सत्यमेव जयते

भारत सरकार –GOVERNMENT OF INDIA

रेल मंत्रालय– MINISTRY OF RAILWAYS

(कार्यालयीन प्रयोग हेतु)– (For official use only)

HANDBOOK ON
OPTICAL FIBRE CABLE JOINTING



CAMTECH/S/PROJ/13-14/OFC/1.0

DECEMBER 2013

अग्रदूत RDSO
रेल अग्रदूत Transforming Railways

An ISO 9001-2008 Certified Organisation
उच्च अनुरक्षण प्रौद्योगिकी केन्द्र
EXCELLENCE IN MAINTENANCE

Indian Railways
Centre for Advanced Maintenance Technology

MAHARAJPUR, GWALIOR – 474 005

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FOREWORD

Invention of fiber-optic technology is a revolutionary departure from the traditional copper cable. Optical fiber communication plays a vital role in the development of high quality and high-speed telecommunication systems. Today, optical fibres are not only used in telecommunication links but also used in the Internet and local area networks (LAN) to achieve high signaling rates.

Performance of optical fibre cable is inversely proportional to the numbers of joints throughout its route as every joint increases signal losses. We ensure that this handbook will help to field staff in preparation of better optical fibre cable joints.

CAMTECH, Gwalior
23rd December 2013

A.R.Tupe
Executive Director

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PREFACE

Optical Fibre cable (OFC) system of communication has several advantages over conventional telecom cables or radio relay communication. It is totally immune to induction effect of the AC traction or interference from thyristor. A single optical fibre can carry really huge numbers of telephone conversations, long distance calls that used to be very expensive have become cheap enough for many people to make them often.

This handbook not only covers the information on optical fibre cable jointing but also have Reasons of Light Losses, Tools & Instruments, Troubleshooting, Maintenance Schedule, Safety Precautions and brief of OFC connectors.

We are sincerely thankful to Shri Vivek Kumar Director/Tele/RDSO, Shri Ravi Shankar Station Manager/RailTel and their supervisors and maintainers who have helped us in preparing this handbook.

Since technological upgradation and learning is a continuous process, you may feel the need for some addition/modification in this handbook. If so, please give your comments on email address dirsntcamtech@gmail.com or write to us at Indian Railways Centre for Advanced Maintenance Technology, In front of Adityaz Hotel, Maharajpur, Gwalior (M.P.) 474005.

CAMTECH Gwalior **D.K.M.Yadav**
Date: 23.12.2013 **Joint Director (S&T)**

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ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/S/PROJ/2013-14/HB-OFC/1.0# XX date .....

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No. of Correction Slip	Date of issue	Page no. and Item No. modified	Remarks

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DISCLAIMER

It is clarified that the information given in this handbook does not supersede any existing provisions laid down in the Telecomm Engineering Manual, Railway Board and RDSO publications. This document is not statuary and instructions given are for the purpose of guidance only. If at any point contradiction is observed, then SEM, Railway Board/RDSO guidelines may be referred or prevalent Zonal Railways instructions may be followed.

OUR OBJECTIVE

To upgrade Maintenance Technologies and Methodologies and achieve improvement in Productivity and Performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability and Utilisation.

If you have any suggestion & any specific comments, please write to us:

Contact person	**:**	**Jt. Director (Signal & Telecommunication)**
Postal Address	**:**	**Centre for Advanced Maintenance Technology, Maharajpur, Gwalior (M.P.) Pin Code – 474 005**
Phone	**:**	**0751 - 2470185**
Fax	**:**	**0751 – 2470841**
Email	**:**	**dirsntcamtech@gmail.com**

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OPTICAL FIBRE CABLE JOINTING

1. Introduction

An **optical fibre** is a flexible, transparent fibre made of high quality extruded glass (silica) or plastic. It can function as a waveguide, or "light pipe", to transmit light between the two ends of the fibre. Optical fibres are used in fibre-optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communication. Fibres are used instead of metal wires thus signals travel with less loss and are also immune to electromagnetic interference.

Optical fibre cable is a medium for carrying information from one point to another in the form of light. A basic fibre optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fibre cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal.
In Indian Railway, Optical Fibre communication system is provided for following types of communication needs: -

(a) Control Communication with emergency communication
(b) Administrative voice and data communication.
(c) Both for control and long haul communication backbone for mobile train radio communication.
(d) Short haul communication for block channels signalling

1.1 Guidelines for use of Optical Fibre System on various routes. [As per Telecom manual chapter 13.1.2]

- New Railway Projects – Gauge Conversion/New lines/Doubling/ Railway Electrification.
  On A, B, C, D & D Spl Routes, following Optical Fibre system configuration should be used.
  - 24 Fibres Optical Fibre Cable (as per RDSO Specification IRS.TC.55/ or latest) with Six Quad cable (as per RDSO specification IRS.TC30/2005 or latest).

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- Short Haul Communication will be on STM-1 System and Primary Digital Multiplexers (PDMUX). For back up a second pair of Fibre shall be used.

- On other routes, following Optical Fibre System configuration using Composite Cables (8/24 Fibre + 6 Quad) as per RDSO specification shall be used.

- Replacement of existing overhead / RE quad cable of control communication.

1.2 Objectives for the System Design
[As per Telecom manual chapter 13.1.3]

(a) Location of optic fibre stations and regenerators/repeaters.
(b) Optical loss budget of each block section. While calculating the Optical loss budget, following will be taken into consideration:

Equipment margin	: 2 dB
Connector loss	: 2 dB
Cable margin	: 0.1 dB per Km.
System operational margin	: 0.03 dB per Km.
Splice loss	: 0.2 dB per Km.

(c) Requirement of system capacity to meet present and future channel requirements.
(d) Availability of the system.
(e) Total expected jitter of the system.
(f) Design of power supply system for each station.
(g) Preparation of an estimate.

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1.3 Capacity of Fibre Optic System [As per Telecom manual chapter 13.1.4]

a) For Control Communication application, SDH System having capacity of STM-1 shall be used. Generally, one E1 shall be used for various control applications.
b) For Long Haul Communication, SDH System with capacity of STM-4/STM-16/STM-64 or above shall be used.

1.4 Features

Transmitting power over an optical fibre has multiple advantages over transmitting the same power over copper conductors as given below.

i) Greater bandwidth

Fibre provides far greater bandwidth and greater fidelity than copper wire.

ii) Low attenuation and greater distance

Because the fibre optic signal is made of light, very little signal loss occurs during transmission, and data can move at higher speeds and greater distances.

iii) Security

Your data is safe with fibre cable. It doesn't radiate signals and is extremely difficult to tap.

iv) Immunity and reliability

Fibre provides extremely reliable data transmission. It's completely immune to many environmental factors that affect copper cable. The core is made of glass, which is an insulator, so no electric current can flow through. It's immune to electromagnetic and radio-frequency interference (EM/RFI), crosstalk, impedance problems, and more.

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v) Design

Fibre is lightweight, thin, and more durable than copper cable. Plus, fibre optic cable has pulling specifications that are up to 10 times greater than copper cable's. Its small size makes it easier to handle, and it takes up much less space in cabling ducts.

vi) Migration

The proliferation and lower costs of media converters are making copper to fibre migration much easier. The converters provide seamless links and enable the use of existing hardware.

vii) Cost

The cost for fibre cable, components, and hardware is steadily decreasing. Installation costs for fibre are higher than copper because of the skill needed for terminations. Overall, fibre is more expensive than copper in the short run, but it may actually be less expensive in the long run.

