularly and ensure emergency stop systems are functional.
- Avoid operating heavy equipment near power lines without protective clearances.

5. Environmental Protection

- Avoid disrupting natural drainage systems and wetlands.
- Control soil erosion using barriers or mats.
- Properly dispose of excavated soil, debris, and construction waste according to environmental norms.
- Prevent contamination of groundwater and soil by using lined pits or retaining structures.

B. Compliance for Specific Terrains

i. Urban Terrain

- Strict adherence to municipal excavation permits.
- Avoid disruption to underground utilities through careful mapping and cautious digging.
- Use noise and dust suppression techniques.
- Protect pedestrians and vehicular traffic with barricades and signage.

ii. Rural Terrain

- Ensure minimal impact on agricultural land by coordinating with landowners.
- Implement erosion control around irrigation systems.
- Avoid disturbing wildlife habitats.

iii. Rocky or Mountainous Terrain

- Conduct geological surveys to assess rock stability.
- Use controlled blasting or specialized cutting equipment with environmental safeguards.
- Plan for safe slopes and secure loose rock formations.

iv. Waterlogged or Coastal Terrain

- Install pumps to manage water accumulation.
- Use waterproof ducts and chambers to protect cables from moisture ingress.
- Apply corrosion-resistant materials in coastal areas with saline water exposure.

v. Forest or Protected Areas

- Obtain clearance from forest departments and environmental bodies.
- Limit tree felling and minimize habitat disruption.
- Use manual digging where machinery access is restricted.

C. Documentation and Compliance Checks

- Maintain daily safety logs and inspection reports.
- Record trench depths, soil conditions, and environmental monitoring results.
- Document worker training, PPE issuance, and emergency drills.
- Archive permits, risk assessments, and communication records for audits.

4.3.12 Environmental Safety and Risk Management Practices in Fiber Network Maintenance

1. Importance of Environmental Safety and Risk Management

During fiber network maintenance, operations such as excavation, equipment handling, and disposal of materials can impact the environment and pose risks to workers and the public. Implementing environmental safety and risk management practices ensures compliance with regulations, protects ecosystems, and promotes sustainable infrastructure development.

2. Key Environmental Safety Practices

Pre-Maintenance Assessment

- Conduct environmental impact assessments before maintenance work begins.
- Identify sensitive areas such as wetlands, forests, wildlife corridors, and water bodies.
- Evaluate potential risks including soil erosion, water contamination, air pollution, and noise.

Minimizing Ecological Impact

- Avoid unnecessary excavation or tree removal.
- Use protective mats or barriers to prevent soil erosion.
- Designate access routes that do not disturb habitats or agricultural land.
- Implement best practices for handling hazardous substances such as oils, lubricants, and sealants.

Waste Management

- Segregate waste materials such as cut fiber scraps, packaging, and contaminated soil.
- Dispose of hazardous waste according to local regulations.
- Recycle non-hazardous materials wherever possible.

Water and Soil Protection

- Prevent water runoff into natural streams by using containment measures.
- Avoid drilling or cutting near underground water pipelines unless properly safeguarded.
- Use absorbent materials in case of spills to prevent groundwater contamination.

Noise and Air Quality Control

- Restrict operations during sensitive times in residential or wildlife areas.
- Use noise barriers or mufflers for heavy machinery.
- Ensure vehicles and generators are well-maintained to reduce emissions.

3. Risk Management Practices

Hazard Identification

- Map out potential hazards such as unstable trenches, nearby utility lines, chemical spills, and vehicle movement.
- Conduct risk assessments before maintenance tasks begin.

Safety Protocols

- Implement site-specific emergency response plans.
- Train workers to identify hazards and take preventive measures.
- Provide PPE such as helmets, gloves, protective eyewear, and high-visibility vests.

Incident Reporting

- Set up communication channels for reporting near-misses, accidents, or environmental hazards.
- Maintain records of incidents for review and training improvements.

Monitoring and Inspections

- Conduct regular inspections to ensure compliance with safety procedures.
- Monitor air quality, noise levels, and water runoff during work.
- Review trench stability and soil conditions periodically.

Coordination with Local Authorities

- Inform local municipalities and environmental bodies before starting maintenance.
- Comply with all environmental clearance requirements.
- Work with emergency services to ensure quick response in case of accidents.

