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Optical fibre cables for buried application

ITU-T Recommendation L.43

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Optical fibre cables for buried application

Summary

This Recommendation describes characteristics, construction and test methods of optical fibre cables for buried application. First, in order that an optical fibre demonstrates sufficient performance, characteristics that a cable should have are described. Then, the method of examining whether the cable has the required characteristic is described. Required conditions may differ according to the installation environment. Therefore, detailed conditions of experiments need to be agreed upon between a user and the supplier on the basis of the environment where a cable is used.

Source

ITU-T Recommendation L.43 was prepared by ITU-T Study Group 6 (2001-2004) and approved under the WTSA Resolution 1 procedure on 22 December 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. 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 Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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

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Optical fibre cables for buried application

1 Scope

After the trunk line networks, the use of optical fibre cables is spreading rapidly to access networks. Today, some cables are buried in order to respect the environmental landscape, to reduce network construction costs, or to reduce the extension of underground facilities like ducts and tunnels.

As they are installed without ducts, tunnels and hard protection, cables should have good resistance characteristics to harsh conditions. Some cables have strong outer armouring, others have outer pipe-systems, or special plastic sheaths.

This Recommendation:

- refers to multi-mode graded index and single-mode optical fibre cables to be used for telecommunication networks in direct buried installation;
- deals with mechanical and environmental characteristics of the optical fibre cables concerned. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with ITU-T Recs G.651, G.652, G.653, G.654 and G.655 which deal with a multi-mode graded index optical fibre and single-mode optical fibres respectively;
- deals with fundamental considerations related to optical fibre cable from the mechanical and environmental points of view;
- acknowledges that some optical fibre cables may contain metallic elements, for which reference should be made to the ITU-T Handbook *Outside plant technologies for public networks* (see ITU-T Rec. L.1), and other L-series Recommendations;
- recommends that an optical fibre cable should be provided with cable end-sealing and protection during cable delivery and storage, as is common for metallic cables. If splicing components have been factory installed they should be adequately protected;
- recommends that pulling devices can be fitted to the end of the cable if required.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

2.1 Normative references

[1] ITU-T Recommendation G.650.1 (2002), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[2] ITU-T Recommendation G.650.2 (2002), *Definitions and test methods for statistical and non-linear attributes of single-mode fibre and cable*.

[3] ITU-T Recommendation G.651 (1998), *Characteristics of a 50/125 μm multimode graded index optical fibre cable*.

[4] ITU-T Recommendation G.652 (2000), *Characteristics of a single-mode optical fibre cable*.

[5] ITU-T Recommendation G.653 (2000), *Characteristics of a dispersion-shifted single-mode optical fibre cable*.

[6] ITU-T Recommendation G.654 (2002), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[7] ITU-T Recommendation G.655 (2000), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre cable*.

[8] ITU-T Recommendation K.25 (2000), *Protection of optical fibre cables*.

[9] ITU-T Recommendation K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground*.

[10] ITU-T Recommendation K.47 (2000), *Protection of telecommunication line using metallic conductors against direct lightning discharges*.

[11] ITU-T Recommendation L.1 (1988), *Construction, installation and protection of telecommunication cables in public networks*.

[12] ITU-T Recommendation L.46 (2000), *Protection of telecommunication cables and plant from biological attack*.

[13] IEC 60793-1-1:2002, *Optical fibres – Part 1-1: Measurement methods and test procedures – General guidance.*

[14] IEC 60793-2:2001, *Optical fibres – Part 2: Product specifications.*

[15] IEC 60794-1-1:2001, *Optical fibre cables – Part 1-1: Generic specification – General.*

[16] IEC 60794-1-2:1999, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures.*

[17] IEC 60794-3:2001, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables.*

2.2 Informative references

[1] ITU-T Handbook (1994), *Construction, Installation, Jointing and Protection of Optical Fibre Cables*.

[2] IEC 60708-1:1981, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath – Part I: General design details and requirements.*

3 Terms and definitions

For the purpose of this Recommendation, the definitions given in ITU-T Recs G.650.1, G.650.2 and G.651 apply.

4 Abbreviations

This Recommendation uses the following abbreviations:

SZ	Reverse oscillating stranding
UV	Ultraviolet ray

5 Characteristics of the optical fibres and cables

5.1 Optical fibre characteristics

Optical fibres described in ITU-T Recs G.651, G.652, G.653, G.654 or G.655 should be used.

