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TMM P021

OPTIC FIBRE CABLE JOINING, TERMINATION & MANAGEMENT

Version 9.0

Issued August 2011

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Engineering Manual

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Document control

Version	Date	Summary of change
9.0	22 August 2011	

Summary of changes from previous version

Summary of change	Section

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1 Purpose

The purpose of this document is to provide a clear set of procedures for the installation and maintenance of RailCorp fibre cable and fibre termination equipment in the rail corridor. Fibre jointing and cable management procedures are also detailed.

2 Terms and definitions

Bend Radius the radius that cables can bend before the risk of damage or decrease in transmission performance.

Butt Joint also called a Straight Joint: a joint between two fibre cables, all fibres from one cable jointing through to the corresponding fibres of the other, to form a continuous circuit.

Cladding the material that surrounds the core of an optical fibre that has a lower refractive index than the core and ensures the internal refraction on which propagation of the optical signal depends (normal diameter of 125μm)

Connector a mechanical device used to provide a means for aligning, attaching and achieving continuity between conductors or fibres.

Core the centre, light guiding part of an optical fibre.

Design Approval the RailCorp officer with authority to approve designs as defined in TMM

Authority C001: Delegations and Descriptions.

Express Joint a spur joint that is introduced into a length of cable where most of the tubes in that cable pass through the joint enclosure unbroken and are stored within the enclosure. Only the tube(s) containing fibre to be access are cut and these fibres are spliced to the spur cable.

Fibre a single element of an optic fibre cable containing core, cladding & Primary coatings

LASER Light Amplification by Stimulated Emission of Radiation is a device that produces coherent light with a narrow range of wavelengths.

LEAF a Corning brand of non-zero dispersion shifted fibre manufactured to ITU-T Recommendation G655

Loss attenuation of an optical signal measured in dB.

Patch cord a length of optical fibre terminated with connectors on both ends.

Pigtail a length of fibre terminated with a connector on one end only. Used to facilitate jointing between that component and another optical fibre or component.

Primary Coating a thin outer cladding of an optical fibre to protect from contamination and abrasion.

Sheath Segment a length of cable between two conjunctions (joints, spurs and or terminations) where the sheath is continuous. Each sheath segment will have a unique identification number.

Slot a groove moulded into a plastic former in which fibres are housed.

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SMF28 a Corning brand of fibre optimized at 1310nm and manufactured to ITU-T Recommendation G652.

Strength member(s) part of an optical fibre cable construction that takes the strain and ensures that no strain is imposed on the fibres.

Spur Cable a cable that taps services from a main cable that passes a location to provide services to that location.

Spur Joint a complex joint between 3 or more cables. Two main large capacity cables and at least one smaller capacity cable which taps off fibres to feed services to a site such as a Railway Station, Signal Box or a substation.

Straight Joint also called a Butt Joint. Joint between two fibre cables, all fibres from one cable jointing through to the corresponding fibres of the other, to form a continuous circuit.

Tube a hard plastic cylindrical container integrated into the cable construction to contain and protect the fibres. A tube can contain up to 12 fibres. Cables usually have multiple tubes and these are colour coded to enable the identification of fibres contained within them.

Unit a unit is a group of fibres that are separated from other fibres by some means for fibre identification and for cable construction. A tube and a slot are examples of a unit.

C&CS Communication & Control Systems Division (RailCorp – Asset Operations))

CMP Configuration Management Plan (Communications)

OTDR Optical Time Domain Reflectometer

NZDS Non-zero dispersion-shifted

SMOF Single Mode Optical Fibre

3 Reference documents

ESM 102 Communications Outdoor Cabling Standard

SPM 0126 Pre-terminated Fibre Tails and Link Cables

SPM 0677 Single Mode Optical Fibre Cable Specification

SPM 1178 Single Mode Optical Fibre Termination, Patching and Management Equipment Specification

SPM 1179 Single Mode Optical Fibre Jointing Equipment Specification

STM 0073 Network Configuration Requirement Specification

MET-OT0042 Mounting of Pit ID Tags for Half & Full Size Pits Arrangement

MET-OT0043 Pit ID Tag Arrangement

SWMS SMS-06-SW-0884 Splicing Fibre Optic Cable (Terminate/Joint) Safe Work Method Statement