4. Emergency Preparedness

- Keep first-aid kits, firefighting equipment, and spill containment materials on-site.
- Train workers on how to respond to injuries, equipment failure, or environmental emergencies.
- Develop evacuation routes and communication trees for emergencies.

Key Risk Areas in Fiber Maintenance:

Risk Area	Potential Impact	Management Practice
Excavation	Soil erosion, habitat disruption	Proper trench support, limited digging
Handling hazardous substances	Groundwater contamination	Safe storage and spill containment
Noise and emissions	Disturbance to residents or wildlife	Use of silencers and emission control
Waste disposal	Land pollution	Segregation and recycling of waste
Nearby utilities	Accidental damage, fire	Mapping and careful excavation
Worker injuries	Safety incidents	PPE and training programs

4.3.13 Work Instruction - Maintenance

1. Following is the 'Work Instructions' for maintenance:
   - Obtain a site layout /design from NOC for patrolling purposes.
   - Ensure permits and sign offs for conducting maintenance activities.
   - Conduct periodic patrolling as per maintenance plan so as to prevent cable disruptions along the OFC routes.
   - Conduct corrective maintenance as per SLA.
   - Ensure availability of equipment & skilled staff for the purpose.
   - Tested report of fiber sections is updated to respective as per the timelines.
2. Following is the 'Work Instructions' for maintaining equipment of POP:
   - Obtain the maintenance schedule from NOC.
   - Executing seasons/timings (monthly, quarterly, half yearly) maintenance activities as per plan.
   - Make sure completion of physical maintenance operations like verifying battery voltage levels, electrolyte levels; DG set auto-start, oil levels; Air conditioner gas level.
   - Filter condition; earthing, fire alarm system and another owner equipment (including MCBs).
   - Ensure general upkeep

Exercise

Short Questions:

1. What are the key documents that need to be updated after completing a fault rectification in an optical fiber network?
2. Explain how OTDR traces are used to identify faults in fiber optic cables.
3. What safety precautions must be taken before heading to a fault location for maintenance work?
4. Describe the importance of using protection sleeves and connectors during fiber splicing.
5. How does Wavelength Division Multiplexing (WDM) improve fiber optic communication, and what troubleshooting techniques are used in WDM systems?

Fill in the Blanks:

1. OTDR stands for ___________ and is used to trace faults in fiber cables.
2. The process of updating all relevant documents such as OTDR registers and as-built diagrams is known as ___________ management.
3. ___________ is a technique that allows multiple signals to travel through the same fiber by using different wavelengths.
4. Before excavation work, workers must ensure that all ___________ and safety gear are checked and worn.
5. Proper back-filling after trenching ensures both structural integrity and ___________ safety.

Multiple Choice Questions (MCQs):

1. Which of the following is essential for diagnosing duct integrity?
   a) Measuring signal wavelength
   b) Checking air-tightness and kink-free conditions
   c) Monitoring power consumption
   d) Testing fiber length only
2. What is the purpose of as-built diagrams in fiber maintenance?
   a) To store historical weather data
   b) To locate physical sites and underground routes accurately
   c) To predict future fiber network failures
   d) To monitor employee attendance
3. Which PPE is mandatory before entering an excavation site?
   a) Safety boots, helmet, gloves
   b) Casual shoes and raincoat
   c) Sunglasses and perfume
   d) None of the above

4. When should additional duct protection such as RCC pipes be considered?
    a) Only in urban areas
    b) When traffic load or soil instability is high
    c) Only when installing fiber indoors
    d) None of the above
5. Which KPI is commonly used to assess signal strength and quality in optical fiber networks?
    a) Temperature fluctuation index
    b) Insertion loss and optical return loss
    c) Number of workers at site
    d) Cable color index

Notes

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

5. Follow Sustainability Practices in Telecom Cabling Operations

TEL/N9111

Key Learning Outcomes

By the end of this module, the participants will be able to:

1. Identify recyclable, reusable, and hazardous materials in fiber optic installations and explain how to categorize them.
2. Describe the waste management, recycling, and disposal protocols for materials used in fiber optic installations.
3. Explain how to optimize material and energy usage during cabling work in fiber optic installations.
4. Discuss the environmental and regulatory standards that must be complied with during fiber optic installations.