5.1.1 Transmission characteristics

The typical transmission characteristics are described for each optical fibre in the respective Recommendation. Unless specified by the users of this specific Recommendation, those values are applied for a cabled optical fibre.

5.1.2 Fibre microbending

Severe bending of an optical fibre involving local axial displacement of a few micrometers over short distances caused by localized lateral forces along its length is called microbending. This may be caused by manufacturing and installation strains and also by dimensional variations of cable materials due to temperature changes during operation.

Microbending can cause an increase in optical loss. In order to reduce microbending loss, stress randomly applied to a fibre along its axis should be eliminated during the fibre's incorporation into the cable, as well as during and after cable installation.

5.1.3 Fibre macrobending

Macrobending is the resulting curvature of an optical fibre after cable manufacture and installation.

Macrobending can cause an increase in optical loss. The optical loss increases if the bending radius is too small.

5.2 Mechanical characteristics

5.2.1 Bending

Under the dynamic conditions encountered during installation, the fibre is subjected to strain from both cable tension and bending. The strength elements in the cable and the installation bend radius must be selected to limit this combined dynamic strain. Any fibre bend radius remaining after cable installation shall be large enough to limit the macrobending loss or the long-term strain which shorten the lifetime of the fibre.

5.2.2 Tensile strength

Optical fibre cable is subjected to short-term loading during manufacture and installation, and may be affected by continuous static loading and/or cyclic loading during operation (e.g., temperature variation). Changes in the tension of the cable due to the variety of factors encountered during the service life of the cable can cause the differential movement of the cable components. This effect needs to be considered in the cable design.

Excessive cable tensile loading increases the optical loss and may cause increased residual strain in the fibre if the cable cannot relax. To avoid this, the maximum tensile strength determined by the cable construction, and more especially by the design of the strength member, should not be exceeded.

NOTE – Where a cable is subjected to permanent loading during its operational life, the fibre should preferably not experience additional strain.

5.2.3 Crush and impact

The cable may be subjected to crush and impact both during installation and operational life.

The crush and impact may increase the optical loss (permanently or for the time of application of the stress) and excessive stress may lead to fibre fracture.

5.2.4 Torsion

Under dynamic conditions encountered during installation and operation, the cable may be subjected to torsion, resulting in residual strain of the fibres and/or damage of the sheath. If this is the case, the design of cable should allow a specified number of cable twists per unit length without an increase in fibre loss and/or damage to the sheath.

5.3 Environmental conditions

5.3.1 Hydrogen gas

In the presence of moisture and metallic elements, hydrogen gas may be generated. Hydrogen gas may diffuse into silica glass and increase optical loss. It is recommended that the hydrogen concentration in the cable, as a result of its component parts, should be low enough to ensure that the long-term effects on the increase of optical loss are acceptable. The method for estimating the concentration of hydrogen in optical cables is given by ITU-T Rec. L.27.

By the use of dynamic gas pressurization, hydrogen-absorbing materials, careful selection and construction (moisture barrier sheath) or elimination of metallic components, the increase in optical loss can be maintained within acceptable limits.

Further information can be found in IEC 60794-1-1, Annex D.

5.3.2 Moisture permeation

When moisture permeates the cable sheath and is present in the cable core, deterioration of the tensile strength of the fibre occurs and the time-to-static failure will be reduced. To ensure a satisfactory lifetime of the cable, the long-term strain level of the fibre must be limited.

Various materials can be used as barriers to reduce the rate of moisture permeation. Alternatively, filled, metal-free cable constructions can be used.

NOTE – If required, minimum permeation is achieved by a longitudinal overlapped metallic foil. A continuous metallic barrier is effective to prevent moisture permeation.

5.3.3 Water penetration

In the event of damage to the cable sheath or to a splice closure, longitudinal penetration of water in a cable core or between sheaths can occur. The penetration of water causes an effect similar to that of moisture. The longitudinal penetration of water should be minimized or, if possible, prevented. In order to prevent longitudinal water penetration within the cable, techniques such as filling the cable core completely with a compound or with discrete water blocks or swellable components (e.g., tapes, roving, etc.) are used. In the case of unfilled cables, dry-gas pressurization can be used.

Water in the cable may be frozen and, under some conditions, can cause fibre crushing with a resultant increase in optical loss and possible fibre breakage.

5.3.4 Lightning

Fibre cables containing metallic elements such as conventional copper pairs or a metallic sheath are susceptible to lightning strikes.

