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

Optical fibre cables for duct and tunnel application

ITU-T Recommendation L.10

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Optical fibre cables for duct and tunnel application

Summary

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

Source

ITU-T Recommendation L.10 was revised 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.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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Optical fibre cables for duct and tunnel application

1 Scope

This Recommendation:

– refers to multi-mode graded index and single-mode optical fibre cables to be used for telecommunication network in ducts and tunnels;

– 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 lines 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 60793-1:2001, *Optical fibres – Part 1: Measurement methods and procedures*.

[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*.

[18] IEC 60189:1986, *Low-frequency cables and wires with PVC insulation and PVC sheath. Part 1: General test and measuring methods*.

2.2 Informative references

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

[2] IEC 60708-1:1981, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath. Part 1: 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 optical fibres and cables

5.1 Optical fibre characteristics

Optical fibres as 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 its respective Recommendation. Unless specified otherwise by the users of the Recommendations, those values apply to the corresponding cabled optical fibre.

5.1.2 Fibre microbending

Severe bending of an optical fibre involving local axial displacement of a few micrometres 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 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 fiber'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 long-term strain limiting 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, especially 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, the increase in optical loss can be maintained within acceptable limits during service life.

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

5.3.2 Moisture permeation

When moisture permeates the cable sheath and reaches the cable core, the tensile strength of the fibre diminishes, and the average 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. If required, minimum permeation is achieved by a longitudinal overlapped metallic foil. A continuous metallic barrier is effective to prevent moisture permeation. In metal-free cables, filling compound is effective in preventing longitudinal water propagation, but does not significantly hinder radial moisture permeation through plastic sheaths.

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.

5.3.4 Lightning

Fibre cables containing metallic elements such as conventional copper pairs or a metallic sheaths 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.

5.3.5 Biotic damage

The small size of an optical fibre cable makes it more vulnerable to rodent attack. Where rodents cannot be excluded, a suitable and effective protection should be provided. Further information is described in ITU-T Rec. L.46, "Protection of telecommunication cables and plant from biological attack".

An effective protection is provided by barriers either metallic (steel tape or wire armouring) or non-metallic (e.g., fibreglass rods, glass yarns/tapes, etc.).

5.3.6 Vibration

When optical fibre cables are installed on bridges, they will be subject to relatively high amplitude vibrations of various low frequencies, depending on bridge construction and on the type of traffic density. Cables should withstand these vibrations without failure or signal degradation. Care should be exercised, however, in the choice of installation method.

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

During their operational lifetime, cables may be subjected to severe temperature variations. In these conditions, the increase of attenuation of the fibres shall not exceed the specified limits.

5.4 Fire safety

Several large-scale communication failures have been known to occur, because of cable burning in the tunnel.

Therefore, optical cables for tunnels are requested to have fire performances in many countries. Requirements for fire performances may differ in each country. Optical cables for tunnels should meet regulations on fire safety in each country or in accordance with each telecommunication carrier.

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.

Primary-coated fibres shall comply with relevant ITU-T Recommendations in the G.65x-series.

6.1.2 Secondary coating

If using tight secondary coating of the fibre, the 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. While quite low coupling may cause fibre movement during the installation process, high coupling causes high fibre stress when the cable is bent.

6.1.3 Fibre identification

Fibre should be easily identified by colour and/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 coatings should be easy to remove and should not hinder the splicing, or fitting of fibre to optical connectors.

6.2 Cable elements

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 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 edge-bonded type, the other is encapsulated type, shown in Figures 1 and 2 respectively. In case of edge-bonded type, optical fibres are bound by adhesive material located between optical fibres. When encapsulated type is adopted, optical fibres are bound by 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.

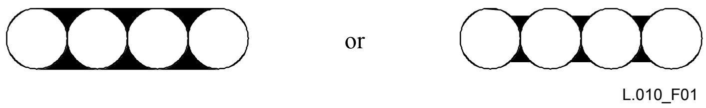

Figure 1/L.10 – Cross-section of a typical edge-bonded ribbon

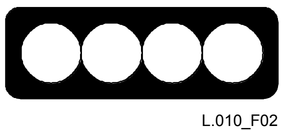

Figure 2/L.10 – Cross-section of a typical encapsulated ribbon

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 may be located into slots. Usually, slots are provided in a helical or SZ configuration on a cylindrical rod. The slotted core usually contains a strength member (metallic or non-metallic). The 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 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 with each other, and in particular should not adversely affect the fibre. These materials should 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 Network* (see ITU-T Rec. L.1).

6.3 Sheath

The cable core shall be covered with a sheath or sheaths 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 be used for the cable sheath in such situations.

6.4 Armour

Where additional tensile strength or protection from external damage (crush, impact, rodents…) 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 taken into consideration. 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, glass-fibre-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 user and supplier.

7 Test methods

7.1 Test methods for cable elements

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.650.1 and G.651, and IEC 60793-1 series.

7.1.1.1 Dimensions

For measuring the 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 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 materials

When fibres come into contact with a filling material used for waterproof, stability of the fibre coating and the filling material should be examined by tests after accelerated ageing.

The stability of the 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 by both user and supplier.

7.1.2 Tests applicable to tubes

7.1.2.1 Tube kink

For measuring kink characteristics of tubes, 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 assess and verify ribbon manufacturing process. The type test shall be carried out in accordance with method IEC 60794-1-2-G2, the visual measurement method. The two remaining methods are used only for product inspection after the manufacturing process has been carried out. These test methods are described in IEC 60794-1-2-G3, aperture gauge, and IEC 60794-1-2-G4, dial gauge. For the inspection purposes, a visual measurement method can also be 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 a supplier agree. When separability is required, the following should be avoided in order to ensure long-term reliability of the fibres:

– damage to mechanical characteristics of fibres;

– removal of the colour coding of each fibre.

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

For test methods, reference shall be made to IEC 60794-1 series.

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 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 in 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 a 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 should be consulted.

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 subject needs further study.

7.3.8 Ageing

This subject is under consideration.

7.3.9 Pneumatic resistance

If a gas pressurization system is used to protect unwaterproofed 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 shall undergo a test described in ITU-T Rec. K.25 or be subject to agreement between the user and supplier.

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