INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

L.25

(10/96)

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre cable network maintenance

ITU-T Recommendation L.25

(Previously CCITT Recommendation)

ITU-T L-SERIES RECOMMENDATIONS

CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

For further details, please refer to ITU-T List of Recommendations.

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation L.25, was prepared by ITU-T Study Group 6 (1993-1996) and was approved by the WTSC (Geneva, 9-18 October 1996).

NOTES

1. In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

2. The status of annexes and appendices attached to the Series L Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

CONTENTS

OPTICAL FIBRE CABLE NETWORK MAINTENANCE

(Geneva, 1996)

Considering

– that a number of Administrations and operating companies have installed or are planning to install maintenance systems which are capable of monitoring the quality of an optical fibre network independent of the transmission equipment;

– that some of these systems are able to monitor the quality of the fibre network whilst it is in use without interfering with the transmission;

– that each monitoring system may use spare (inactive) fibres or may be multiplexed with the transmission signals onto working (active) fibres;

– that the type of maintenance involving such work as:

- periodic testing,
- fibre degradation testing, and
- network element control

before a fault occurs is classified as *preventative maintenance;*

– that the type of maintenance involving such work as:

- reception of an alarm or a trouble report,
- testing, and
- cable repair or removal

after the occurrence of a fault is classified as *post-fault maintenance;*

– that preventative maintenance and post-fault maintenance can both be described as having three activities as listed in Table 1;

– that preventative maintenance can be applied to trunk/long-distance or local distribution optical cable networks,

it is recommended that

– maintenance functions be classified as shown in Table 1:

Table 1/L.25

Maintenance category	Maintenance activity	Functions	Status
Preventative maintenance	**Surveillance** (e.g. Periodic testing)	Detection of fibre loss increase Detection of fibre deterioration Detection of water penetration	Optional (Note 1) Optional (Note 2) Optional
	Testing (e.g. Fibre degradation testing)	Measurement of fibre fault location Measurement of fibre strain distribution Measurement of water location	Optional Optional (Note 2) Optional
	Control (e.g. Network element control)	Fibre identification Fibre transfer system	Optional Optional (Note 3)
Post-fault maintenance	**Surveillance** (e.g. Reception of transmission system alarm or customer trouble report)	Interface with path operation system Interface with customer service operation	Optional Optional
	Testing (e.g. Fibre fault testing)	Fault distinction between transmission equipment and fibre network Measurement of fibre fault location	Required Required
	Remedy (e.g. Cable repair/removal)	Restoration/permanent repair Fibre identification Fibre transfer system	Required Required Required (Note 4)

NOTE 1 – For point-to-point networks, the detection of fibre loss increase is recommended.

NOTE 2 – Further study is required.

NOTE 3 – When the monitoring system is multiplexed with the transmission signals onto working (active) fibres, synchronous control of fibre transfer may be an option.

NOTE 4 – Fibre transfer may be achieved in a variety of ways, for example:

– by the use of fibre transfer splicing (optionally synchronous);
– by switching the transmission equipment to prior connected standby circuits which may be provided by a ring topology or diverse or duplicated fibre feeds.

Passive optical network elements such as splitters or wavelength division multiplexing components can be housed in easily replaceable units.

Appendix I

Japanese experience

Introduction

Many government Administrations and operating companies have been installing optical fibre networks for a number of years and essentially all of the transmission systems on these networks monitor the transmission bit-error rate in accordance with ITU-T Recommendations. When the bit-error rate gets too high, the systems are turned off and necessary repairs are performed. Obtaining knowledge of the bit-error rate, however, is insufficient at present to determine whether the problem is in the transmission equipment or in the optical fibre network. Determining the cause may require researching both the transmission equipment and the optical fibre network, which can be very time consuming.

Recently, a number of Administrations and operating companies have installed or are planning to install maintenance systems that will monitor the quality of the optical fibre network independent of the transmission equipment. Some of these systems are able to monitor the quality of the fibre network while it is in use, without interfering with the transmission. Each monitoring system may use spare (inactive) fibres or may be multiplexed with the transmission signals onto working (active) fibres.