To prevent or minimize lightning damage, consideration should be given to ITU-T Recs K.25, K.29 and K.47.

When a non-metallic cable is used, the cable should be filled and protected against mechanical and thermal damage.

5.3.5 Biotic damage

It is important to give enough consideration to possible biotic attacks on buried cables. Potential biotic damage may be inflicted by rodents, fungus, termites, moles, etc. Although the safest method would be to select cable routes free from these factors, it is also possible to propose methods to protect cables from such biotic attacks. Further information is described in ITU-T Rec. L.46, *Protection of telecommunication cables and plant from biological attack*.

5.3.6 Vibration

Underground optical fibre cable may be subject to vibrations from traffic, railways, pile-driving and blasting operations. Here again, cables should withstand vibrations generated by these activities without degradation.

A well-established surveillance routine will identify the activity in order to make a careful choice of route to minimize this type of problem.

5.3.7 Temperature variations

The cables will be subject to temperature changes during their whole lifetime.

Thermal variation causes different dimensional changes in each element of the cable, since they have different thermal expansion coefficients, which difference can go up to 100 times between the smallest and the greatest value. This difference in behavior can cause attenuation increase of the optical fibres due to microbending or macrobending. Therefore, it is necessary to investigate in advance about the temperature of the place where a cable is laid, and to choose the cable suitable for the environment.

5.3.8 Chemical attack

After the installation, contact with several chemical agents may degrade the cable sheath characteristics, leading to the weakening of the cable core protection.

To avoid this problem, cable sheath material should be selected carefully, based on its robustness against chemical agents. First of all, it is important to assess what kind of chemical agents may exist in the the area where the cable is to be laid. Then, sheath material durability for such chemical agents should be examined.

5.3.9 Mechanical aggression

It is difficult to estimate the level of mechanical aggression that the cable may undergo during its handling, installation and maintenance. However, it is clear that a buried cable is less protected than cables in ducts. Therefore, internationally recognized requirements such as impact, alternated flexions, torsion, compression and bending tests should be adhered to. Specific tests or specific conditions for usual tests should be agreed upon by users and suppliers.

5.4 Installation and removal

5.4.1 Installation method

The cable installation pulling force varies from case to case and depends upon the installation process. Installation method should be agreed to between a user and the installer.

5.4.2 Removal method

Compared to cable in a duct, a buried cable is usually more difficult to remove without damaging it. The removal method should be agreed upon between user and the remover. If the cable is to be reused, then a removal method has to be chosen that causes minimum damage to the cable.

6 Cable construction

6.1 Fibre coatings

6.1.1 Primary coating

Silica fibre itself has an intrinsically high strength, but its strength is reduced by surface flaws. A primary coating must therefore be applied immediately after drawing the fibre to size.

The optical fibre should be proof-tested. In order to guarantee long-term reliability under service conditions, the proof-test strain may be specified, taking into account the permissible strain and required lifetime.

In order to prepare for splicing, it should be possible to remove the primary coating without damage to the fibre, and without the use of materials or methods considered to be hazardous or dangerous.

The composition of the primary coating, coloured if required, should be considered in relation to any requirements of local light-injection and detection equipment used in conjunction with fibre jointing methods.

NOTE 1 – The coating should have a nominal diameter of 250 μm.

NOTE 2 – The primary coated fibres should be proof-tested with a strain equivalent to at least 0.5% for a duration of one second. The test method should be in accordance with IEC 60793-1-30.

NOTE 3 – Further study is required to advise on suitable testing methods for local light-injection and detection.

6.1.2 Secondary coating

If using tight secondary coating of the fibre, following items should be requested.

- It should be easily removable for fibre splicing.
- Nominal diameter should be between 800 μm and 900 μm, with the agreement between the user and supplier. A tolerance should be ±50 μm. Non-concentricity between fibre and secondary coating should not exceed 75 μm unless otherwise agreed between the user and the supplier.

NOTE 1 – When a tight secondary coating is used, it may be difficult to use local light-injection and detection equipment associated with fibre jointing methods.

NOTE 2 – Mechanical coupling between fibre and cable should be carefully designed; a low coupling may cause fibre movement during installation process; a high coupling causes high fibre stress when cable is bent.

6.1.3 Fibre identification

Fibre should be easily identified by colour or position within the cable core. If a colouring method is used, the colours should be clearly distinguishable and have good colour-fast properties also in the presence of other materials, during the lifetime of the cable.

6.1.4 Removability of coating

The primary and secondary protections should be easy to remove and should not hinder the splicing, or the fitting of fibre to optical connectors.