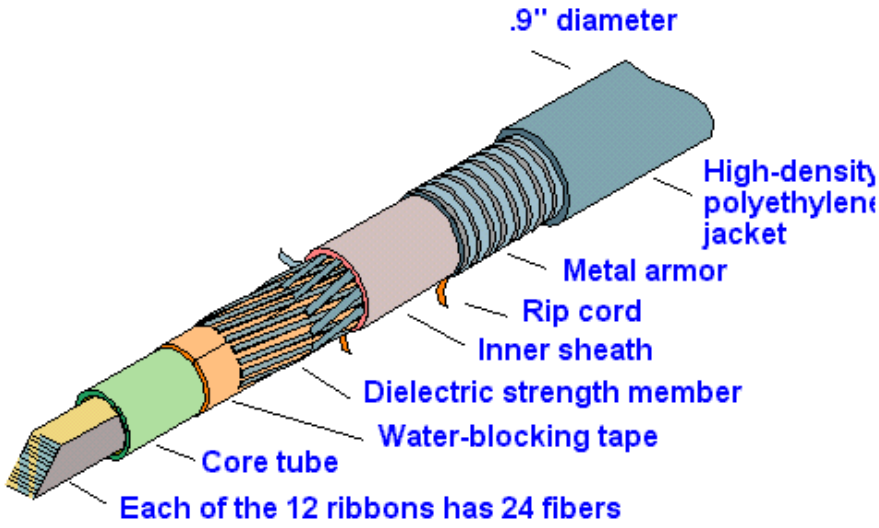
1.5 Limitations of OFC

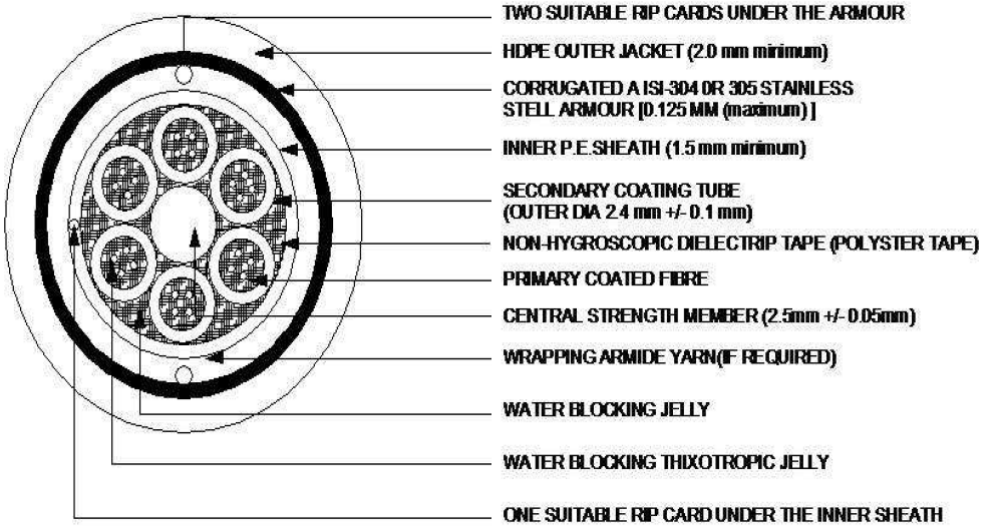
· Difficulty in jointing (splicing)
· Highly skilled staff would be required for maintenance
· Precision and costly instruments are required
· Tapping for emergency and gate communication is difficult.
· Costly if under- utilised
· Special interface equipments required for Block working
· Accept uni-polar codes i.e. return to zero codes only.

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2. Construction of OFC

Simple self explanatory sketch and cross sectional view of optical fibre cable, being use in railway is shown below. For construction detail, handbook on Optical Fibre Cable prepared by CAMTECH may be referred.

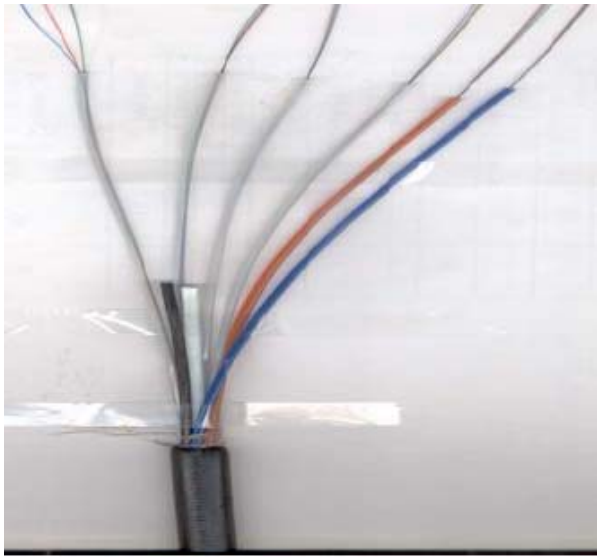




Cross-sectional view of 24 Fibre cable used in Indian Railways

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OFC having 24 Fibres armoured cable is normally used for underground laying. It consists of 6 loose tubes as shown below:



As per IRS:TC 55-2006, Rev.1 colour code of loose tubes is as shown below:

1.	(F1) - Blue	4.	(F4) - Brown
2.	(F2) - Orange	5.	(F5) - Slate
3.	(F3) - Green	6.	(F6) - White.

Each loose tube contains 4 fibres: Blue, Orange, Green & Natural.

OFC having 12 numbers of Fibres armoured cables are used for underground/ Arial (over head) laying. It contains single loose tube with 12 fibres as following colour code.

1.	F1 - Blue	7.	F7 - Red
2.	F2 - Orange	8.	F8 - Black
3.	F3 - Green	9.	F9 - Yellow
4.	F4 - Brown	10.	F10 - Violet
5.	F5 - Slate	11.	F11 - Rose
6.	F6 - White	12.	F12 - Aqua

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3. Reasons of Light Losses in Optical Fibre Joint

When jointing optical fibres, the opposite cores must be properly aligned. Optical fibre connector / splice loss occurs mostly due to following reasons:

a. Poor Concentricity

Poor concentricity of optical fibres joint causes a connector / splice loss. In the case of general purpose single-mode fibres, the value of connector / splice loss is calculated roughly as the square of the amount of misalignment multiplied by 0.2 (For example, if the light source wavelength is 1310nm, misalignment by 1 µm results in approximately 0.2dB of loss.)



b. Axial Run-Out

A connector / splice loss occurs due to an axial run-out between the light axes of optical fibres to be jointed. It is necessary to avoid an increased angle at fibre cut end when using an optical fibre cleaver before fusion splicing, since such an angle can result in splicing of optical fibres with run-out.



c. Gap

An end gap between optical fibres causes a connector / splice loss. If optical fibre end faces are not correctly butt-jointed in mechanical splicing cause a splice loss.



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d. Reflection

An end gap between optical fibres results in 0.6dB of maximum return loss due to the change in refractive index from the optical fibre to the air. Cleaning optical fibre ends is important for optical connectors. In addition, the whole optical connector ends should be cleaned because loss can also occur due to dirt between optical connector ends.

4. Tools & Instruments

4.1 Tools & Equipments Required for Jointing and Termination

Sr.No.	Tool's Name
1.	Branch Joint Closure
2.	Termination Box
3.	Rubber and Block
4.	Sheath Clamp
5.	Bushing
6.	Strength Member holder
7.	Heat Shrinkage tube
8.	Arc fusion splicer machine
9.	Power cord AC/DC
10.	Walkie-Talkie 12V DC source
11.	Tube heater
12.	Precision cleaver
13.	Cable sheath stripper
14.	Fibre stripper/ Cable ties
15.	Knife for HDPE cutting
16.	Hacksaw for strength membrane
17.	Isopropyl alcohol
18.	Cotton Buds
19.	Tweezers
20.	Gun heater blower type
21.	Protection Sleeves
22.	OTDR
23.	Stabilized optical power source and power meter
24.	Optical Talk set
25.	Stickers for numbering of splicers
26.	Patch Cords - Two numbers
27.	Generator set for charging the battery and lighting

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4.2 Tools required for sheath Removal

S.No.	Name of tool	Function
1	Cable cutter	To cut the cable in full
2	Jacket remover	To remove outer jacket
3	Utility knife	To cut narrow jacket circumferentially
4	Scissors	To cut rip cord, Aramid yarn, & Binders
5	Diagonal cutting pliers	To cut central members, fillers etc.
6	Sheath Ripper	To cut the polythene binders
7	Vinyle insulation tape	For proper marking of cable
8	Gel off paper	To clean the jelly
9	Towel cloth	To clean the cable
10	Number Book	For cable and buffer tubes identifications
11	Measuring Tape	For different length measurements
12	Buffer Stripper	To strip the buffer tubes
13	Paint Marker	To mark on cable

4.3 Tools required for fusion splicing

S.No	Name of tool	Function
1	Fibre Stripper	To strip the plastic cover coating of fibre
2	Fibre Cleaver	To cut the fibre end perpendicular to the axis
3	Tissue Papers	To clean the fibre after stripping
4	Cleaning liquid	To clean the fibre and splicing machine's lens, V groove etc.
5	Jewellers Screw	To adjust some potentiometer in fusion splicing machine
6	Cotton swab	To clean the fibre and splicing machine's lens, V groove etc.
7	NO-NIK Tool	To remove white colour coating of tight buffer tube
8	Flash Light	To test the pig tails (tight buffer tube)

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4.4 Tools required for preparation of splicing - closure

S.No	Name of tool	Function
1	Tensioning Tool	To tight the clamping bends over the ends caps, clamping bars etc.
2	Opening Hook	To open the closure (used with tensioning tool)
3	Screw Drivers	To tight and loose the screw nuts etc.
4	Adjustable Wrench	To tight nuts and bolts in supporting bars.
5	Hammer	To open and close the clamping bars.
6	Ty-raps	To tie the buffer tubes into splice tray.
7	Ty-rap Fastner	To tie the buffer tubes into splice tray.
8	RTV Sealant	To tight the Ty-rap.
9	Tweezer	To lift and hold the fibre.
10	Spatula	To set the fibre splices into splice tray organiser.
11	Cleaning Khadi Cloth	To clean the cable outer jacket.
12	Crimping Pliers	To fix the buffer tubes in splice tray.