This appendix offers advice on the concept and the functions required of optical fibre cable maintenance.

I.1 Scope

This appendix:

- refers to the maintenance of trunk/long-distance and local distribution optical fibre cables that are used for telecommunications networks;
- deals with optical fibre cables constructed (mainly) by single-mode fibres;
- refers to the concept of optical fibre cable maintenance;
- refers to the necessity of preventive maintenance;
- acknowledges functions of maintenance necessary for works such as surveillance, testing and control;
- deals with a non-gas-pressurized method (for maintenance, a gas-pressurized method is recommended in Recommendation L.6 "Methods of keeping cable under gas pressure", and is discussed in Part III of the Handbook "Outside Plant Technologies for Public Networks").

Passive Double Star (PDS) topology in which splitters are included in point-to-multipoint optical fibre cable network is under consideration.

I.2 Concept of optical fibre cable network maintenance

I.2.1 Situation of maintenance

1) *Elements of operation: Task*

   Operation proceeds between customers and Network Elements (NEs). Optical fibre cable operation is classified into two operations: a customer service operation, and NE operation (refer to Figure I.1). The former consists of tasks, such as reception of service order, billing information inquiry, and reception of trouble report. The latter also consists of tasks, such as provision, construction, installation, maintenance and administration. These tasks are closely related.

2) *Elements of maintenance: Activities*

   Maintenance consists of three activities: surveillance, testing and control of NE. These are described below:

   Surveillance – to monitor the condition of NE. Surveillance has two functions: to inform of NE degradation before trouble occurs, and to inform of NE abnormality when trouble occurs.

   Testing – to measure characteristics of NE and to check whether the characteristics satisfy a required level or not.

   Control – to restore NE to normal or to take action to maintain service quality.

Generally, the type of maintenance involving such works as monitoring NE degradation, testing and NE control before trouble occurs is considered to be preventive maintenance.

On the other hand, the type of maintenance involving such works as reception of an alarm or a trouble report, testing and NE controlling after a fault has occurred is considered as post-fault maintenance.

From the standpoint of preventive maintenance, optical fibre cable maintenance is composed of three activities such as periodic testing, fibre degradation testing and network element control.

Periodic testing – to periodically detect fibre loss increase, fibre deterioration and water penetration.

Fibre degradation testing – to perform measurement on fibre loss increase, fibre strain distribution and water location after receiving information from periodic testing.

Network element control – to identify fibre, transfer and splice fibre – synchronously, if necessary.

In preventive maintenance, all activities are performed using spare (inactive) fibres or working (active) fibres that are multiplexed with the transmission signals without interfering with the transmission signals.

On the other hand, from the standpoint of post-fault maintenance, optical fibre cable maintenance involves reception of a transmission system alarm or trouble report from a customer, fibre fault testing, and cable repair/cable removal (that is, cable re-routing).

Therefore, optical fibre cable maintenance can be composed of the following:

- surveillance;
- testing; and
- control;

as shown in Table 1.