6.2 Cable element

The make-up of the cable core, in particular the number of fibres, their method of protection and identification, the location of strength members and metallic wires or pairs, if required, should be clearly defined.

6.2.1 Optical fibre ribbon

Optical fibre ribbons consist of optical fibres aligned in a row. Optical fibre ribbons are divided into two types, based on the method used to bind optical fibres. One is the edge-bonded type; the other is the encapsulated type shown in Figures 1 and 2 respectively. In the case of the edge-bonded type, optical fibres are bound by adhesive material located between optical fibres. When the encapsulated type is adopted, optical fibres are bound by a coating material. In ribbons, optical fibres shall remain parallel and do not cross. Each ribbon in a cable is identified by a printed legend or unique colour. Optical fibre ribbons are specified in IEC 60794-3.

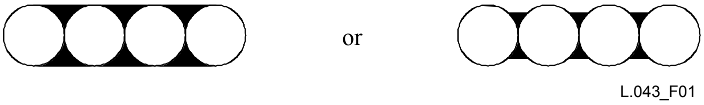

Figure 1/L.43 – Cross-section of a typical edge-bonded ribbon

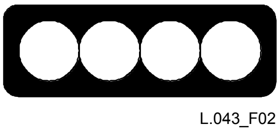

Figure 2/L.43 – Cross-section of a typical encapsulated ribbon

6.2.2 Slotted core

In order to avoid direct pressure from the outside of the cable on optical fibres, optical fibres and/or ribbon fibres are located in slots. Usually, slots are provided in a helical or SZ configuration on a cylindrical rod. The slotted core usually contains a strength member. A strength member shall adhere tightly to the slotted core in order to obtain temperature stability and avoid their separation when a pulling force is applied during installation. Water-blocking material may be contained in the slots.

6.2.3 Tube

A tube construction is frequently used for protecting and gathering optical fibres and/or ribbon fibres. Water-blocking material may be contained in the tube.

6.2.4 Strength member

The cable should be designed with sufficient strength members to meet installation and service conditions so that the fibres are not subjected to strain levels in excess of those agreed upon between customer and supplier.

The strength member may be either metallic or non-metallic.

6.2.5 Water-blocking materials

Filling a cable with water-blocking material or wrapping the cable core with layers of water-swellable material are two means of protecting the fibres from water ingress. A water-blocking element (tapes, filling compound, water-swelling powder or combination of materials) may be used. Any materials used should not be harmful to personnel. The materials in the cable should be compatible, one with the other, and in particular should not adversely affect the fibre. These materials shall not hinder splicing and/or connection operations.

6.2.6 Pneumatic resistance

If the cable requires dry air pressurization during operation, the pneumatic resistance should be specified.

NOTE – It is intended that a cable can be pressurized only if it allows a flux of air which is in accordance with the criteria defined in Part III of the ITU-T Handbook *Outside plant technologies for public networks* (see ITU-T Rec. L.1).

6.3 Sheath

The cable core shall be covered with a sheath or sheathes suitable for the relevant environmental and mechanical conditions associated with storage, installation and operation. The sheath may be of a composite construction and may include strength members.

Sheath considerations for optical fibre cables are generally the same as for metallic conductor cables. Consideration should also be given to the amount of hydrogen generated from a metallic moisture barrier. The minimum acceptable thickness of the sheath should be stated, together with any maximum and minimum allowable overall diameter of the cable.

NOTE – One of the most used sheath materials is polyethylene (see clause 22 of IEC 60708-1). There may, however, be some conditions where it is necessary, for example, to limit fire hazards; special materials should then be used for the cable sheath in these situations.

6.4 Armour

Where additional tensile strength or protection from external damage (crush, impact, rodent, etc.) is required, armouring should be provided.

Armouring considerations for optical fibre cables are generally the same as for metallic conductor cables. However, hydrogen generation due to corrosion must be considered. It should be remembered that the advantages of optical fibre cables, such as lightness and flexibility, will be reduced when armour is provided.

Armouring for metal-free cables may consist of aramid yarns, fibre-glass-reinforced strands or strapping tape, etc.

6.5 Identification of cable

If a visual identification is required to distinguish an optical fibre cable from a metallic cable, this can be done by visibly marking the sheath of the optical fibre cable. For identifying cables, embossing, sintering, imprinting, hot foil and surface printing can be used by agreement between the user and the supplier.