UNIT 5.1: Sustainability Practices in Telecom Cabling Operations

Unit Objectives

By the end of this unit, the participants will be able to:

1. Explain organizational policies on sustainability, waste reduction, and material reuse in telecom infrastructure projects.
2. Describe the procedures for recycling, hazardous waste handling, and safe disposal of telecom-related materials.
3. Discuss the importance of sustainability in long-term infrastructure planning and the environmental impact of telecom waste.
4. Elucidate the classification of materials used in optical fiber cabling, including recyclable, reusable, and hazardous components.
5. Explain standard waste management procedures for telecom operations, including segregation, labeling, and disposal methods.
6. Describe methods to reduce material wastage, such as accurate measurements, careful handling of fiber optic cables, and optimized trenching techniques.
7. Discuss the environmental hazards associated with improper disposal of optical fibers, batteries, and chemical adhesives.
8. Explain the regulations and compliance requirements for hazardous material disposal under national and international environmental laws.
9. Elucidate energy-efficient work practices, including low-power tools, optimized route planning, and reduced excavation techniques.
10. Describe the importance of proper record-keeping for disposal and recycling to ensure compliance and accountability.
11. Demonstrate how to identify, segregate, and store materials used in cabling operations, including recyclable, reusable, and hazardous materials, ensuring compliance with safety and waste management procedures.
12. Show how to follow SOPs for safe handling, disposal, and documentation of non-recyclable and hazardous materials, including fiber shards, cable sheaths, and chemical adhesives.
13. Demonstrate how to ensure proper labeling, safe storage, and disposal of hazardous waste to prevent contamination or accidents.
14. Show how to minimize waste by reducing excess material use, reusing components, and optimizing cabling work through accurate measurements and efficient layout designs.
15. Demonstrate how to maintain clean, organized work sites to prevent environmental contamination, promote safety, and comply with environmental guidelines.
16. Show how to use energy-efficient tools and machinery and ensure proper maintenance of cabling tools and equipment to reduce material consumption and unnecessary repairs.
17. Demonstrate how to coordinate and dispose of waste materials at designated collection points and report any violations or environmental hazards.
18. Show how to use and promote eco-friendly materials, such as low-impact protective coatings and biodegradable packaging.
19. Demonstrate how to follow national and local environmental regulations, workplace policies, and sustainability practices related to telecom cabling operations.
20. Show how to maintain accurate documentation of sustainability activities, including logs of disposed and recycled materials, to meet regulatory and audit requirements.
21. Demonstrate how to conduct periodic self-audits and educate team members on best practices for sustainability, waste segregation, and responsible energy consumption.
22. Show how to report violations of environmental policies, hazardous material spills, or unsafe disposal practices to the designated supervisor or regulatory body.

5.1.1 Organizational Policies on Sustainability, Waste Reduction, and Material Reuse

Telecom infrastructure projects involve large-scale deployment of materials such as cables, connectors, batteries, and protective coatings. Organizations today are increasingly focused on ensuring that such deployments are not only cost-effective but also environmentally responsible. Policies are framed to guide employees and contractors through sustainable practices, waste minimization strategies, and reuse protocols.

Core Elements of Sustainability Policies:

- Commitment to reducing carbon footprint and conserving natural resources.
- Encouraging efficient use of materials through better planning, accurate measurements, and waste audits.
- Promoting reuse of durable materials, such as metal frames, ducting structures, and fiber spools.
- Integrating environmental awareness into standard operating procedures.
- Aligning sustainability efforts with corporate social responsibility (CSR) initiatives and green certifications such as ISO 14001.

Material Reuse Policy Highlights:

- Inspection and cleaning protocols for reusable parts before re-deployment.
- Documentation of reused materials to ensure traceability and safety.
- Encouragement of modular designs that allow reuse across multiple sites.

Waste Reduction Strategy:

- Lean inventory management to avoid over-ordering.
- Monitoring consumption patterns to identify and reduce excess material usage.
- Designing workflows that avoid unnecessary handling and movement of materials.

Training and Awareness:

- Regular workshops to sensitize teams on environmental impacts.
- Reporting mechanisms that encourage workers to flag practices that result in waste.

5.1.2 Procedures for Recycling, Hazardous Waste Handling, and Safe Disposal

Recycling, Hazardous Waste Handling, and Safe Disposal are three essential components of sustainable waste management practices, particularly relevant in industries like telecom, manufacturing, and construction, where large volumes of materials and electronic components are used.