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5. Brief Description of Instruments

5.1 Fusion Splicing Machine

It melts the two ends of fibre optic cables together to form a continuous cable. To do this properly, machines must align the cable, touch the ends together, and send heat or an electric arc through the joint to melt the glass. This process requires a great deal of precision and accuracy. Photograph of typical splicer is given below:





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5.2 Optical Time Domain Reflectometer (OTDR)

An OTDR may be used for estimating the fibre's length and overall attenuation, including splice and mated-connector losses. It may also be used to locate faults, such as breaks, and to measure optical return loss. Photograph of typical OTDRs are given below:





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5.3 Cleaver

A perpendicular cut in a optical fibre cable is critical to the success of the splice or joint. A cleaver breaks the glass cable with high precision. Photograph of typical cleaver is given below:



5.4 Optical Source

An optical source is a major component of optical transmitters. Fiber optic communication systems often use semiconductor optical sources such as Light emitting diodes (LEDs) and semiconductor lasers. Some of the advantages are: Compact in size, High efficiency, Good reliability, Right wavelength range, Small emissive area compatible with fibre core dimensions, Possibility of direct emulation at relatively high frequencies. A typical photograph is shown below.



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5.5 Optical Power Meter

An **optical power meter** (**OPM**) is a device used to measure the power in an optical signal. A typical optical power meter consists of a calibrated sensor, measuring amplifier and display. The sensor primarily consists of a photodiode selected for the appropriate range of wavelengths and power levels. On the display unit, the measured optical power and set wavelength is displayed. Power meters are calibrated using a traceable calibration standard such as a NIST standard.

Sometimes optical power meters are combined with a different test function such as an Optical Light Source (OLS) or Visual Fault Locator (VFL), or may be a sub-system in a much larger instrument. When combined with a light source, the instrument is usually called an Optical Loss Test Set.

An Optical Time Domain Reflectometer (OTDR) can be used to measure optical link loss if its markers are set at the terminus points for which the fibre loss is desired.



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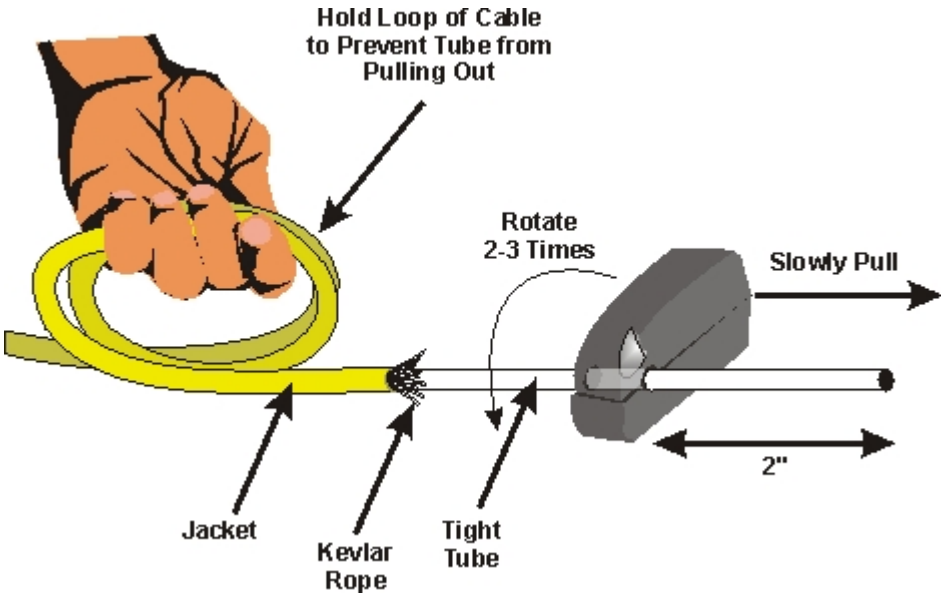
6. Brief Description of Tools

i. Buffer Tube Cutter

This compact and light weight tool is used for stripping of loose tube (buffer tube) from fibre. It is very simple tool with automatic return spring for ease of use and speed.



Buffer Tube Stripping



Above figure shows how tight buffer tube stripping removes the tight buffer tube from optical fibre. This diagram shows that the tubing cutter contains a knife edge that is pressed onto the buffer tube of the optical cable. The tubing cutter is then rotated around the optical fibre several times to create a cut in the buffer tube without cutting the optical fibre

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strand. The tubing cutter is then gently pulled to apply pressure to the buffer tube resulting in the sliding of the buffer tube off of the optical fibre. This example also shows that the optical cable is looped and held (loop not to exceed bend radius) to prevent the buffer tube from pulling through the optical cable.

ii. Cutting Nippers

It is used for handling the delicate work while terminating, installing or splicing of the optical fibre in the Termination Box or in the joint Closure.



iii. Fibre Strippers

It is used for cutting and removing the primary coating of the optical fibres during splicing the optical fibre cable.



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iv. FRP Cutter

It is used for cutting of the optical fibre cable perpendicular to the axis of the fibre reinforced plastic (FRP).



v. Cable Cutter

It is used for cutting of optical fibre cable perpendicular to cable axis.



vi. Nose Plier

It is used for handling the delicate work while terminating installing or splicing of the optical fibre in the Joint Closures.



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vii. Wire Stripper Cutter

It is used for Stripping the outer jacket (nominal jacket dia of 3 mm) of single fibre cable i.e. Pigtails, Patch cord.



viii. Cable Sheet Cutters

It is used for cutting and removing the HDPE sheath and nylon jacket of the optical fibre cable.



ix. Cleaner

Isopropyl rubbing alcohol can be used to clean wires to remove dirt, gel, and grease.



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x. Heat Shrink Sleeves

Whether fused or mechanically joined, a spliced optical fibre cable is prone to breaking. It is best to use a plastic sleeve over a joint to prevent breaking due to handling. These sleeves can be shrunk onto a joint using heat.



xi. Scissors



xii. Measuring Tape: Used for measurement of cable during splicing.



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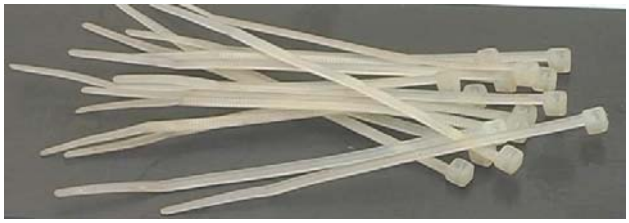
xiii. Numbering Ferrule: Used for numbering & counting of fibres.



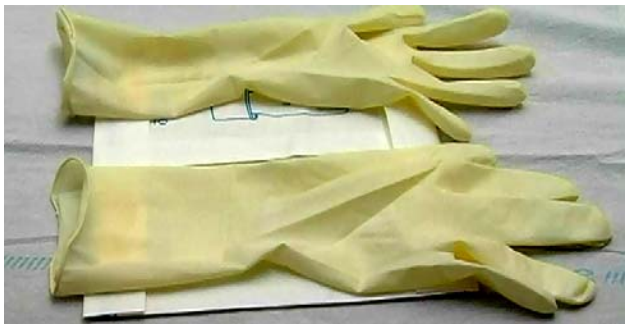
xiv. Tissue Paper: Used for cleaning of Fibres.



xv. Cable Ties: Used for fitting fibres in trays



xvi. Hand Gloves : Used for safety during splicing



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7. Jointing (Splicing) of Optical Fibre Cable

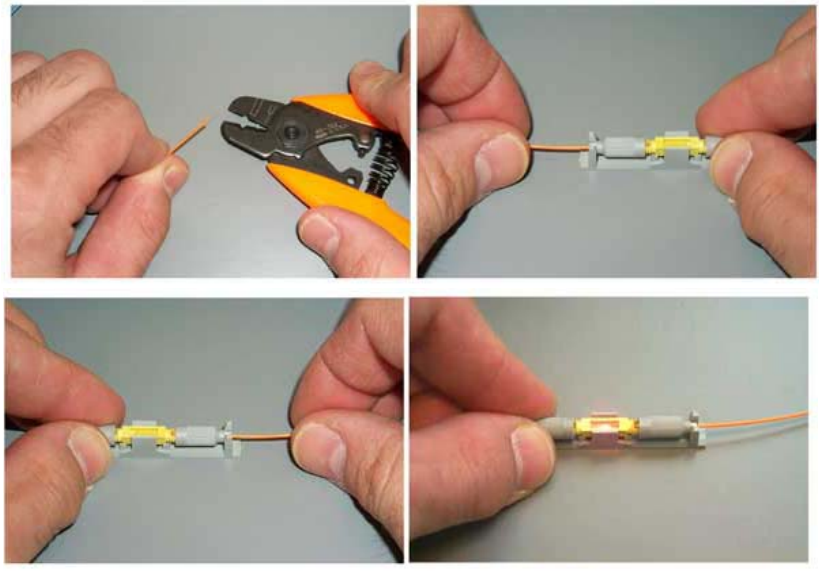
Optical fibre cable jointing or Splicing is a permanent connection of two pieces of fibres. Optical fibre cable splicing Techniques is of two types.

7.1 Mechanical Splicing

Mechanical splicing is perform with a small mechanical splicer which joints permanently the two optical fibres. Mechanical splicer is a small fibre connector that aligns the axis of the two bare fibres to be joined and physically hold them together. A snap-type cover, an adhesive cover, or both, are used to permanently fasten the splice. Insertion loss per joint is less than 0.5dB. Mechanical splicing is used for temporary splicing of fibres or where fusion splicing is impractical or undesirable.