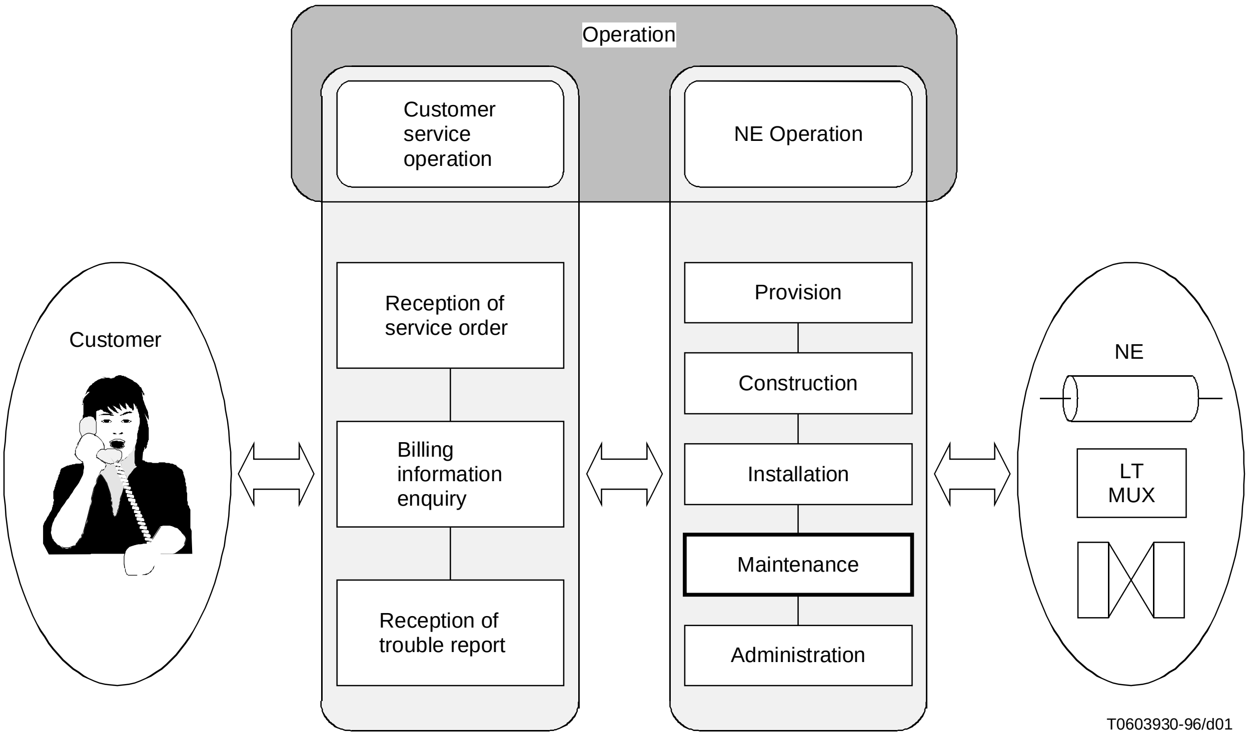

Figure I.1/L.25 – Situation of maintenance

I.2.2 Fibre faults and their origins

Fibre faults may be classified into three types: fibre failure, fibre loss increase and fibre connector abnormality.

Fibre failure may be caused by:

- tensile strain and bending strain in a cable;
- bending strain and torsion strain in a cable closure;
- lateral stress in a crushed cable conduit.

Fibre loss increase may be caused by:

- microbending loss increase due to fibre axial strain in a cable;
- fibre (macro) bending loss increase in a cable closure;
- hydrogen absorption loss increase in cable or a cable closure.

Fibre connector abnormality may be caused by:

- tensile strain and a change in the fibre alignment.

Optical fibres in an installed cable have residual strains from tension, torsion and bending. Bent fibres in a closure suffer larger strains than those in a cable (as for fibre strain in installed cable, refer to Recommendation L.14 "Measurement method to determine the tensile performance of optical fibre cables under load"), and the fibre strength decreases accordingly. Furthermore, the fibre strength deteriorates more rapidly if water penetrates the cable and the closure.

Two major origins, fibre residual strain and bending loss in the cable and the closure induce most of the fibre faults. Water penetration is believed to accelerate the possibility of fibre failure and fibre loss increase.

Therefore, appropriate actions in optical fibre cable maintenance are desired before fibre faults occurs by the two major origins.

I.2.3 Preventive maintenance

Conventional optical fibre cable maintenance has followed the concept of metallic cable maintenance, which is, if anything, neither effective nor efficient because the knowledge about the bit-error rate is insufficient to determine whether the trouble is occurring in the transmission equipment or in the optical fibre network. Consequently, a lot of time is taken in the series of work starting from reception of the trouble report to a return to normality.

A number of optical fibre cables have been introduced into subscriber networks in various countries. Consequently, a need has arisen to effectively and efficiently maintain these fibre networks. However, the concept for this differs from that of metallic cable maintenance. This is because optical fibre faults may be caused by fibre residual strain, fibre loss increase, and/or water penetration (see 2.2). If the origins of these causes could be detected in advance, it would be possible to take effective action and prevent faulty fibres. In fact, such maintenance which surveys fibre degradation (along with deterioration and loss increase) and conducts necessary fibre degradation testing and fibre transfer control before a fibre fault occurs, is considered as preventive maintenance.