AS/ACIF S008 Requirements for Authorised Cabling Products

AS/ACIF S009 Installation Requirements for Customer Cabling (Wiring Rules)

AS/NZS 2211.1 Safety of laser products - Equipment classification, requirements and user's guide

AS/NZS 2211.2 Safety of laser products - Safety of optical fibre communication systems (OFCS)

AS/NZS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules)

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AS/NZS 3080 Telecommunications installations-Integrated telecommunications cabling system for commercial premises

AS 3084 Telecommunications installations-Telecommunications pathways and spaces for commercial buildings

AS/NZS 3085.1 Telecommunications installations-Administration of communications cabling systems Part 1: Basic requirements

AS/NZS ISO/IEC 24702 Telecommunications installations – Generic cabling – Industrial premises

HB 243 Communications Cabling Manual Module 1 - Australian regulatory arrangements

HB 29Communications Cabling Manual Module 2 - Communications cabling handbook

ITU-T Rec. G652 Characteristics of single-mode optic fibre & cable

ITU-T Rec. G655 Characteristics of non-zero dispersion-shifted single-mode optic fibre & cable

ITU-T Rec. G657 Characteristics of a bending loss insensitive single-mode optic fibre & cable for the access network

4 Change management process

4.1 General

The RailCorp C&CS Services & Support group provide configuration management for the RailCorp telecommunications cable network.

4.2 Cable, Sheath and Joint Identification

C&CS Services & Support will provide cable joint and sheath segment identification numbers for each new joint and length of cable installed within the rail corridor. The project manager / works coordinator shall label each joint and the cables at each joint and at each termination. The cable labelling shall be in accordance with Appendix B.

Where new cables are installed, where existing cables are relocated or removed or where new joints are introduced, the project manager / works coordinator shall report and provide as built documentation to the C&CS Services & Support group, in accordance with the relevant provisions of the Communications Configuration Management Plan (CMP). This shall apply whether the works are initiated by design or by restoration action.

Similarly, the introduction, variation or removal of any services over the fibre cable shall be in accordance with the CMP.

4.3 Pit identification

The project manager / works coordinator shall label each pit with stainless steel identification tags. (See *MET-OT0043B*) The mounting of the identification tags shall be in accordance with *MET-OT0042A*.

Once labelled the project manager / works coordinator shall report and provide the pit numbering details to the C&CS Services & Support group.

Numbered stainless steel identification tags are available from the C&CS Senior Specialist Engineer (Cables).

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5 Training

Only competent, fully trained personnel shall carry out preparation and splicing of the optical fibre cable.

6 Cable management

6.1 General

Prior to the purchase & installation of any fibre cable a complete cable running schedule shall be presented to the RailCorp Design Approval Authority for approval. The cable running schedule will include the expected length of each cable run, the location of any proposed joints and the location of slack storage pits.

6.2 Location of joints

Unless special authority is given by the Design Approval Authority, joints shall be located such that the operations of trains will not interfere with access to the joint at any time, and, as such the following shall apply:

- The distance between nearest edge of a jointing pits and the running edge of the track shall be not less than four (4) metres.
- Joints shall not be made in tunnels
- Joints shall not be made in areas where 24 hour a day, 7-day a week access cannot be achieved.

6.2.1 Placement of joints

Joints shall not be placed any closer than 250m from a fibre termination.

In a new installation, joints shall be placed as far apart as possible taking in to consideration the terrain and the service requirements. Where there are relocations or rearrangements, joints shall not be placed any closer than 250m (track kms) from each other and the average distance between joints in any 5000 metre section (track kms) shall not be less than 1000m. This does not include express joints.

6.2.2 Emergency and temporary location of joints

Emergency and temporary location of joints that do not comply with these requirements shall be followed up as soon as practicable with restoration works that do comply.

6.3 Location of joint enclosures in pits

Coils should be stored vertically against the side of the pit leaving sufficient room for persons to enter the pit without having to climb over the cable. Joint enclosures shall be mounted horizontally near the top of the pit on suitable purpose built brackets.

6.4 Slack storage at a joint

At each joint, a minimum of 10 metres of excess cable (slack) shall be provided for each cable entering the joint enclosure. This is so the joint may be serviced outside the cable pit well away from the track. It also enables the capability of alteration to the configuration of the cable in the future.