This is done by applying localized heating (i.e. by electric arc or flame) at the interface between the butted, pre-aligned fibre end, causing them to soften and fuse together.

7.1.1 Mechanical Splicing Process



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The splicing process is basically the same for all types of mechanical splices. The first step is to strip, clean & cleave the fibres to be spliced. Strip the primary buffer coating to expose the proper length of bare fibre. Clean the fibre with appropriate wipes. Cleave the fibre using the directions appropriate to the cleaver being used. Using a high quality cleaver such as those provided with fusion splicers will yield more consistent and lower loss splices.

7.1.2 Making the Mechanical Splice

Insert the first fibre into the mechanical splicer. Most splicers are designed to limit the depth of the fibre insertion by the stripped length of buffer coating on the fibre. Clamp the fibre in place if fibres are held separately. Some splicers clamp both fibres at once. Repeat these steps for the second fibre.

You can optimize the loss of a mechanical splice visually using a visual fault locator, a visible laser test source if the fibre ends being spliced are visible. Gently withdraw one of the fibres a slight amount, rotating it slightly and reinserting it until the visible light is minimized, indicating lowest loss.

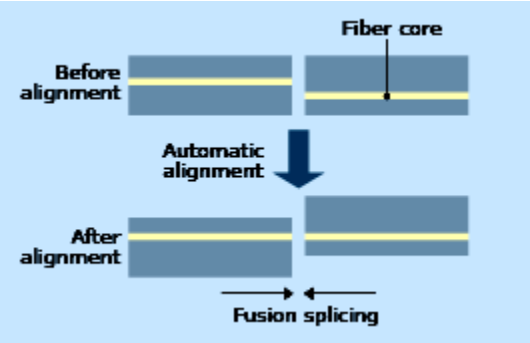
7.2 Fusion Splicing

Fusion splicing involves the melting and jointing of optical fibres using heat generated by an electric arc between electrodes. Fusion splicing is classified into the two methods, as follows.

i. Core Alignment Method

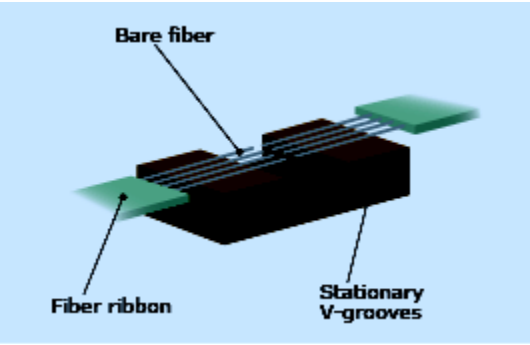
Optical fibre cores observed with a microscope are positioned with the help of image processing so that they are concentrically aligned. Then, an electric arc is applied to the fibre cores. The fusion splicer used has cameras for observation and positioning in two directions.

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ii. Stationary V-groove Alignment Method

This fusion splicing method uses V-grooves produced with high precision to position and orient optical fibres and utilizes the surface tension of melted optical fibres for alignment effects (cladding alignment). Splices made by this method achieve low loss, which has improved the dimensional accuracy regarding the placement of core. This method is primarily used for splicing a multi-fibre cable in a single action.



Optical fibre cable fusion splicing provides the lowest insertion loss less than 0.1dB. Special equipment called fusion splicer is used for it. The fusion splicer performs optical fibre fusion splicing in two steps.

- Precisely align the two fibres
- Generate a small electric arc to melt the fibres and weld them together

Fusion splicing is perform by Fusion splicer, a machine used to weld (fuse) two optical fibres together. The fibre ends are prepared, cleaved,

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and placed in alignment fixtures on the fusion splicer. At the press of a button, the fibre ends are heated with electrodes, brought together, and fused. We can preset the splicing parameters or choose factory recommended settings that will control the splicing process itself. Each manufacturer's product is slightly different and requires somewhat different procedures. A photograph of typical splicer is shown below:



7.2.1 Preparation of cable for jointing

- During the installation, a minimum of 10 meter of cable at each end is coiled in the jointing pit to provide for jointing to be carried out at convenient location as well as spare length to be available for future use in case of failures.
- The pit size shall be so as to ensure the length of the wall on which joint is mounted is greater than closure length plus twice the minimum bending radius of the cable. A pit length of 1 meter is sufficient for most of the cable and joint closures. Bracket to support eh cable coil are also fixed on the wall of the pit. Details of cable pit are given in Drawing No.RDSO/TCDO/COP-21.
- The cable is then coiled on to the pit wall in the same position as required after the joint is complete. The marking is done on all the loops so that it will be easier to install it later.

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- The distance from the last centre to the end of the cable must be at least 1.8 meters. This is the minimum length to be stripped for preparation of joint.
- Sufficient cable length at both ends up to the jointing vehicle/enclosure is then uncoiled from the pit for jointing.

7.2.2 Stripping/Cutting of the Cable

- The cable is stripped of outer and inner sheath with each sheath staggered approximately 10mm from the one above it.

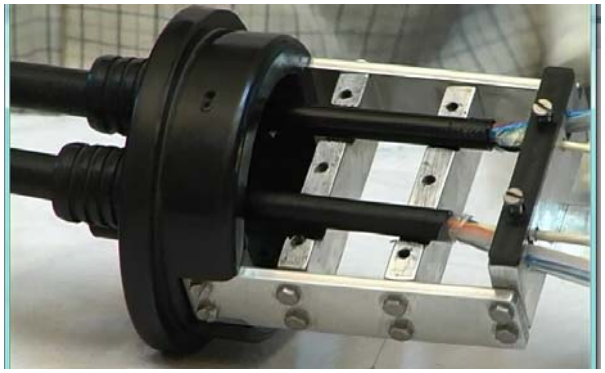


- Proper care must be taken when removing the inner sheath to ensure that the fibres are not scratched or cut with the stripping knife or tool. To prevent this, it is better to score the inner sheath twice on opposite sides of the cable, rather than cutting completely through it. The two scores marking on either side of the cable can be easily stripped of the inner sheath by hand.

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- The fibres shall be then removed from cable one by one and each fibre is cleaned individually using kerosene oil to remove the jelly.
- Armouring shall remain outside the gland and will not be connected through.



7.2.3 Preparation of Cable Joint Closure for Splicing

- The type of preparation work performed on the cable prior to splicing differs on the type of joint closure and fibre organizer used. However, the following steps shall be usually common for different types of joint closure.

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(a) The strength member of each cable shall be joined to each other and/or the central frame of the joint closure.
(b) The joint closure shall be assembled around the cable.
(c) The sealing compound or heat shrink sleeve shall be applied to the cables and closure, or prepared for application after splicing is complete.
(d) Tags which identify the fibres number shall be attached at suitable location on the fibres.
(e) Splice protectors shall be slipped over each fibre in readiness for placing over the bare fibre after splicing.

7.2.4 Stripping and Cleaving of Fibre

- (a) Prior to splicing, primary protective coating of each fibre shall be stripped off up to length of 50 mm. by using fibre stripper. Fibre strippers shall be manufactured to fine tolerances and only score the coating without contacting the glass fibre.
-



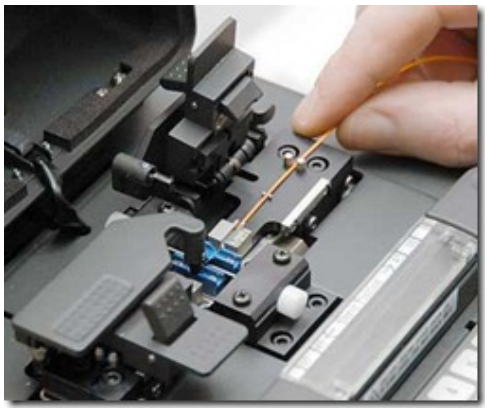
Click for Contents

- The bare fibre shall be then wiped with a lint tissue paper rinsed with ethyl alcohol.
- Cleaving of the fibre shall then be performed to obtain as close as possible to a perfect 90 degree face on the fibre.