7 Test methods

7.1 Test methods for cable element

7.1.1 Tests applicable to optical fibres

In this clause, optical fibres test methods related to splicing are described. Mechanical and optical characteristics test methods for optical fibres are described in ITU-T Recs G.650 and G.651.

7.1.1.1 Dimensions

For measuring secondary coating diameter, method IEC 60793-1-21-B shall be used.

For measuring tube, slotted core and other ruggedized elements, method IEC 60793-1-21-B or in IEC 60189 shall be used.

7.1.1.2 Coating strippability

For measuring the strippability of primary or secondary fibre coatings, IEC 60793-1-32 shall be used.

7.1.1.3 Compatibility with filling material

When fibres come into contact with a waterproofing filling material, stability of the fibre coating and of the filling material should be tested after accelerated ageing.

Stability of coating stripping force shall be tested in accordance with method IEC 60794-1-2-E5.

Dimension stability and coating transmissivity should be examined by the test method agreed upon between a user and the supplier.

7.1.2 Tests applicable to tubes

7.1.2.1 Tube kink

For measuring kink characteristics of tube, method IEC 60794-1-2-G7 shall be used.

7.1.3 Tests applicable to ribbons

7.1.3.1 Dimensions

For measuring ribbon dimensions, three test methods should be used properly. The first one, called a type test, is used to establish and assure ribbon manufacturing process. The type test shall be carried out in accordance with method IEC 60794-1-2-G2, which is the visual measurement method. The two remaining methods are used only for product inspection after the manufacturing process is established. Those test methods are described in IEC 60794-1-2-G3, aperture gauge, and IEC 60794-1-2-G4, dial gauge. For inspection purposes, the visual measurement method can be also used.

7.1.3.2 Separability of individual fibres from a ribbon

A separability requirement can be given to a fibre ribbon if a user and the supplier agree. When separability is required, the following should be avoided in order to ensure long-time reliability of the fibres:

1) damage to the mechanical characteristics of fibres;
2) removal of colour coding of each fibre.

In fact, it is difficult to completely avoid such phenomena. However, if a user and the supplier agree, test method IEC 60794-1-2-G5 shall be used to examine fibre separability. Also, other special test methods can be used upon agreement between a user and the supplier.

7.2 Test methods for mechanical characteristics of the cable

This clause recommends appropriate tests and test methods for verifying the mechanical characteristics of optical fibre cables.

7.2.1 Tensile strength

This test method applies to optical fibre cables installed under all environmental conditions.

Measurements are made to examine the behaviour of the fibre attenuation as a function of the load on a cable during installation.

The test shall be carried out in accordance with method IEC 60794-1-2-E1.

The amount of mechanical decoupling of the fibre and cable can be determined by measuring the fibre elongation, with optical phase shift test equipment, together with the cable elongation.

This method may be non-destructive if the tension applied is within the operational values.

7.2.2 Bending

This test method applies to optical fibre cables installed under all environmental conditions.

The purpose of this test is to determine the ability of optical fibre cables to withstand bending around a pulley, simulated by a test mandrel.

This test shall be carried out in accordance with method IEC 60794-1-2-E11.

7.2.3 Bending under tension (flexing)

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study.

7.2.4 Crush

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method IEC 60794-1-2-E3.

7.2.5 Squeezing (abrasion resistance)

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method IEC 60794-1-2-E2A.

7.2.6 Torsion

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method IEC 60794-1-2-E7.

7.2.7 Impact

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method IEC 60794-1-2-E4.

7.2.8 Kink

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method IEC 60794-1-2-E10.

7.2.9 Repeated bending

This test shall be carried out in accordance with method IEC 60794-1-2-E6.

7.2.10 Coiling performance

This test shall be carried out in accordance with method IEC 60794-1-2-E20.

7.3 Test methods for environmental characteristics

This clause recommends the appropriate tests and test methods for verifying the environmental characteristics of optical fibre cables.

7.3.1 Temperature cycling

This test method applies to optical fibre cables installed under all environmental conditions.

Testing is by temperature cycling to determine the stability of the attenuation of a cable due to ambient temperature changes which may occur during storage, transportation and operation.

This test shall be carried out in accordance with method IEC 60794-1-2-F1.

7.3.2 Longitudinal water penetration

This test method applies to completely filled outdoor cables installed under all environmental conditions. The intention is to check that all the interstices of a cable are continuously filled with a compound to prevent water penetration within the cable.

This test shall be carried out in accordance with method IEC 60794-1-2-F5.