Fig. 5.1.1 Recycle E-waste

Recycling Telecom Materials:

- Segregation at Source: Waste materials must be sorted into categories such as metals, plastics, and paper.
- Designated Collection: Each site must have clearly labeled containers for recyclable items.
- Processing: Materials are transported to authorized recycling centers, where metals are melted, plastics are reshaped, and fiber scrap is processed.
- Documentation: The quantity and type of materials recycled must be recorded to track the effectiveness of recycling programs.

Handling Hazardous Waste:

- Identification: Hazardous materials include battery cells, chemical adhesives, lubricants, and damaged optical fibers.
- Protective Handling: Workers must wear gloves, face shields, and respirators when dealing with hazardous materials.
- Storage: Waste containers must be sealed, corrosion-resistant, and clearly labeled with hazard warnings.
- Transportation and Disposal: Only licensed waste handlers should move hazardous materials to treatment or landfill facilities. Transport logs and disposal receipts must be maintained.

Safe Disposal Methods:

- Landfilling: Non-recyclable but non-hazardous materials like damaged cable insulation can be disposed of in sanitary landfills.
- Incineration: Certain waste types, such as contaminated cloths or adhesives, may be safely incinerated following environmental permits.
- Return Programs: Battery cells or other electronic components may be sent back to manufacturers for responsible disposal or recycling.

5.1.3 The Importance of Sustainability in Long-Term Planning and Environmental Impact of Telecom Waste

The Importance of Sustainability in Long-Term Planning refers to the integration of environmentally responsible practices, efficient resource use, and strategic foresight into an organization's operations to ensure that its growth, productivity, and profitability are maintained without compromising the ability of future generations to meet their needs. In telecom operations, sustainability ensures that energy use, material consumption, and waste generation are managed in a way that supports environmental balance, regulatory compliance, and social responsibility.

Environmental Impact of Telecom Waste refers to the harmful effects that improperly managed telecom waste—such as discarded cables, batteries, electronic parts, plastics, and chemicals—has on ecosystems, natural resources, and human health. This impact includes pollution, habitat destruction, soil and water contamination, and increased greenhouse gas emissions.

Together, sustainable long-term planning and awareness of environmental impacts help telecom organizations mitigate risks, reduce operational costs, and foster resilience while protecting the planet.

Why Sustainability Matters:

- Environmental Stewardship: Poor disposal practices contribute to pollution, affecting ecosystems and communities.
- Operational Efficiency: Reducing material wastage lowers procurement costs and enhances project timelines.
- Regulatory Compliance: Governments worldwide are enforcing stricter waste management and reporting standards.
- Community Relations: Organizations seen as responsible stewards of the environment earn public trust and goodwill.

Impact of Telecom Waste:

- Plastic Waste: Cable sheaths and packaging materials may persist in landfills for decades.
- Chemical Spills: Adhesives and solvents can poison soil and water sources.
- Metal Scrap: Leftover connectors or fittings may leach heavy metals into the environment.
- Fiber Shards: Sharp debris poses safety risks to workers and wildlife.

By incorporating sustainability into long-term planning, telecom companies ensure their projects are future-ready and compliant with evolving environmental standards.

5.1.4 Classification of Materials Used in Optical Fiber Cabling

Categories of Materials

Additional Notes and Best Practices

- Reusable materials must pass visual and mechanical inspections to ensure structural integrity.
- Hazardous waste should never be mixed with recyclable streams to prevent contamination and regulatory violations.
- Containers must be labeled with Material Safety Data Sheets (MSDS), hazard warnings, and storage guidelines.
- Organizations should designate waste management coordinators to oversee proper disposal and material segregation.

Category	Materials	Handling Recommendations
Recyclable	Metal cables, aluminum clips, steel frames, copper wiring, cable jackets made from recyclable polymers	Sort by type, clean contaminants, ensure separation from hazardous waste, and transport to authorized recycling centers equipped to process telecom scrap

Reusable	Cable ducts, protective sheaths, clamps, conduit fittings, spools, trays	Inspect thoroughly for cracks, corrosion, or wear; clean and disinfect; record material condition and ensure compatibility with future projects before reuse
Hazardous	Adhesives, batteries, lubricants, fiber shards, solvents, lead-based materials	Store in corrosion-resistant containers, label with hazard symbols, follow local and international disposal standards, and train staff in emergency handling procedures

5.1.5 Standard Waste Management Procedures

Telecom Waste Management refers to the systematic process of handling, reducing, recycling, disposing of, and safely managing waste generated from the operations, maintenance, and expansion of telecommunication networks and infrastructure. This includes equipment, cables, packaging materials, batteries, metals, plastics, and hazardous substances used in telecom installations such as fiber optic cables, towers, switches, routers, and other devices.