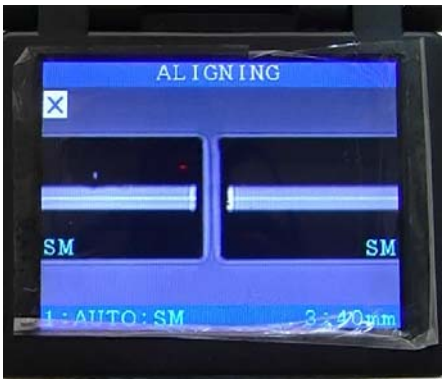


7.2.5 Fusion splicing of fibre

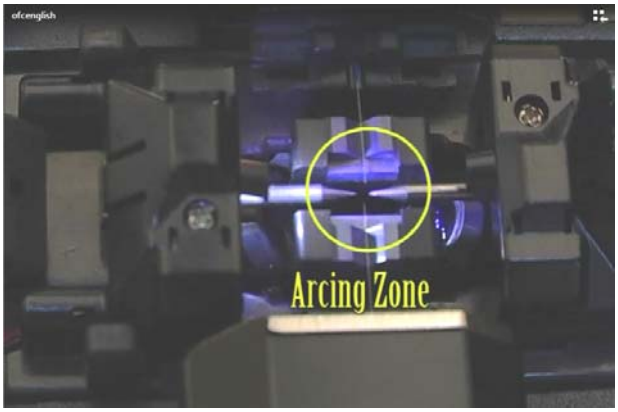
- Some of the general steps with full automatic micro processor control splicing machines shall be as under:
- (a) Hands shall be thoroughly washed prior to commencing this procedure.
- (b) The clean bare fibre shall be dipped in the beaker of ethyl alcohol of the ultrasonic cleaver and ultrasonic clever switched on for 5-10 seconds.
- (c) The bare fibre shall then be placed inside ‘V’ groove of the splicing machine by opening clamp handle, in such a way so that 1 mm gap is available between the electrodes and the end of fibre being spliced and heat shrink protector inserted.



- (d) The same procedure shall be repeated for other fibre.
- (e) The start button on the splice controller shall be pressed.
- (f) The machine shall pre-fuse set align both in ‘X’ and ‘Y’ direction and then finally fuse the fibre.



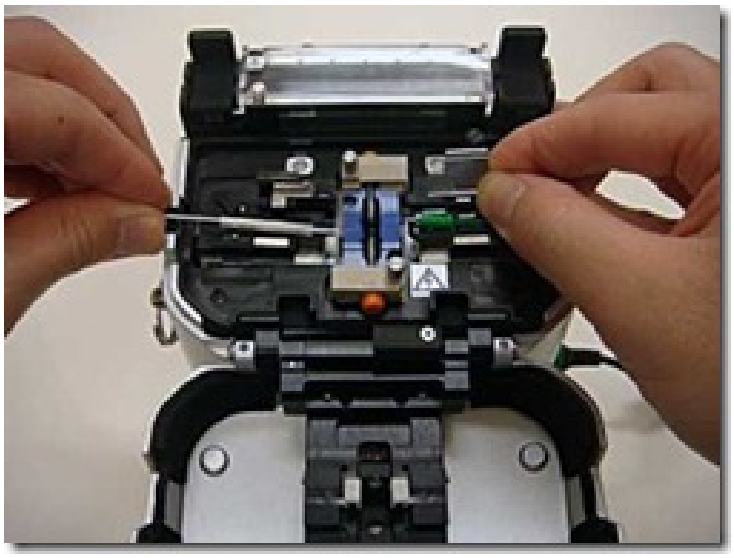




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- (g) The splice shall be inspected on monitor provide on the fusion splicing machine, there shall be no nicking, bulging and cores are adequately aligned. The above procedure shall be repeated if the splice is not visually good looking.

- (h) The heat shrink protector shall be slid over the splice and tube shall be placed in tube heater. Heating shall be considered complete when soft inner layer is seen to be 'oozing' out of the outer layer of the protector.



- (i) The steps a) to (h) above shall be repeated for other fibres.

7.3 Organising fibre and finishing joints

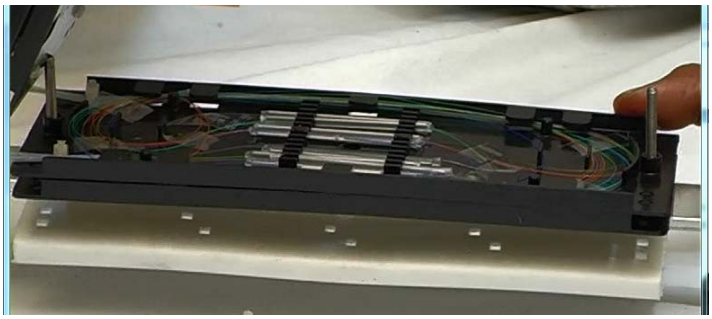
- (a) After each fibre has been spliced, the heat shrink protection sleeve shall be slipped over the bare fibre before any handling of fibre takes place as uncoated fibres are very brittle and cannot withstand small radius bends without breaking.

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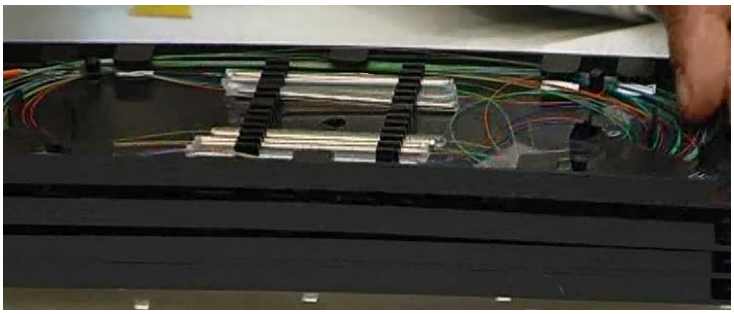


- (b) The fibre shall then be organized into its tray by coiling the fibres on east side of the protection sleeve using the full tray side to ensure the maximum radius possible for fibre coils.
- (c) The tray then shall be placed in the position.





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- (d) OTDR reading shall be taken for all splices in this organized state and recorded on the test sheet to confirm that of all fibres attenuation is within specified limits. The OTDR test confirms that fibres were not subjected to excessive stress during the organizing process. Care should be taken that the fibres are not interchanged while jointing.
- (e) The joint shall then be closed with necessary sealing etc. and considered ready for placement in the pit.



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7.4 Placing of completed joint in pit

- (a) Joint shall be taken out from the vehicle and placed on the tarpaulin provided near the pit.
- (b) The cable is laid on the ground and looped according to the marking done in the beginning. These loops shall then be tied together with the tape.
- (c) The joint shall be permanently closed and sealed by heating heat shrinkable sleeve, etc.
- (d) The joint closure shall be fixed to the bracket on the pit wall and pit closed.



7.5 Some guidelines for splicers are given below.

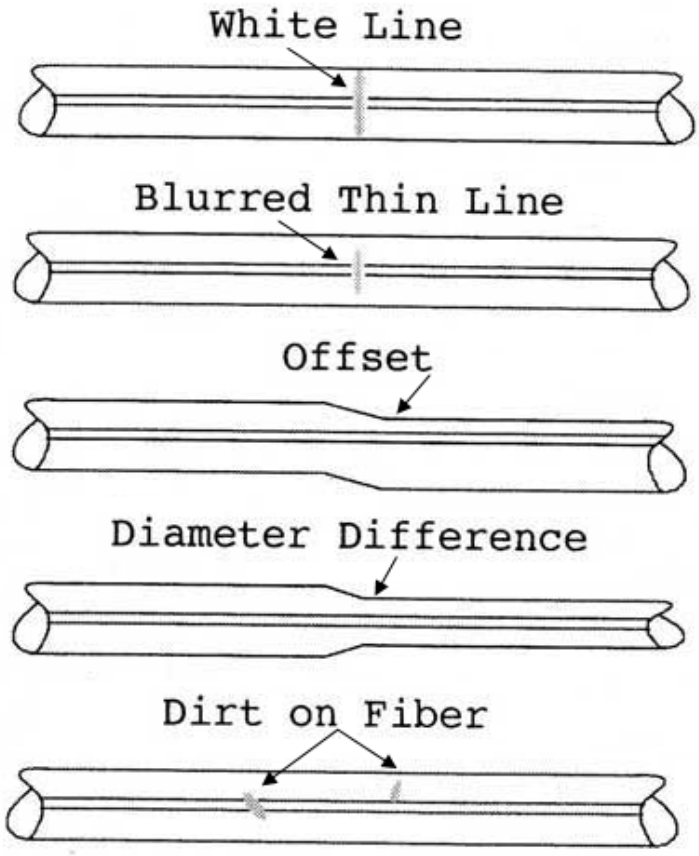
- Follow the applicable equipment manufacturer's guidelines through operating manual for setup and maintenance of all splice equipment. Besides cleaning regularly, they require electrode alignment and occasional replacement.
- Maintain clean equipment and a clean splice environment, being especially wary of windy and/or dusty conditions.
- Splice loss specifications should be set with the total link power budget in mind and be based on average splice loss.

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8. Testing of Splicing

8.1 Good Splicing

Visually inspect the splice after the program has run, using both X and Y views. Some flaws that do not affect optical transmission are acceptable, as shown below. Some fibres (e.g. fluorine-doped or titanium coated) may cause white or black lines in splice region that are not faults. Some graphics of a typical splicer “Sumitomo” manual are given below.