7.3.3 Moisture barrier

This test method applies to optical fibre cables installed under all environmental conditions.

This test applies to cables supplied with a longitudinal overlapped metallic foil. The moisture penetration can be tested according to the test method as described in Part I, Chapter III of the ITU-T Handbook *Outside plant technologies for public networks* (see ITU-T Rec. L.1).

7.3.4 Freezing

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study and is currently under consideration in the method IEC 60794-1-2 F6.

7.3.5 Hydrogen

This test method applies to optical fibre cables installed under all environmental conditions.

In the case of a metal-free cable or one employing a moisture barrier sheath with the selection of cable components that are low in the generation of hydrogen either by themselves or in combination with others (for example, water), the build-up of hydrogen gas within the cable core will not lead to a significant increase in optical loss.

For other cable constructions, ITU-T Rec. L.27 shall be considered.

7.3.6 Nuclear radiation

This test method assesses the suitability of optical fibre cables to be exposed to nuclear radiation.

This test shall be carried out in accordance with method IEC 60794-1-2-F7.

7.3.7 Vibration

This test method assesses the suitability of optical fibre cables for bridge and underground application.

This subject needs further study.

7.3.8 Ageing

Under consideration in IEC SC86A WG3.

7.3.9 Pneumatic resistance

If the gas pressurisation system is used to protect non-waterproofed cables, this test shall be carried out in accordance with method IEC 60794-1-2-F8.

7.3.10 Lightning

When a metallic material is used as a cable element, the lightning protection of a cable should comply with a test described in ITU-T Rec. K.25 or be agreed upon between a user and the supplier.

Appendix I

Direct buried optical fibre cables: the Brazilian experience

I.1 Introduction

As Brazil is a country where there is a high incidence of lightning, and where large cities can be extremely far from each other, the use of a fully dielectric optical cable for long-distance direct buried installation is a very attractive and economical solution.

I.2 Requirements

The basic requirements determined by a telecommunication carrier are:

1) fully dielectric cable with "loose tube" technology;
2) low costs when compared with those of cables with steel tape as sheath protection;
3) good transmission, mechanical and thermal performances compared with those of the metallic cable.

The following performance characteristics were examined.

I.2.1 Resistance to traction

For this requirement, we tried to ensure that the efforts applied to the cable during its installation would not affect the lifetime and the transmission characteristics of the optical fibres.

The cable installation pulling force varies from case to case and depends upon the installation process. However, as it is a directly buried cable, we saw that the maximum force could not exceed 1000 N in manual installation (by placing the cable in pre-dug ditches), and also in mechanical installation (by using a plough).

It was specified that the cable strength members should have enough strength resistance to support the cable-pulling installation force without causing attenuation increase, localized optical discontinuity or deformation of optical fibres above 0.20% when pulled, and 0.05% after releasing the effort.

It is recognized that, to ensure a minimum lifetime of 20 years, with reliability above 99%, optical fibres should not be submitted to tensions above 1/3 of the proof-test tension. As the proof-test standard used in Brazil at the time of this development was 0.55 GPa or 0.50% of elongation, the value of 0.20% was adopted as the maximum fibre elongation during the cable installation.

The value of 0.05% of acceptable deformation, after tension is released, tries to ensure that, after installation, the cable remains unstrained. During installation, there is friction between the cable and the contact material (earth), acting against this tension release. Therefore, in some parts of the cable, the fibres may be permanently strained, but it is desirable that this strain be below deformation level.

I.2.2 Resistance to moisture penetration

Contact with water and moisture is harmful to optical fibres. This contact affects their transmission characteristics and life. The cable must have a mechanism to prevent moisture penetration because, in the case of any damage or breaks in the jacket, the water should never touch the cable core, nor the optical fibres.

Therefore, it was specified that the inner part of the cable should be fully filled with a compound which works as a barrier against moisture. It should be odourless, non-toxic, and harmless to the skin, to prevent accidents during cable handling. This compound should also be easily removable and colourless so as not to hinder cable installation and maintenance.

I.2.3 Resistance to abrasion

Due to its installation methods, this is a cable that will be submitted to considerable abrasion.

The abrasion will act on the external jacket and can reduce its thickness affecting its protection performance.

It was specified that, after being submitted to the abrasion test, the cable diameter should not be reduced by less than 1 mm.

I.2.4 Resistance to chemical attack

After the installation, the cable may be in contact with several chemical agents which might cause degradation of its coating and reduce the cable core protection.