In the provisioning of the slack, cable installers should note that most joint enclosures require around 2 metres of cable to be stripped back in preparation for jointing within the

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enclosure. There for it is recommended that between 20 to 30 metres of excess cable be provided for each of the cables being jointed.

6.5 Slack Pits

A pit shall be installed at approximately every 1000m for the storage of cable loops (slack). This extra length provides for a new joint should repairs be required or for the provision of a new service in a location between established joints. The extra cable can be pulled back from a slack pit so that only one new joint is required.

Slack pits shall contain between 40 and 60 metres of excess cable. The cable shall be coiled in a way to prevent twists and so that should the cable be removed from the pit and laid out on the ground as straight as possible there would be no torsion on the cable.

6.6 Coiling of slack

The cable shall be coiled such that all cables entering the joint are parallel to each other and coiled neatly together. It is preferred, for the first 5 metres from the enclosure that these cables are bundled together loosely with either cable ties or insulation tape before they are coiled. (Tying the cables tight will only strain the interface to the enclosure and risk leakage at the seal of the enclosure).

Where there are multiple cables, the cable coils shall not be entangled. They shall be able to be individually separated and removed from the pit to be worked upon without the disturbance of other cables in the pit.

Where a fibre joint or termination is located within a building or cabinet the slack may be stored within a nearby pit or coiled in a suitable location within the building or cabinet.

6.7 Cable identification

At each equipment room, at all pits containing a joint and at every termination, all cables shall be labelled with the cable identification number, a description of the cable and the destination of the cable.

Eg. 2ATS10674
24 LEAF + 72 SMOF
to Lindfield

Where cables enter a joint enclosure or a termination enclosure, the cable will be labelled close to where the cable enters this joint or termination enclosure. See Appendix B for more detail.

6.8 Sealing cable ends

Whenever a cable is cut to length and the end of the cable is not immediately sealed within a joint enclosure, the exposed end of the cable will be sealed with a heat shrink cap to prevent moisture ingress.

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7 Fibre handling

7.1 Removal of jelly

During the preparation of the cable, jelly shall be removed from the tubes and the central strength member. No solvents shall be used in this process. Tubes and fibres shall be wiped clean with dry cotton waste or similar.

7.2 Minimum bending radius

The installer shall not bend fibres to smaller radii than the minimum bending radii of fibres and tubes extending from the cable, patch cords and pigtails. The minimum bending radii are as shown in Table 1:

Fibre type/Tube	Radius
250µm coated fibre	30 mm
Tight buffered fibre 0.9mm	30 mm
Patch cord / pigtails 2.0 - 3.0mm	30 mm
Tubes from the cable	60 mm

Table 1 - Minimum Bending Radii

7.3 Strength members

Strength member(s) of the cables entering a fibre termination enclosure or joining enclosure shall be firmly anchored within the enclosure in accordance with the manufacture's instructions.

7.4 Fibres

Once fibre-splicing works are complete, bare fibre cladding shall not be exposed at any point. Only within the splice tray shall the 250µm coated fibre be exposed and only within the jointing box shall the 900µm tight buffered fibre pigtails be exposed.

Tubes and pigtails shall be firmly anchored to the splice tray.

8 Optic fibre splicing

8.1 Fibre splicing

Splicing shall be in accordance with the splice diagram, table or instruction which will provide details of the interconnection of the fibres for each joint and termination.

Unless otherwise approved fibres are to be jointed by fusion splice. Each splice is then protected with a reinforced heat shrink splice protector and stored within the organizer (splicing tray). Sufficient slack fibre shall be left within the organizer (600 to 800mm) to enable re-configuration if required at a future date. This slack shall be arranged within the tray so that the fibres cannot be tangled and so that the minimum bending radius requirement of the fibre is not violated.

8.2 Labelling of splice trays

Each splice tray shall be labelled identifying the fibres spliced and the cable from which they come.

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Eg. Substation Spur 1-6 2ATS17632 -x- Main E 36-42 2ATS17631
Substation Spur 7-12 2ATS17632 -x- Main W 36-42 2ATS17633

8.3 Re-configuration

Fibre terminations within enclosures will need to be re-configured from time to time. The installer must consider the following. Work must be neat, ordered and accessible, fibre pigtails shall be either numbered or colour coded, tubes shall be coiled neatly but not twisted together and cables shall be labelled. Where possible tubes and pigtails should enter the splice trays from only one end to make the trays in the middle of a stack more accessible.