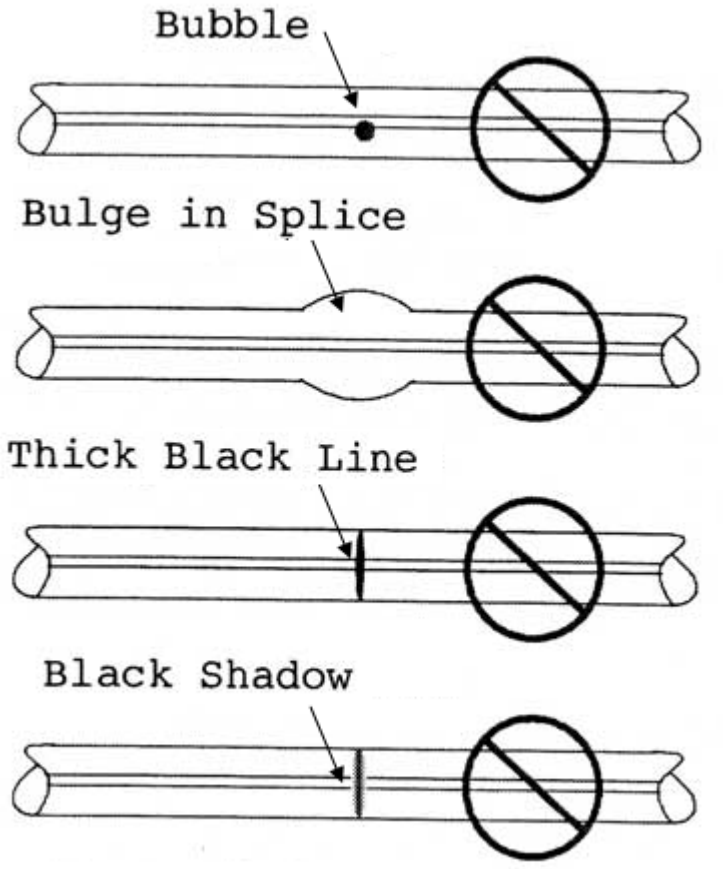


Fusion splices provide a high-quality joint with the lowest loss (in the range of 0.01 dB to 0.10 dB for single-mode fibres) and are practically non- reflective.

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8.2 Bad Splicing

Some flaws are unacceptable and require starting the splicing process over. Some, like black spots or lines, can be improved by repeating the ARC step, but never more than twice. For large core offsets, bubbles or bulging splices, always redo. Some graphics of a typical splicer "Sumitomo" manual are given below.

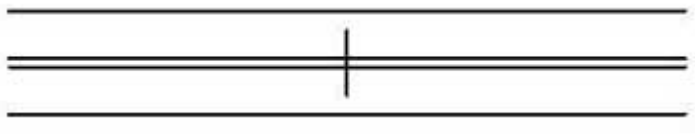


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9. Splice Problem Troubleshooting

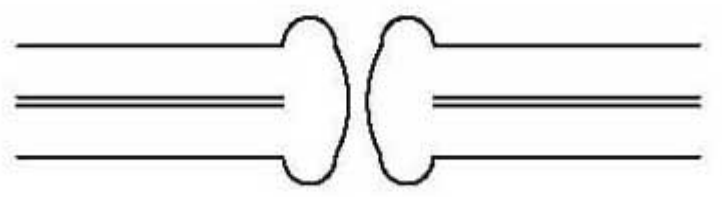
Here are some common problems and likely causes.

1. Not Fused Through



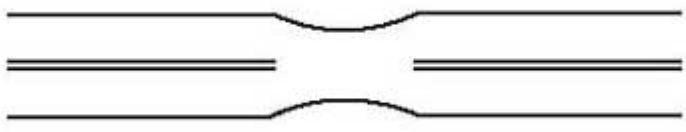
Reasons: Fusion current too low, Prefusion time too short

2. Match heads



Reasons: Contaminated electrodes, Fusion current much too high refusion time much too long, Prefusion current much too high, Autofeed too small, Gap too large.

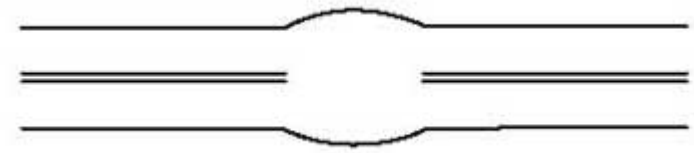
3. Constriction



Reasons: Current too high, Feed rate too slow, Prefusion time too long, Prefusion current too high, Gap too wide, Contaminated electrodes.

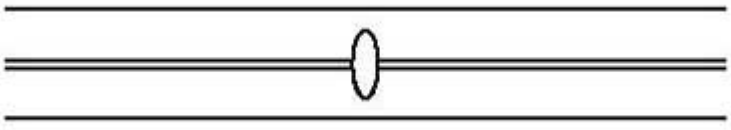
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4. Enlargement



Reasons : Auto feed too fast, Incorrect current

5. Bubble or Inclusion



Reasons : Contaminated fibre end faces, Poor cleave, Fusion current too high, Prefusion current or time too low.

6. Additional Problems

Fusion splicers generally have stored programs for most fibres and the user can modify 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 fibre you are installing.

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

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10. Maintenance schedule for fibre optic system equipment

Equipment	Item	Maintainer	Sectional Supervisor	Supervisor Incharge
Power Supply Equipment	Maintenance of Batteries	Weekly	Monthly	Quarterly
	Meas. of Battery voltages	Weekly	Monthly	Quarterly
	Maintenance of Charger and In/Out voltages and Currents	Weekly	Monthly	Quarterly
	Checking of fuses and terminations	Weekly	Monthly	Quarterly
	Check of Earthing	Weekly	Monthly	Quarterly
General	Cleaning of the flooring	weekly	--	--
	Removal of dust from the equipment and cards	weekly	--	--
	Measurement of room temperature	weekly	--	--
	Earthing of the racks, power equipment etc.	Weekly	Monthly	Quarterly
	Measurement of earth resistance	--	Quarterly	Quarterly
	Check of electrical devices	weekly	Monthly	Quarterly
	Maintenance of pigtails, fibre distribution frame	weekly	Monthly	Quarterly
Optical	OTDR	--	Quarterly	--

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Equipment	Item	Maintainer	Sectional Supervisor	Supervisor Incharge
Fibre Cable	Measurement of spare fibres			
Cable Route	Integrity of cable route	Fortnightly	Quarterly	Yearly
	Protective works on bridges & culverts	Fortnightly	Quarterly	Yearly
	Cable route markers	Fortnightly	Quarterly	Yearly
	Cable sheath Earthing	Fortnightly	Quarterly	Yearly
Periodical Line Up	OTDR meas. on all Fibre	--	--	Yearly
	Tx/Rx optical power	--	--	Yearly
	Pulse mask for all digital interfaces	--	Quarterly	Yearly
	Channel meas. as per CCITT	--	Quarterly	Yearly
	G821/G823 tests on 64KBPS/2MBPS for 10 days	--	Quarterly	Yearly
	Loss measurement with optical source & power meter	--	Quarterly	Yearly
	Measurement of Order wire performance circuits.	--	Quarterly	Yearly

Note :

1. Items related to cable gang shall be done by cable maintenance Gang.
2. Items related to equipment shall be done by equipment maintenance gang.

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11. T&P Items and Measuring Equipments for Maintenance Staff

Sr. No.	GANG	Recommended T&P Items & Equipments
1.	**Equipment Maintenance**	• Soldering Iron • Vacuum Cleaner • Standard Tool Kit containing Screw Drivers, etc. • Digital Multi-meter • Optical Fibre connector Cleaning kit
2.	**Sectional Supervisor Equipment**	• All equipments as prescribed for eqpt maint gang. • Portable BER & PCM Test Set • Meager • Optical Attenuation Measurement set consisting of optical power meter, optical source and optical attenuator
3.	**Supervisory Incharge for equipments**	• Test and Repair Van • PCM Transmission Analyzer • PCM Channel Analyzer along • Digital Storage Oscilloscope • Frequency Counter • Fibre Optic tool kit • Mini portable Generator • SDH analyzer
4.	**Sectional Engineer Cable Maintenance**	• Digital Multi-meter\ • Mini ODTR • Mechanical splicing kit • Ruggedised Optical Fibre cable 200 Mts • Splicing machine with battery • Fibre Optic Tool Kit • All types of Adopters & Connectors • Fibre Optic Talk set • Insulation Tester • TMS kit
5.	**HQ gang for cable**	• 200 Mtr of OFC cable

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Sr. No.	GANG	Recommended T&P Items & Equipments
		• Test & Repair van • Portable generator • Automatic Fusion Splicing machine • OTDR • Fibre Optic Tool Kit • Mechanical Splicing kit • Optical Talk set • All types of Adopters & Connectors. • Lighting arrangements & emergency lamps(2Nos) • Emergency phones (4 Nos) • Walkie-Talkie sets (4 Nos) • Torches with batteries (6 sets) • Spare batteries for splicing machines (1No) • Puncha (to remove ballast) (2 Nos) • Pickaxe (4 Nos) • Motar pan & showel (4 Nos) • Spade (4 Nos) • Portable tent (1 No) • Crow bar (2 Nos) • OFC spare cables (cables of adequate length) • HDPE pipe pieces (10 Nos) • Drinking water can (20 litres) (1 No) • Glasses (2 Nos) • Folding table and chair (1 each) • Stool light weight (2 Nos) • First aid box (1 No)

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12 Safety

When working with fibre there are a few rules that MUST always be remembered and practiced.