Compared with conventional cable maintenance which is activated after a trouble occurs, optical fibre cable maintenance takes action before a fibre fault occurs to ensure high reliability of the optical fibre cable network and therefore reduces the number of customer complaints and trouble reports. It also allows maintenance departments to plan works and reduces operation costs. The procedures for preventive maintenance are shown below:

- periodic testing.

When an abnormality is found, the procedures continue as follows:

- fibre degradation testing;
- network element control;
- return to normal operation.

I.2.4 Post-fault maintenance

Post-fault maintenance such as reception of a trouble report, fault testing, cable repair and cable removal has been the main part of conventional cable maintenance.

In a trunk/long-distance plant, when the optical fibre cable is damaged or an optical fibre is broken, action is taken immediately in response to an alarm from a transmission system or a customer complaint. In this case, the possibility of optical fibre cable maintenance is to re-route traffic to an alternate path, to perform testing to find the fibre fault location, and to utilize a restoration cable kit to make a temporary path across the damaged portion of the cable. The restoration cable is prepared in advance for rapid repair. The procedures for post-fault maintenance in the trunk/long distance plant is as follows:

- reception of transmission system alarm;
- re-routing;
- fault distinction between fibre line and transmission equipment;
- fibre fault testing;
- craft dispatch;
- cable repair;
- repair verification;
- return to normal operation.

In a local distribution plant, after reception of a trouble report from a customer and testing for the cable/fibre fault, repair is done by a restoration cable kit or transferring fibre. The procedures for post-fault maintenance in the local distribution plant is as follows:

- reception of trouble report from a customer;
- fault distinction between fibre line and transmission equipment;
- fibre fault testing;
- craft dispatch;
- cable repair;
- repair verification;
- return to normal operation.

Cable removal is in fact cable re-routing work due to a claim from a road administrator or a customer. When cable removal work is to be done, fibre transfer control to another fibre circuit, in a point-to-point system, is necessary. Fibre transfer control has an advantage that it can transfer in parts of cables. In cable removal work, path transfer is done at both ends of all paths in the fibre cable, so the work area for path transfer is much more widely expanded than that for fibre transfer.

The process of cable removal is as follows:

- preparation of a newly installed fibre to be transferred to;
- transfer from the active fibre to a spare fibre
- identification of the fibre to be transferred;
- cutting the fibre and splicing with newly installed fibre;
- testing of the spliced fibre;
- transfer from the spare fibre to the spliced fibre.

I.3 Functions required for optical fibre cable network maintenance

I.3.1 Surveillance

I.3.1.1 Functions required for preventive maintenance

1) *Detection of fibre loss increase*

   In a trunk/long-distance plant, the condition of the optical fibre network is monitored using (an) active fibre(s) or (a) spare fibre(s) periodically. A light source and an optical power meter are used for monitoring purposes to detect automatically fibre loss increase caused by microbending, macrobending or hydrogen absorption. In the case of (an) active fibre(s) the transmission signal as well as a monitoring signal exist on a Single-Mode (SM) fibre using Wavelength Division Multiplexing (WDM) components. The monitor wavelength is different from the transmission wavelength to prevent transmission from being interrupted.

In a local distribution plant, the condition of the optical fibre network is monitored using (an) active fibre(s) or (a) spare fibre(s) periodically. An Optical Time Domain time Reflectometer (OTDR) and reflection waveform analysis are used to detect automatically fibre loss increase. Reflection waveform analysis allows the maintenance centre to compare the monitoring trace with the reference trace such as the initial installation trace. In the case of (an) active fibre(s), the OTDR wavelength is different from the transmission wavelength to prevent service interruption.

2) *Detection of fibre deterioration*

As described in I.2.2, optical fibres in an installed cable has residual strains from tension, torsion and bending. Fibre deterioration means a decrease in the fibre strength from such strains. Therefore, functions are required to detect the condition of fibre deterioration.