8.4 Fibre off cuts

The works coordinator is responsible to ensure that all fibre off cuts are safely contained and removed from the site. (See *SMS-06-SW-0884*)

9 Testing of optic fibre cable and splices

The optical fibre cores shall be tested with an Optical Time Domain Reflectometer (OTDR) to prove the integrity of the cable and splices.

9.1 Cable attenuation

Attenuation of the fibres within the cable when measured with an OTDR shall be not greater than the maximum acceptable loss as shown in Table 2. This fibre attenuation does not include losses produced by splices or connectors.

Fibre Type	Wavelength	Fibre Loss per km	
		Maximum Acceptable	Typically
G652.D	1310nm	0.40dB	0.35dB
	1550nm	0.22dB	0.19dB
G655 NZDS	1550nm	0.23dB	0.20dB

Table 2 - Cable attenuation

No point losses shall exceed 0.1dB in any fibre in any length of cable at any time.

9.2 Splice Losses

Attenuation caused by fusion splicing, when measured at 1550nm, shall not exceed the maximum acceptable loss as shown in Table 3.

Fibres Types Being Spliced		Splice Loss	
		Maximum	Average
G652.D (standard single mode)	G652.D (of exactly the same type)	0.10dB	0.05dB
G652.D (standard single mode)	G652.D (of a different type)	0.15dB	0.10dB
G652.D (standard single mode)	G655 (NZDS)	0.30dB	0.20dB
G655 (NZDS)	G655 (NZDS) (of exactly the same type)	0.10dB	0.05dB
G655 (NZDS)	G655 (of a different type)	0.15dB	0.10dB

Table 3 - Splice attenuation

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The average loss is defined as the average of the losses in all fibres in one tube measured in both directions with an OTDR. In practice, bi-directional measurement need only occur if losses appear to be high in all fibres.

Testing of splices need only occur at 1550nm however where there is an irregularity, it may be beneficial to test the fibre at 1310nm as well. This can often help in determining the reasons for the irregularity and aid in its correction.

To test the splice to the pigtail and connector at the near end with an OTDR will require the use of a launch fibre of around 500m. A trailing fibre of around the same length will be required to test the splice to the pigtail and connector at the far end.

Test results shall be provided to the project manager in a tabulated form showing the losses for each and every splice and termination. In this table, joints shall be referenced by both joint ID and track kilometres and termination referenced location and track kilometres.

9.3 Fibre safety

Precautions shall be taken to ensure that no person is exposed to dangerous levels of laser light as defined in *AS/NZS 2211.1* during fibre testing. (See *SMS-06-SW-0884*)

10 Termination enclosures

10.1 Enclosures

Termination enclosures shall be manufactured in accordance with specification 1178 and shall be approved for use. The enclosures shall be mounted in accordance with the manufacture's instructions, the clauses of this document and as instructed by the RailCorp representative.

10.2 Anchoring of cable

The central strength member(s) of the cables entering a fibre Termination enclosure shall be firmly anchored within the enclosure in accordance with the manufacture's instructions. Glands shall be tightened firmly against the cable sheath in such a manner as to avoid damage to the cable.

10.3 Tube storage

The installer shall refer to the enclosure manufacture's instructions to determine the length and arrangement of tubes within the enclosure. The tubes shall be well organized with minimal crossovers to enable future alterations to be made with a minimum of disruption to existing services.

The installer shall ensure that there is no possibility of accidentally pinching, catching, kinking or damaging the fibre tubes in any way.

10.4 Part termination of fibre

If only part of the cable is to be terminated, say only six fibres of a twelve-fibre cable, then the tubes of remaining fibres shall be left at full length and stored neatly within the termination enclosure.

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10.5 Connector types

Currently RailCorp is using the SC type connector as specified by *SPM 1178*. SC/PC connectors shall be used for standard single mode (G652) and SC/APC (Angled) shall be used for NZDS (G655) fibre terminations.

10.6 Dust caps and blank ports

Any fibre termination port that is not patched shall have a dust cap inserted to protect it. Dust caps not only protect from the ingress of dust but also protect against unintentional exposure to laser light. Similarly, unused ports shall be covered with a blanking plate.