Safety Glasses

- **Safety glasses MUST be worn** at all times during the fibre optic lab exercises or anytime termination or splicing work is performed on a fibre cable. The biggest hazard when working with fibre optics are small and sharp shards of the fibre produced when stripping or cleaving the cable.

Glass Fibre Shards

- Be very careful when disposing of fibre ends. Use a Disposable Fibre Trash Bin (Fibre Disposal Unit FDU) to hold small bits of glass until they can properly disposed of in the trash. For safety, remember to cover the holes on top of the FDU before storing your bin (unit) in your tool kits (box).
- If you don't have a FDU to use when working in some environments, then carefully make a container, like a half empty water bottle or soda can, before using. This helps to prevent accidents.
- The glass fibre creates slivers or shards that can easily cause injury to the eyes or create glass splinters in fingers or hands that are difficult to see to remove from skin, which can become infected if not completely removed. Always keep a disposable fibre trash bin nearby for all fibre scraps. Develop the habit of picking up scraps from the work surface and the floor too. You may know a glass shard is dropped or lost and can take care, but another person like a co-worker or cleaning crew may come along and not be aware that fibre was being worked in the area.
- Scotch tape can be used to pick up small shards of fibre. Fold the scotch tape around the glass shards before disposing in the trash can. This helps to keep others, like members of the cleaning crew, from becoming hurt accidentally.

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Black Paper

- Black paper or other dark colored paper or fabric can be used to give a dark colored work surface. This helps make the fibre more visible when working with it.

Chemicals

- When doing fibre work epoxy, anaerobic adhesive, and isopropyl alcohol will be used. The isopropyl alcohol is flammable. Take extra care when handling these substances. It is best to develop the habit of watching for bits of epoxy on your tools or work surface and cleaning it with the alcohol. Develop the habit of wiping all tools frequently with a fibre free cloth or wipe and alcohol. Keep in mind that epoxy is not removable from clothing.

Skin Oils

- Do not touch bare fibres with fingers. The oil from your skin can weaken the fibre over time. It tends to make the glass fibre brittle.

Hot ovens & terminators

- Terminators removed from the curing ovens will be EXTREMELY HOT. Use caution when touching hot terminators. Small amounts of alcohol on a fibre free wipe may be used to help cool the terminator more quickly. After the terminator is removed from the oven, the exposed fibre is dangerous and more brittle. Take great care to ensure the glass rod does not break, pierce the skin, or get into the eyes.

General Precautions

- How to handle optical fibre.
- When the fibre is not handled properly – stress as torsion, bend, tension etc.
- Lorry with air cond. If dust is presence in the splicing – loss will increase.
- Cutting OFC – do not use a metallic saw, use a cable cutter.
- Keep your hand clean.

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13. Connectors

An **optical fibre connector** terminates the end of an optical fibre, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibres so light can pass. Better connectors have very little light lose due to reflection or misalignment of the fibres.

Optical fibre connectors are used to join optical fibres where a connect/disconnect capability is required. The basic connector unit is a connector assembly. A connector assembly consists of an adapter and two connector plugs. Optical fibre connectors are used to connect equipment and cables, or to cross-connect cables.

Most optical fibre connectors are spring-loaded, so the fibre faces are pressed together when the connectors are mated. The resulting glass-to-glass or plastic-to-plastic contact eliminates signal losses that would be caused by an air gap between the joined fibres.

Every fibre connection has two values:

- Attenuation or insertion loss
- Reflection or return loss.

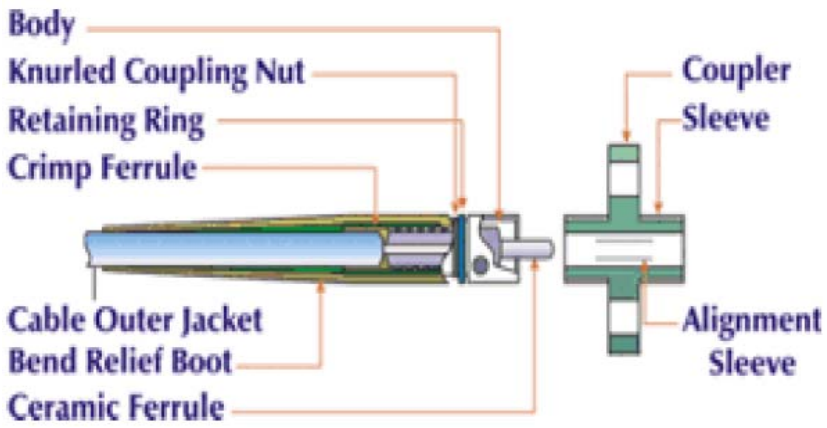
A variety of optical fibre connectors are available, but SC and LC connectors are the most common types of connectors. Typical connectors are rated for 500–1000 mating cycles. The main differences among connectors are dimensions and methods of mechanical coupling. Different connectors are required for multimode, and for single-mode fibres.

Features of good connector design:

- Low insertion loss
- High return loss (*low* amounts of reflection at the interface)
- Ease of installation
- Low cost
- Reliability
- Low environmental sensitivity
- Ease of use

Typical connector is shown in figure given below:

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13.1 Parts of connector and their description

i. Ferrule

The fibre is mounted in a long, thin cylinder, the ferrule, which acts as a fibre alignment mechanism. The ferrule is bored through the centre at a diameter that is slightly larger than the diameter of the fibre cladding. The end of the fibre is located at the end of the ferrule. Ferrules are typically made of metal or ceramic, but they may also be constructed of plastic.

ii. Connector Body

Also called the connector housing, the connector body holds the ferrule. It is usually constructed of metal or plastic and includes one or more assembled pieces which hold the fibre in place. The details of these connector body assemblies vary among connectors, but bonding and/or crimping is commonly used to attach strength members and cable jackets to the connector body. The ferrule extends past the connector body to slip into the coupling device.

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iii. Cable

Cable is attached to the connector body. It acts as the point of entry for the fibre. Typically, a strain-relief boot is added over the junction between the cable & the connector body, providing extra strength.

iv. Coupling Device

Most fibre optic connectors do not use the male-female configuration common to electronic connectors. Instead, a coupling device such as an alignment sleeve is used to mate the connectors. Similar devices may be installed in transmitters & receivers to allow these devices to be mated via a connector. These devices are also known as feed through bulkhead adapters.

13.2 Characteristics of connectors

Parameter	Description
Insertion loss	• Loss due to use of connector (unavoidable) • Manufacturers specify typical value • Use of strain relief boot over the junction between the cable & connector body and attaching strength member to the connector minimize the insertion loss
Repeatability (loss)	Connector is re-useable (up to 500 times). The increase in loss shall be less than the repeatability loss
Suitability	Suitable to SM / MM fibre
Return loss	Important factor for SM fibres (shall be less than 60 db)

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13.3 Connector Type

a. FC Connector

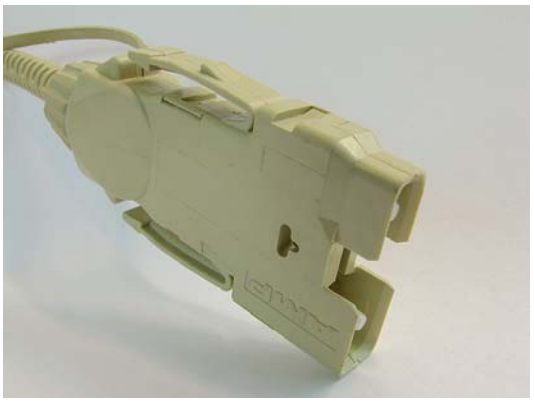
FC/PC is one of the most popular single mode connectors. It screws on firmly, but make sure you have the key aligned in the slot properly before tightening. It's being replaced by SCs and LCs.





Insertion loss	Repeat-ability	Fibre type	Application
0.5 to 1.0 db	0.20 db	SM / MM	Transmission NW

b. FDDI Connector (Fibre Distributed Data Interface)



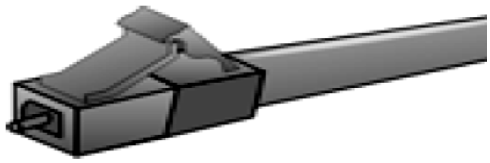
Insertion loss	Repeatability	Fibre type	Application
0.2 to 0.7 db	0.20 db	SM / MM	FDDI LAN

c. LC Connector

LC is a new connector that uses a 1.25 mm ferrule, half the size of the ST. Otherwise, it's a standard ceramic ferrule connector, easily

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terminated with any adhesive, good performance, highly favored for single mode.