3) *Detection of water penetration*

When a cable sheath and/or a cable closure are damaged, water penetration may occur. Such water may generate hydrogen which may lead to a hydrogen loss increase. In order to prevent water penetration into the cable itself, various cable structures can be used. The cable might be jelly-filled or contain Water-Blocking (WB) materials. In the former case, the jelly blocks water from penetrating into the sheath at a cut or hole, and minimizes the incidence of faults capable of being caused through water penetration. In the latter case, a water-blocking tape is used to prevent water penetration. If water penetrates the sheath at a cut or hole, the WB material swells and blocks further penetration of water.

A water sensor installed in an unfilled closure can detect water penetration. If water penetrates the closure, the water-absorbent material in the sensor expands and causes the fibre bender in the water sensor to bend the spare fibre; the macrobending loss of the fibre loss increases. This loss increase is detectable when the fibre is monitored.

An alternative procedure would be to use an unfilled cable structure and gas-pressurization of the cable and closure. The maintenance methods discussed in Part III of the Handbook "Outside Plant Technologies for Public Networks" would be used to protect these cables.

I.3.1.2 Functions required for post-fault maintenance

The bit-error rate is monitored in trunk/long-distance transmission systems. If the bit-error rate exceeds the threshold level of an alarm, the alarm sends a signal through the interface along the path (transmission) operation system to the fibre cable maintenance centre. In a local distribution system, trouble reports mainly from customers are sent over to the fibre cable maintenance centre.

I.3.2 Testing

I.3.2.1 Functions required for preventive maintenance

1) *Measurement of fibre fault location*

The standard testing tool for fault locating is the OTDR. The OTDR has enough resolution to measure back scatter over even the longest fibre. A fault point caused by loss increase is easy to locate using a testing light wave on an active fibre, as a remote unit to the fibre cable maintenance centre.

2) *Measurement of fibre strain distribution*

Fibre axial strain induces a change in the Brillouin frequency shift in fibres; functions are required to measure this change. Fibre strain distributions, especially tensile strain distributions, in fibres can be measured by Brillouin Optical fibre Time Domain Analysis (B-OTDA). Refer to COM VI-45, July 1991, "The new measuring method of fibre strain". Ways of measuring of other fibre strain distributions such as bending and torsion are under consideration.

3) *Measurement of water location*

As described in I.3.1.1 3), the water-absorbent material in the sensor expands and causes a loss in the spare fibre due to macrobending. If the water sensor is identified beforehand, the location where water was penetrated can be measured the moment the fibre loss is monitored.

I.3.2.2 Functions required for post-fault maintenance

1) *Fault distinction between transmission equipment and fibre line*

When a system trouble occurs, action is taken in response to a customer complaint or an alarm from a transmission system. The monitoring system has the responsibility of determining whether the trouble is occurring in the transmission equipment or in the fibre line. Because the function of monitoring the fibre network quality is independent of the transmission equipment, it is possible to make this distinction.

2) *Measurement of fibre fault location*

The standard testing tool for fault locating is the OTDR. The fault point is located using a transmission signal wave and/or a testing light wave on a faulty fibre. The OTDR is operated independently with its own software. Some OTDRs are now portable enough to be carried in the palm of the hand.

I.3.3 Control

Cable control is performed when faulty fibres are found when cables are damaged and fibres are broken, or when cable re-routing or replacement is required.

For preventive maintenance in a trunk/long-distance plant, functions are required to identify fibres to be transferred to, to splice fibres and to transfer from spare fibres to spliced fibres synchronously between cable splice points. In a local distribution plant, fibre transfer splicing in the fibre cable maintenance centre is under consideration.

For post-fault maintenance, the functions of cable repairing, fibre identification and fibre transfer splicing in the field, are required for both the trunk/long-distance plant and for the local distribution plant.

There are two types of cable removal: one is the use of automatic switching to standby transmission equipment and fibres, between both ends of the path or cable splicing points, especially in a trunk/long-distance plant, and the other is the adoption of automatic fibre transfer splicing in the local distribution plant.