The aim is to minimize environmental impact, ensure compliance with regulations, and promote sustainable practices throughout the lifecycle of telecom assets. Effective telecom waste management involves identifying recyclable materials, segregating hazardous waste, promoting reuse, and safely disposing of non-recyclable or toxic components in line with environmental guidelines and corporate sustainability goals.

Key Aspects of Telecom Waste Management

1. Waste Identification and Segregation: Classification of waste into recyclable, reusable, and hazardous materials.
2. Recycling and Reuse: Recovering metals, plastics, and components for reuse or resale.
3. Safe Disposal: Following protocols for disposing of hazardous materials like batteries, chemicals, and electronic waste.
4. Documentation and Reporting: Maintaining records of waste generation, treatment, and disposal in compliance with local environmental laws.
5. Compliance with Environmental Guidelines: Aligning with national and international regulations such as E-waste management rules and sustainability policies.
6. Training and Awareness: Educating field teams and staff on best practices, safety measures, and environmental responsibilities.

Fig. 5.1.2 Telecom Waste Management

Step-by-Step Waste Handling Workflow

1. Segregation at the Source
    - Install multiple bins on-site marked “Recyclable,” “Reusable,” and “Hazardous.”
    - Train staff to identify materials based on their composition, size, and usage.
2. Labeling Guidelines
    - Use color-coded stickers or tags to mark bins and containers.
    - Include critical information such as waste type, origin, date, and handling instructions.
3. Storage Practices
    - Store hazardous materials in locked cabinets with ventilation.
    - Keep flammable items away from ignition sources and maintain separate containment areas.
4. Collection and Transport
    - Schedule regular pickups to prevent accumulation.
    - Ensure transport vehicles are equipped with spill containment kits and secure storage compartments.
5. Documentation and Reporting
    - Maintain digital logs and physical records of waste quantities and disposal locations.
    - Provide periodic reports to regulatory bodies as part of environmental audits.

5.1.6 Methods to Reduce Material Wastage

Reduce Material Wastage refers to the deliberate actions, strategies, and processes implemented to minimize the unnecessary use, loss, or discard of materials during operations, manufacturing, maintenance, or disposal activities. It focuses on using materials efficiently, reusing components where possible, and preventing waste generation at every stage of the lifecycle, thereby conserving resources, lowering costs, and protecting the environment.

In telecom operations, reducing material wastage means optimizing the use of cables, metals, packaging, batteries, and other equipment components to avoid excess consumption and ensure responsible handling of resources.

The methods are:

Accurate Measurements

- Utilize GPS-based mapping tools and automated measurement devices to calculate cable length requirements.
- Cross-check data before procurement to avoid excess ordering.

Careful Handling

- Educate staff on optimal reel unwinding techniques and proper bending radius requirements.
- Store cables in moisture-controlled areas to prevent degradation.

Optimized Trenching Techniques

- Analyze terrain types to determine whether mechanical or manual excavation is suitable.
- Plan routes that minimize soil disruption while reducing cable wastage.

Reusing Packaging and Materials

- Inspect and clean fiber reels, reusing them multiple times.
- Replace single-use packaging with reusable containers or biodegradable alternatives.

Fig. 5.1.3 Reduce E-waste

5.1.7 Environmental Hazards Associated with Improper Disposal

Environmental Hazards Associated with Improper Disposal refer to the negative impacts on the environment that occur when waste—especially hazardous or non-biodegradable materials—is not handled, treated, or disposed of according to prescribed safety and environmental guidelines. Improper disposal of telecom waste, industrial waste, or other materials can lead to soil contamination, water pollution, air degradation, and harm to ecosystems and human health.

These hazards arise when waste is dumped in unauthorized areas, mixed with regular waste, burned, or left untreated, allowing harmful substances like heavy metals, chemicals, plastics, and electronic components to enter the environment.

The hazards and measures are:

Hazard Identification

- Adhesive Chemicals: Certain adhesives release volatile organic compounds that contribute to air pollution and cause skin irritation.
- Battery Leakage: Lead, cadmium, and mercury contamination from improperly stored batteries can seep into groundwater supplies.
- Fiber Waste: Sharp shards pose a puncture hazard and may injure wildlife if not securely disposed.
- Plastic Packaging: Non-biodegradable plastics can persist in the environment for decades, impacting soil and marine life.