10.7 Pigtails

Pigtails within termination enclosures will usually have 900µm tight buffers. These fibre pigtails are coloured coded and shall be spliced and mounted within ports in accordance with the colour code in Appendix A Table 4. Where pigtails are of the 3mm jacketing type they are usually all the same colour. These pigtails shall be numbered with either a side-on or an adhesive tag so that each can be identified.

Pigtails shall be at least 300mm long measured from where they exit the splice tray and shall be neatly arranged within the termination enclosure in accordance with the manufacture's instructions.

10.8 Pre-terminated fibre tails

Pre-terminated fibre tails are used where the splicing trays will be housed separately to the fibre termination ports. This system will be used where there are large complex interconnection between cables. (Splice rearrangements can take place without disturbing the fibre patching.) Pre-terminated tails shall comply with *SPM 0126*. The fibre tails shall be housed and protected between the termination housing and splice housing.

11 Jointing enclosures

11.1 Enclosures

Fibre joint enclosures shall be manufactured in accordance with *SPM 1179* and shall be approved for use. The preferred arrangement for fibre joint enclosures is that fibres enter from one end only. (The fibre cables parallel to each other rather than inline).

11.2 Sealing the joint

The joint enclosure shall be sealed against the inner polyethylene sheath of the cable.

11.3 Tube handling

The installer shall refer to the enclosure manufacture's instructions to determine the length and arrangement of tubes within the enclosure. The tubes shall be well organized with minimal crossovers to enable future alterations to be made with a minimum of disruption to other fibres.

The installer shall ensure that there is no possibility that the fibre tubes can be accidentally pinched, caught, kinked or damaged in any way. Unspliced tubes shall left at their full length and stored neatly within the enclosure. See section 7 for general requirements on fibre handling

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11.4 Express joints

The term Express joint refers to a spur joint in a cable where some of the tubes of a cable pass through the enclosure without being broken. Only the tubes that need to be accessed are cut and the fibres are spliced to another cable or other cables.

Where an express joint is used tubes shall be stored neatly within the enclosure. They shall not be twisted up and if cable ties are used, they shall be relatively loose so that tubes can slide over each other if the bundle of tubes is rearranged.

12 Fibre safety

All fibre optic cable termination, splicing & jointing should be carried out in accordance with the provisions of the *SMS-06-SW-0884*.

The following safety tips are given as a general guide only in an addition to the instructions given in *SMS-06-SW-0884*.

12.1 General safety

The light used for transmission on the optical fibres is in a region of the electromagnetic spectrum that the human eye cannot detect. Even though the light cannot be seen, it can still cause damage to your eyes. With this in mind the following safety precautions must be observed:

a) never look into the end of an optical fibre, pigtail, or patch-cord, or into any laser output, such as that of a fibre optic transmission system, light source or fault locator.

b) ensure everyone working on cables knows what is happening at the other end, maintaining voice contact with the other end of the cable if possible. In this way any situation where a person could be exposed to dangerous, invisible laser light, which is being injected at the other end of the cable, can be avoided.

c) ensure all staff working on the testing, jointing, termination or maintenance of fibre optic cables or terminal equipment have adequate training. As a minimum, these persons must be aware of the safety precautions.

d) properly dispose of fibre offcuts so that no offcuts are left lying around any work site or in any situation where these offcuts can come into contact with persons. It is the responsibility of the works coordinator to ensure that all fibre off cuts shall be safely contained and removed from the site.

e) precautions must be taken to ensure that no person is exposed at any time to dangerous levels of laser light as defined in *AS2211*.

12.2 Fibre microscope safety instruction

A fibre microscope shall not be used on a fibre unless it can be firmly established that that fibre is dark. ie: that the fibre is not connected to a laser light source.

Examples of proven dark fibres are:

- A patch lead unconnected at both ends.
- An unspliced pigtail.
- A pigtail that has been spliced to a cable and that has been checked with a proven level meter to show that it is indeed dark.

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All other fibres are to be treated as active.

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Appendix A Optical Fibre Colour Codes & Properties

Loose Tube Design

All optic fibre cables incorporate a colour-coding scheme that enables each fibre to be uniquely identified. In the case of loose tube type cables this is achieved by colour coding of the fibre outer coating and colour coding the fibre tube.