About restoration, please refer to the Handbook “Construction, installation, jointing and protection of optical fibres cables, Chapter VI Protection/Restoration” (1994 edition).

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Appendix II

UK experience

II.1 Introduction

Maintenance of an optical fibre system will be shaped by the topology of the network and the construction of the optical fibre cables. If the network is fibre rich with an optical circuit to each customer there could be advantages in introducing preventative maintenance. However, in the UK a fibre lean network is adopted with the sharing of an optical fibre circuit between customers by the use of passive splitters. The optical transmission stability of the fibres is ensured by:

- the use of stable fibre coatings in the presence of moisture;
- the use of loose packaging of fibres to isolate them from local disturbances of the sheath;
- preventing water from entering the cables by the use of compound filled cables;
- controlling cable design and installation practice so that the fibres are not strained to a magnitude that would decrease their predicted lifetime which is related to specified proof testing of the fibre;
- installing the optical fibre cables in a single cable per miniduct system;
- exposure of fibre to the craft person only as necessary.

For the above reasons preventative maintenance practices are not common in the UK networks. From a consideration of the methodology employed, comment is offered as given below.

II.2 Preventative maintenance – surveillance

II.2.1 *Fibre loss increase* is not essential for access applications where the dynamic range of the receiving equipment is categorized according to path length.

II.2.2 *Fibre deterioration* occurs suddenly (if at all) in the UK experience with modern cable systems and plant. The System Element Manager (SEM) identifies the network segment which contains the fault.

II.2.3 *Detection of water penetration* is not necessary along continuous cable lengths which have an overlapped longitudinal aluminium laminate tape water barrier and interstitial cable water blocking. For housings containing passive optical network elements, laboratory measurements show that certain splitters may be tolerant of water ingress. Should the risk be considered to be excessive, a remote sensing system could be employed.

II.3 Preventative maintenance – testing

II.3.1 *Measurement of fibre fault location* (not affecting service) may not be required (see II.2.2) and may be harmful as it may lead to induced faults (working party interruptions).

II.3.2 *Measurement of fibre strain distribution*. This may require the use of a sophisticated and at present experimental test equipment (working with Brillouin scattering). Class 3B lasers would be required and live working would be prevented. Correct cable installation of loose tube fibre cable, the use of sub-duct and positive fibre management in housings (see Recommendation L.17) should obviate this need.

II.3.3 *Measurement of water location*. The System Element Manager (SEM) would detect **service affected** faults in the rare occurrence of a cable being physically damaged to allow the ingress of water into it. Hence, the ingress of water into a cable is unlikely to happen without affecting service and therefore without being detected.

II.4 Preventative maintenance – control

II.4.1 *Fibre identification*. In some systems the SEM or Network Element Control (NEC) does not hold fibre identification information. A separate physical layer record is held.

II.4.2 *Fibre transfer system*. The case of switching a service satisfactory fibre would be very rare in the UK especially since the switching operation may induce errors.

II.5 Post-fault maintenance – surveillance

II.5.1 *Interface with path operation system* is not required in cases where the SEM registers a transmission alarm and shows the customer segment(s) lost. The fibre plant affected can be identified via the stand-alone physical layer records.

II.6 Post-fault maintenance – testing

II.6.1 *Fault distinction between transmission equipment and fibre network*. Applicable especially to Passive Optical Networks (PONs), the Optical Line Terminal (OLT) distinguishes between network and transmission equipment faults.

II.6.2 *Measurement of fibre fault location.* For fibre network faults, the passive optical network element (field replaceable unit) is identified by the SEM and the precise location of the fault can be determined by field test equipment (OTDR, clip-on or power meter).

II.7 Post-fault maintenance – remedy

II.7.1 *Restoration/permanent repair*. It may be necessary to reconfigure the network to restore service before physical repairs are carried out.

II.7.2 *Fibre identification*. In some systems the SEM or NEC does not hold fibre identification information. A separate physical layer record is held.

II.7.3 *Fibre transfer system* (see Note 4 of Table 1).

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