Precautionary Measures

- Conduct site inspections to ensure compliance with hazardous material storage protocols.
- Train workers to handle spills and leaks with appropriate containment and cleanup procedures.
- Implement reporting systems to flag hazardous incidents immediately.

5.1.8 Regulations and Compliance Requirements

Regulations and Compliance Requirements refer to the set of laws, rules, standards, and guidelines that organizations must follow to operate legally, ethically, and safely within a particular industry or sector. These requirements are typically set by government bodies, regulatory authorities, or industry organizations and are designed to ensure safety, protect the environment, promote fair practices, and uphold quality and accountability.

In telecom operations, regulations and compliance requirements cover areas such as spectrum usage, data privacy, environmental protection, waste disposal, occupational health and safety, and energy consumption.

1. Applicable Frameworks

- Environment Protection Act (EPA): Outlines procedures for safe disposal of hazardous telecom materials.
- Waste Management Rules (2016 and amendments): Provide guidelines for segregation, transport, and disposal practices.

- ISO 14001: Encourages structured environmental management systems and regular audits.
- Basel Convention: Addresses global standards for the transportation and disposal of hazardous waste.

2. Compliance Practices

- Maintain waste transport manifests signed by authorized personnel.
- Perform quarterly audits to check for proper handling and documentation.
- Conduct training sessions aligned with environmental law updates and compliance requirements.

5.1.9 Energy-Efficient Work Practices

Energy-Efficient Work Practices refer to methods, behaviors, and procedures adopted in workplaces to reduce energy consumption, optimize resource usage, and minimize environmental impact while maintaining productivity and operational efficiency. These practices involve using energy in a smarter and more sustainable way by eliminating waste, improving equipment performance, and encouraging responsible energy use among employees.

In the context of telecom operations, energy-efficient work practices can include using energy-saving devices, optimizing network configurations, managing standby power, and ensuring proper maintenance to avoid unnecessary energy loss.

The practices are:

1. Low-Power Tools
    - Use solar-powered lights during night shifts.
    - Invest in battery-efficient trenchers and drills that reduce energy consumption without sacrificing performance.
2. Route Optimization
    - Incorporate mapping software that calculates the shortest, safest installation paths.
    - Avoid redundant trenching by coordinating with existing infrastructure layouts.
3. Maintenance and Preventive Checks
    - Schedule periodic maintenance for equipment to avoid breakdowns.
    - Implement checklists to ensure tools are stored and handled correctly after use.
4. Energy Audit Reports
    - Track energy usage per site and create efficiency benchmarks.
    - Encourage energy-saving practices through reward-based systems.

5.1.10 Importance of Proper Record-Keeping

Record-Keeping of Telecom Waste is the process of systematically documenting all activities related to the generation, handling, storage, transportation, recycling, and disposal of waste produced in telecom operations. Proper record-keeping ensures regulatory compliance, promotes environmental responsibility, enables traceability, and helps identify areas where waste reduction and recycling can be improved.

Types of Records

- Hazardous material handling logs, including type, quantity, and disposal method.
- Inventory of reusable materials and condition assessment reports.
- Waste disposal reports validated by transport and processing facilities.
- Energy usage logs and maintenance schedules.

Benefits

- Helps organizations remain audit-ready and compliant with environmental laws.
- Provides actionable data to identify areas for process improvements.
- Enhances operational planning by forecasting future material needs.

Exercise

Short Questions:

1. Explain how organizational policies on sustainability and material reuse contribute to reducing telecom infrastructure waste.
2. Describe the steps involved in safely handling and disposing of hazardous telecom waste like adhesives and batteries.
3. Why is accurate record-keeping important in ensuring compliance with environmental laws in telecom projects?
4. List methods that can help reduce material wastage during fiber optic cable installation.
5. How can energy-efficient tools and optimized route planning support sustainable telecom infrastructure projects?

Fill in the Blanks:

1. Hazardous materials like fiber shards and adhesives should always be stored in ___________ containers to prevent accidents.
2. Accurate ___________ helps telecom companies reduce material wastage and plan sustainable projects effectively.
3. The ___________ Convention governs the safe disposal and transport of hazardous waste internationally.
4. Using ___________ tools such as battery-efficient drills helps reduce energy consumption during telecom operations.
5. Proper ___________ of waste disposal activities ensures accountability and helps telecom companies meet audit requirements.