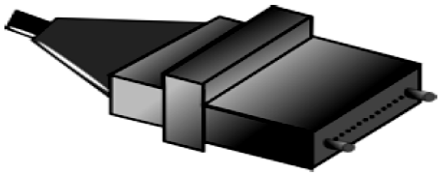




Insertion loss	Repeat-ability	Fibre type	Application
0.15 db (SM) 0.10 db (MM)	0.20 db	SM / MM	High density interconnection

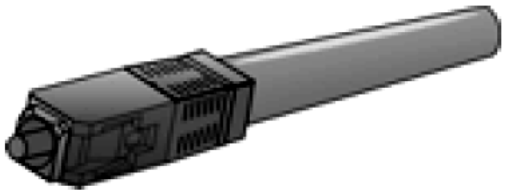
MT RJ Connector





Insertion loss	Repeatability	Fibre type	Application
0.3 to 1.0 db	0.25 db	SM / MM	Ribbon fibre **cables**

SC Connector

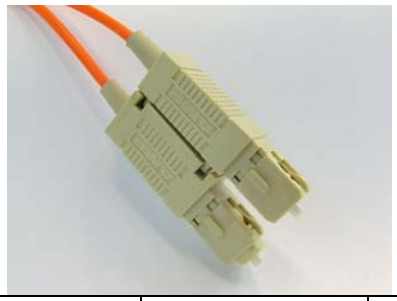


Insertion loss	Repeat-ability	Fibre type	Application
0.2 to 0.45 db	0.10 db	SM / MM	Transmission **NW**

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f. SC Duplex Connector

SC is a snap-in connector that is widely used in single mode systems for it's excellent performance. It's a snap-in connector that latches with a simple push-pull motion. It is also available in a duplex configuration.



Insertion loss	Repeatability	Fibre type	Application
0.2 to .45 db	0.10 db	SM/ MM	Transmission NW

g. ST Connector

ST is the most popular connector for multimode networks. It has a bayonet mount and a long cylindrical ferrule to hold the fibre. Most ferrules are ceramic, but some are metal or plastic. And because they are spring-loaded, you have to make sure they are seated properly. If you have high loss, reconnect them to see if it makes a difference.

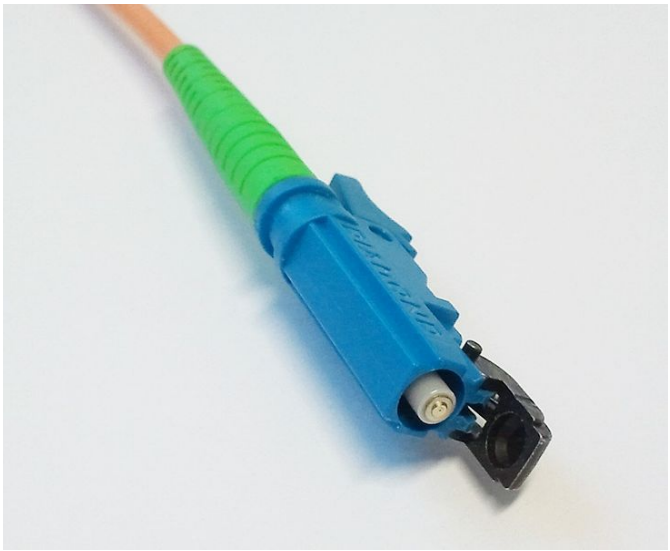


Insertion loss	Repeatability	Fibre type	Application
0.4db (SM) 0.5db (MM)	0.4db (SM) 0.2db(MM)	SM / MM	Inter/Intra Building

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h. E-2000 Connector

E2000 connector exceeds all standards for performance and operation. The E2000 features a latch lever locking mechanism to prevent accidental disconnection. With the power of today's laser transmitters reaching levels that are a danger to an unprotected user, the E2000 offers a level of protection no other connector can match. Each E2000 connector and adapter has its own shutter that automatically opens and closes as the connector slides into its adapter.



Connector Type	Polishing	Insertion Loss	Cable
SM	PC/UPC	0.12/0.25	3.5
SM	APC APC	0.12/0.25	3.5
MM	PC	0.2/0.5	3.5

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13.4 Steps in attaching connectors to fibre

1. Cut the cable one inch longer than the required finished length.
2. Carefully strip the outer jacket of the fibre with “no nick” fibre strippers. Cut the exposed strength members, and remove the fibre coating. The fibre coating may be removed two ways: by soaking the fibre for two minutes in paint thinner and wiping the fibre clean with a soft, lint-free cloth, or by carefully stripping the fibre with a fibre stripper. Be sure to use strippers made specifically for use with fibre rather than metal wire strippers as damage can occur, weakening the fibre.
3. Thoroughly clean the bared fibre with isopropyl alcohol poured onto a soft, lint-free cloth such. NEVER clean the fibre with a dry tissue. Note: Use only industrial grade 99% pure isopropyl alcohol.
4. The connector may be connected by applying epoxy or by crimping. If using epoxy, fill the connector with enough epoxy to allow a small bead of epoxy to form at the tip of the connector. Insert the clean, stripped fibre into the connector. Cure the epoxy according to the instructions provided by the epoxy manufacturer.
5. Anchor the cable strength members to the connector body. This prevents direct stress on the fibre. Slide the back end of the connector into place (where applicable).
6. Prepare the fibre face to achieve a good optical finish by cleaving and polishing the fibre end. Before the connection is made, the end of each fibre must have a smooth finish that is free of defects such as hackles, lips, and fractures. These defects, as well as other impurities and dirt change the geometrical propagation patterns of light and cause scattering.

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14. Precautions

- Don’t handle the bare fibre with bare hands, always use hand gloves.



- Don’t cleave the fibre without removing the primary coating otherwise the diamond edge of the cleaver is damaged.



- Don’ts use the bare fibre without cleaning properly for splicing

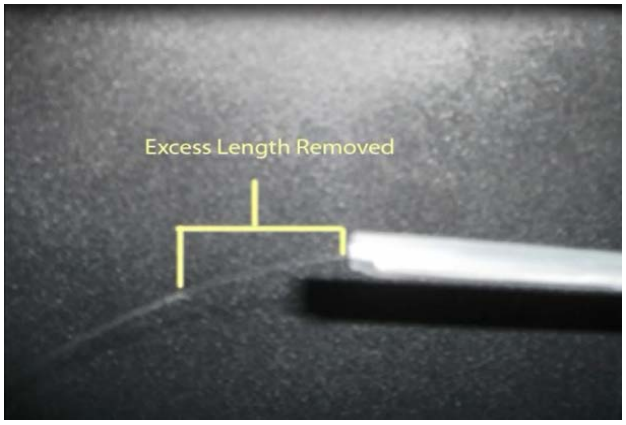


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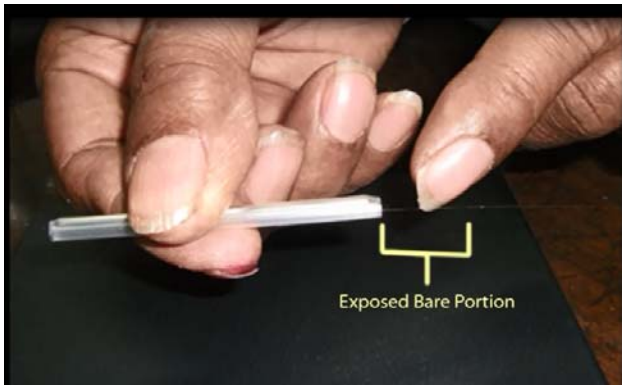
- Don’t clean the bare fibre after cleaving



- Don’t remove excessive length of primary coating beyond the dimensions of the sleeve.

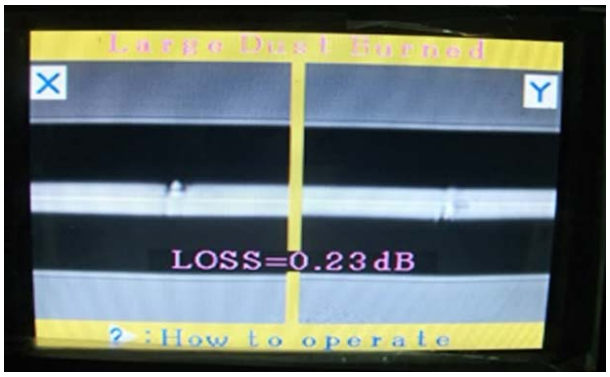


- Don’t expose the bare portion of the fibre outside the sleeve while enclosing the joint inside the sleeve.

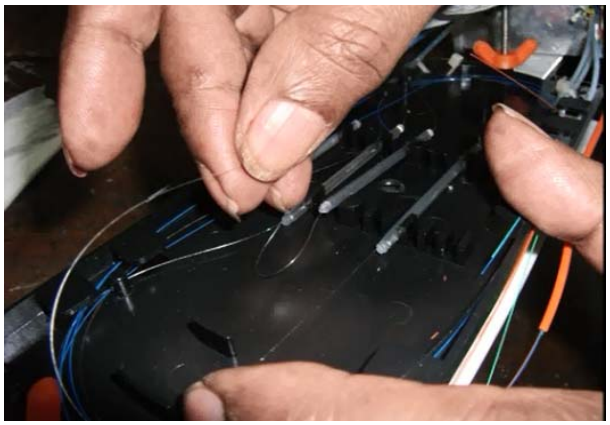


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- Don’t use the spliced fibre with heavy splice loss (more than .08dB) for communication.



- Don’t allow any sharp bends on the fibre while organising the fibre in the splicing tray.



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