To avoid this problem, it was specified that the characteristics of the jacket material could not be changed above certain limits after coming into direct contact with water, acid solutions ($pH = 1$), basic solutions ($pH = 13$) and gasoline (standardized by a solution of isooctane/toluene in the ratio of 70:30).

I.2.5 Resistance to temperature variations

The cables will be submitted to temperature changes throughout their lifetime.

A thermal variation causes different dimensional changes in each element of the cable, since they have different thermal expansion coefficients, which difference can go up to 100 times between the smallest and the greatest value. This difference in behaviour can cause attenuation increase of the optical fibres due to microbending or macrobending.

The purpose of the specified requirement of thermal excursion (from –20 to +65 ºC) is to evaluate the behaviour of the optical fibre attenuation when the cable is exposed to extreme values of operating temperature, which can be found in the various regions of the country. The cable design, production process and material can be evaluated by submitting the complete cable to a thermal test.

I.2.6 Resistance to biological aggressions

As the cable is in direct contact with the soil, it was considered indispensable that the materials of the external jacket should provide appropriate protection against biological aggressions, such as fungi growth and termite attack.

For this reason, it was specified that the mechanical characteristics of these materials, when submitted to the fungi attack resistance test, should not deteriorate excessively.

To provide the cable with protection against termite attack, it was specified that the cable jacket should incorporate a polyamide 12 coating, which reduces noticeably the incidence of damage to the cables caused by these insects. This polyamide layer coating is extruded between the inner and the outer polyethylene jacket, or over the outer jacket, for cables designed for duct installations.

I.2.7 Resistance to other mechanical aggressions

As it is impossible to foresee the level of mechanical aggression that the cable may undergo during handling, installation and maintenance, internationally recognized requirements were adopted such as impact, alternated flexions, torsion, compression and bending tests, among others.

I.2.8 Cable removal and reinstallation

In the case of in-duct direct buried cable applications, it is desirable to be able to remove easily the optical cable laid inside the duct protection (see Figure I.2), in cases of defect, in order to replace it by another cable.

There is a specific test method to determine the friction coefficient in underground in-duct optical cable installation.

I.3 Product design and construction

There are two different kinds of optical cable for direct buried installation being used in Brazil.

I.3.1 Double polyethylene-plus-nylon jacket optical cable for direct buried installation

As shown in Figure I.1, this cable may be composed of from 2 to 72 optical fibres, in bundles of 2 or 6 fibres inside jelly-filled loose tubes. These tubes are helically strained around a dielectric central strength member, whose interstices are completely filled with an appropriate jelly compound. A non-hygroscopic or a water-blocking tape is then wrapped around this tube to complete the cable core. Then, a first layer of polyethylene is extruded over the cable core, to form the inner jacket. To protect the cable against termites, a special layer of polyamide 12 is extruded over the inner jacket. Finally, to complete the cable core protection, an outer jacket of polyethylene is extruded over the polyamide layer.