Multiple Choice Questions (MCQs):

1. What is the primary reason for segregating recyclable and hazardous waste in telecom operations?
   a) To increase the storage space
   b) To prevent contamination and ensure safe disposal
   c) To reduce employee workload
   d) To avoid using protective equipment
2. Which of the following is an eco-friendly material option in telecom cabling projects?
   a) Lead-based solder
   b) Biodegradable packaging
   c) Plastic sheaths with PVC coating
   d) Solvent-based adhesives
3. What documentation is essential for hazardous material disposal compliance?
   a) Employee attendance sheet
   b) Waste disposal logs with hazard classification
   c) Telecom network performance reports
   d) Daily tool maintenance records

4. Which regulation controls the movement and disposal of hazardous waste across borders?
    a) ISO 9001
    b) Basel Convention
    c) WTO Trade Act
    d) OSHA Safety Standard
5. What is the best practice for minimizing fiber waste during installation?
    a) Over-ordering materials in bulk
    b) Ignoring trench alignment for convenience
    c) Using accurate measurements and optimized layouts
    d) Storing cables in unprotected areas

Notes

Scan the QR Code to watch the related videos

https://www.youtube.com/watch?v=WvyWmXrDTwM

What Are Regulatory Compliance Requirements?

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

Telecom Sector Skill Council

6. Employability Skills (30 Hours)

It is recommended that all training include the appropriate. Employability Skills Module. Content for the same can be accessed https://www.skillindiadigital.gov.in/content/list

DGT/VSQ/N0101

7. Annexure

Annexure I - QR Codes –Video Links

Annexure - I

QR Codes –Video Links

Chapter No.	Unit Name	Topic	Page No.	URL Links	QR code (s)
Chapter 1: Introduction to the Sector and the Job Role of an Optical Fiber Technician	Unit 1.1 - Introduction to Telecom Sector and Role of an Optical Fiber Technician	What is Fiber-Optic Cable with Full Information	15	https://www.youtube.com/watch?v=77dOO5hvd58	
Chapter 2: Coordinate Installation and Commissioning of Optical Fiber Cables	Unit 2.2 - Choosing the Right Type of Optical Fiber	Optical fiber cables, how do they work?	37	https://www.youtube.com/watch?v=jZOg39v73c4	
	Unit 2.3 - Fiber Optic Tools and Tool Kit	Fiber Optic cable splicing	48	https://www.youtube.com/watch?v=fCX7U2oCWes	
	Unit 2.4 - Installation of Fiber Optic Cable	10 tips for installing fiber optic cables	74	https://youtu.be/46JAjiQfCkg	
	Unit 2.5 - Safety, Quality, and Environmental Compliance in Optical Fiber Installation	Fiber Optic Safety Introduction	81	https://www.youtube.com/watch?v=mkwScwUVyuM	
Chapter 3: Undertake Condition Based Maintenance and Planned Repair Activities	Unit 3.1 - Carry Out Testing of Optical Fiber	VFL(visual Fault Locator)	108	https://www.youtube.com/watch?v=wnCOnzGc0iU	
		How to test the insertion loss of Fiber Optic Cable		https://www.youtube.com/watch?v=jML7kgQ-MjA	

Chapter No.	Unit Name	Topic	Page No.	URL Links	QR code (s)
	Unit 3.2 - Optical Fiber Testing, Documentation, and Predictive Maintenance	Optical Fiber Splicing Safety	125	https://www.youtube.com/watch?v=A-190m4LvEg	
Chapter 4: Perform Corrective Maintenance/Restoration of Optical Fiber Faults	Unit 4.2 - Fault Localization and Restoration	Optical Fiber Cable (OFC) Splicing	155	https://www.youtube.com/watch?v=7GL9nDCEJQk	
Chapter 5: Follow Sustainability Practices in Telecom Cabling Operations	Unit 5.1 - Sustainability Practices in Telecom Cabling Operations	What Are Regulatory Compliance Requirements?	187	https://www.youtube.com/watch?v=WvyWmXrDTwM	

NCVET
कौशल गुणवत्ता प्रगति

Skill India
कौशल भारत - कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
RE IMAGINE FUTURE

Telecom
Sector
Skill
Council

Telecom Sector Skill Council
Estel House,3rd Floor, Plot No: - 126, Sector-44
Gurgaon, Haryana 122003
Phone: 0124-2222222
Email: tssc@tsscindia.com
Website: www.tsscindia.com