Fibre Identification within the Tube

The outer coating of each fibre in each tube (unit) is colour coded as shown in table 4 below:

Fibre Number and Unit Number	Fibre Coating Colour and Unit Colour	
1		BLUE
2		ORANGE
3		GREEN
4		BROWN
5		GREY
6		WHITE
7		RED
8		BLACK
9		YELLOW
10		VIOLET
11		PINK
12		TURQUOISE

Table 4 - Colour Code

Unit Identification for Lose Tube Cable

A unit is defined as a tube loosely containing one or more fibres. Tubes normally have 6 or 12 fibres and are identified by the unique colour of the tube which is in accordance with the table above. However, one early scheme for loose tube unit identification coloured only the first two tubes blue and orange, remaining tubes are coloured white. The blue tube is the first tube and the orange (the second) marks the direction for counting for the remaining tubes
Some cables with larger fibre counts have more than one layer of tubes. In this case numbering starts with the tubes of the inner layer and then progresses to the tubes of the outer layer(s).

Fibre numbering is achieved by numbering the fibres sequentially from the first unit to the last in the order of their colour code.

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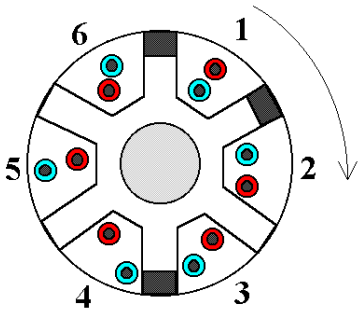
Slotted Core Design

Slotted Core Design is not in used in any cables manufactured today but can be found in some early cables installed in the rail network.



Coloured ribs on both sides of the slot identify unit 1 (or slot 1). The remaining units (slots) are counted sequentially with the direction of rotation determined by the closest proximity of a third coloured rib with one uncoloured rib between it and the two ribs marking unit 1.

Note: Yellow binder tapes are used as the standard to identify single mode optical fibre cable

Fibre numbering is achieved by numbering the fibres sequentially from the first unit to the last in the order of their colour code.

Group Refractive Index

The table of Effective Group Index of Refraction below can be used to calibrate an OTDR used for testing the fibre.

Effective Group Index of Refraction (Neff)

Manufacturer	Product	Wavelength		
		1310nm	1550nm	1625nm
Corning	SMF28 & 28e	1.4677	1.4682	-
Corning	LEAF	-	1.469	-
Optimal	AllWave G652.D	1.467	1.467	-
Optimal	TrueWave G.655	1.471	1.470	1.470
Prysmian	G652.D	1.467	1.468	1.468
Prysmian	G655	-	1.468	1.469

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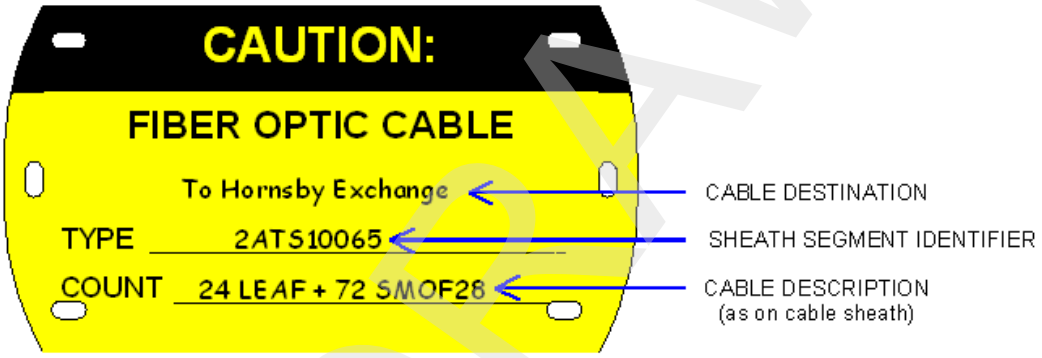
Appendix B Labelling of cables

Cables shall be labelled at each joint and at each termination such that each cable sheath segment is labelled at both ends with:

- Destination of the cable
- Fibre Sheath Segment Identifier
- Cable description as printed on cable sheath

The cable labelling tag is to be secured to the cable with cable ties

A cable sheath segment is a continuous length of cable with an unbroken sheath running between fibre termination frames and/or joints. The Fibre Sheath Segment Identifier is a unique alphanumeric code allocated by the Telecommunications Network Configuration group (TNC group) and given to each sheath segment to enable it to be identified.



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