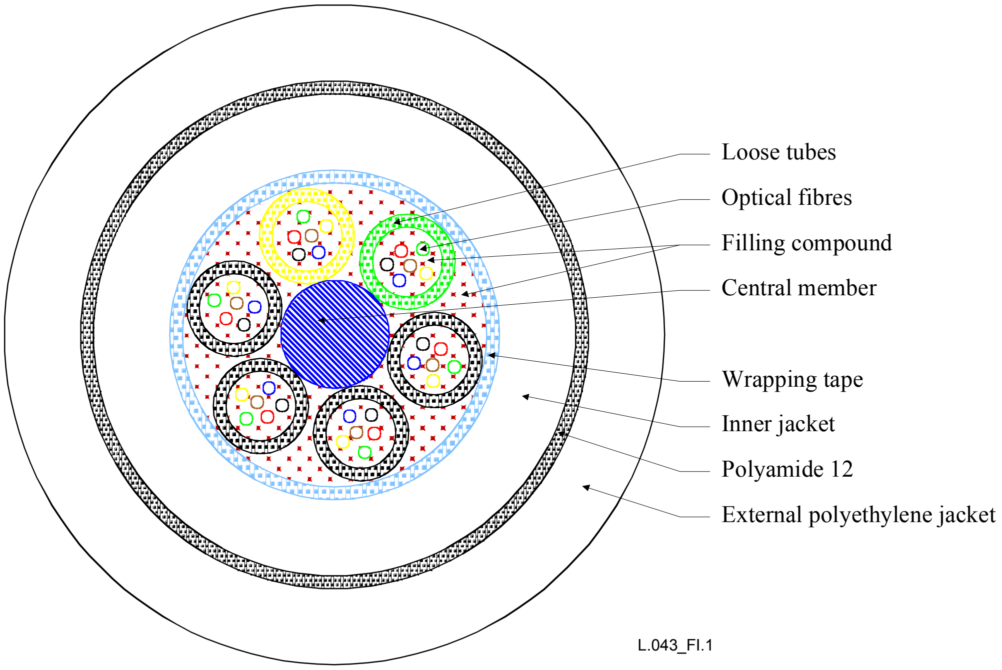

Figure I.1/L.43 – Double polyethylene-plus-nylon jacket 36-optical-fibre cable for direct buried installation

I.3.2 Direct buried underground in-duct-protected optical cable

As shown in Figure I.2, this cable may be composed of from 2 to 72 optical fibres, in bundles of 2 or 6 fibres inside jelly-filled loose tubes. These tubes are helically strained around a dielectric central strength member, whose interstices between the tubes are completely filled with an appropriate jelly compound. Over that is applied a non-hygroscopic or a water-blocking wrapping tape, to complete the cable core.

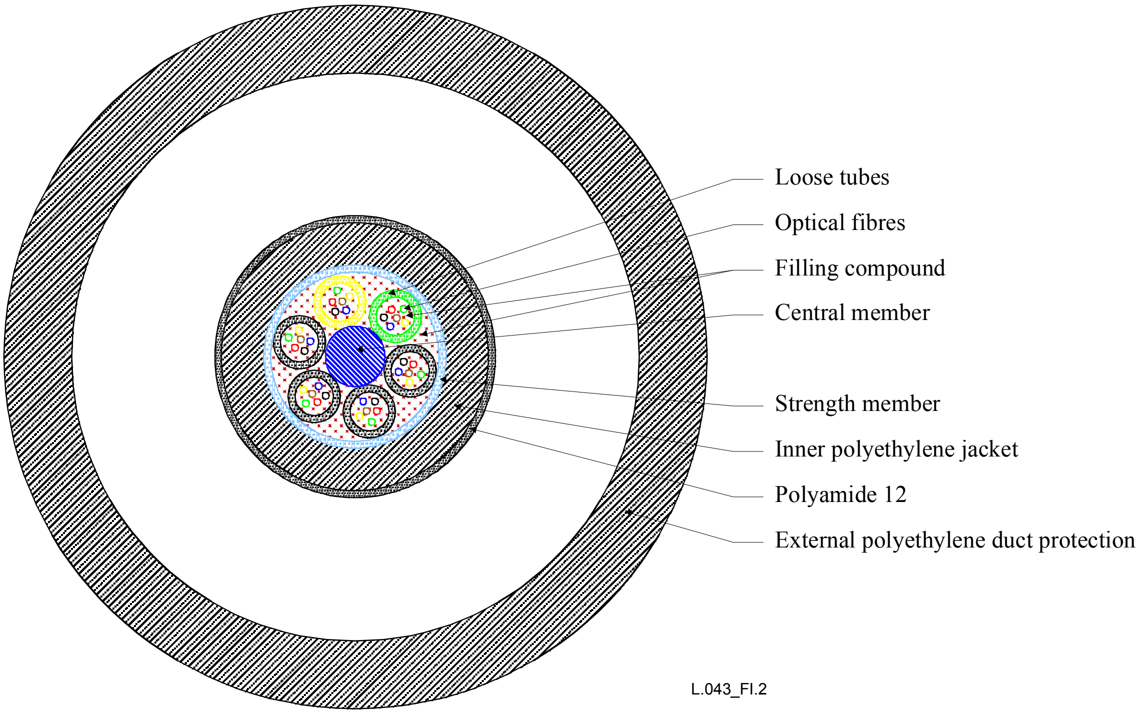

Figure I.2/L.43 – Cross-section of a 36-fibre direct buried in-duct-protected optical cable

A special layer of aramid yarns is applied over the wrapping tape, to provide the cable with the necessary strength resistance to the pulling force.

Then, a first layer of polyethylene is extruded over the aramid yarns, to form the inner jacket. To protect the cable against termites, a special layer of polyamide 12 is extruded over the inner jacket.

Finally, that cable is protected by an outer polyethylene duct, whose inner diameter is large enough to permit removal and reinstallation of the optical cable.

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