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

Single-mode fibre optic connectors

ITU-T Recommendation L.36

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Summary

ITU-T Recommendation L.36 describes the main features of fibre optic connectors, in terms of types, fields of application, configurations and technical aspects. Further, this Recommendation examines the optical, mechanical and environmental characteristics of fibre optic connectors, advising on general requirements and test methods.

While taking into account ITU-T Recommendation G.671 as far as the transmission parameters are concerned, this Recommendation is based on the most recent work carried out within IEC 86B Working Groups 4, 6 and 7, namely the IEC 61753-series.

Source

ITU-T Recommendation L.36 was approved on 8 January 2008 by ITU-T Study Group 6 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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Single-mode fibre optic connectors

1 Scope

This Recommendation:

– gives general information on fundamental types of fibre optic connectors, their field of application and the main requirements about their characteristics in terms of optical, mechanical and environmental behaviour;

– makes a classification of these components in terms of the configurations used into fibre optic plants;

– gives a general description of the basic principles of operation and of technologies of fabrication of fibre optic connectors;

– describes all the most important optical parameters and gives general specifications on the optical, mechanical and environmental performances of fibre optic connectors;

– describes the main test methods of fibre optic connectors;

– is limited to factory installed connectors; these are connectors that have been applied to the fibre and/or cable in a controlled factory environment, as opposed to so called "field installable" connectors, that are applied to the fibre by an installer in field conditions.

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.

[ITU-T G.650.1] ITU-T Recommendation G.650.1 (2004), *Definition and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[ITU-T G.650.2] ITU-T Recommendation G.650.2 (2007), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

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

[ITU-T G.652] ITU-T Recommendation G.652 (2005), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.653] ITU-T Recommendation G.653 (2006), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.654] ITU-T Recommendation G.654 (2006), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[ITU-T G.655] ITU-T Recommendation G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] ITU-T Recommendation G.656 (2006), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.657] ITU-T Recommendation G.657 (2006), *Characteristics of a bending loss insensitive single mode optical fibre and cable for the access network*.

[ITU-T G.671] ITU-T Recommendation G.671 (2005), *Transmission characteristics of optical components and subsystems*.

[IEC 61753-1] IEC 61753-1 (2008), *Fibre optic interconnecting devices and passive components performance standard – Part 1: General and guidance for performance standards*.

[IEC 61755-1] IEC 61755-1 (2005), *Fibre optic connector optical interfaces – Part 1: Optical interfaces for single mode non-dispersion shifted fibres – General and guidance*.

[IEC/TR 62000] IEC/TR 62000 (2005), *Single-mode fibre compatibility guidelines.*

3 Definitions

None.

4 Abbreviations

This Recommendation uses the following abbreviations:

A Attenuation

APC Angled Physical Contact

PC Physical Contact

RL Return Loss

5 Conventions

None.

6 General information

Fibre optic connectors provide a method for jointing the ends of two optical fibres. Such a joint is not a permanent one, but it can be opened and closed several times. The optical connectors are required in the points of the network in which it is necessary to have flexibility in terms of network configuration and test access.

Fibre optic connectors have application in all types of network, at the input and output ports of the transmission systems and are also used to connect test equipment and instrumentation.

The connection can have a plug-adapter-plug or a plug-socket configuration.

The main effects of the introduction of a connector in an optical line are an attenuation on the transmitted signal and a reflection of a part of the signal.

7 Types and configurations

Fibre optic connectors can be classified on the basis of:

– the type of cable;
– the type of fibre;
– the fibre alignment system;
– the fibre end face finish;
– the number of jointed fibres;

– the type of coupling mechanism;
– the outer diameter of the ferrule *(2.5 mm or 1.25 mm)*;
– the connector mating lay out ("plug and socket" or "plug-adapter-plug").

7.1 Fibre types

The type of connector and in particular its grade of mechanical accuracy depend on the type of fibre to be jointed. The fibres to be considered are those specified in ITU-T Recs G.650.1 to G.657. Particularly, great accuracy is necessary to align two single mode fibres in which the light is guided in a core of about 9 μm.

7.2 Cable types

The connector can be assembled with:
– primary coated fibre (250 μm);
– secondary coated fibre (900 μm); and
– single fibre cable (typically from 1.5 mm to 3 mm).

7.3 Fibre alignment system

a) *Direct alignment*: In this type of solution the bare fibre is directly aligned by V-groove or capillary tubes.

b) *Secondary alignment*: In this case the fibre is fixed in a structure. These structures are usually cylindrical ferrule for single or duplex fibre connections or rectangular section body for duplex or multiple fibre joint. These structures are aligned by means of sleeves, pins or other systems.

c) *Lens alignment*: The optical alignment of the fibres is obtained by means of a lens.

NOTE – Secondary alignment is the most commonly applied design; loss criteria of most standards are established for this type of connector.

7.4 Fibre end face finish

For both direct alignment and ferrule-based connectors, the end face of the fibre or the ferrule is prepared (normally by polishing) to give fibre to fibre contact either where the end faces are perpendicular to the fibre axis or at a small angle to the perpendicular. For ferrules two common cases are found:

a) *Physical contact (PC)*: This finish is typically used in a single or duplex fibre connector. The end face is polished to a spherical shape in order to obtain a perfect contact between the two fibre cores and to improve the transmission performances of the connector. A typical spherical radius is 5-30 mm.

b) *Angled physical contact (APC)*: This finish is similar to the PC, but in this case the polished end surface of the ferrule is angled with respect to the fibre axis. This solution gives low values of reflected power. Typical angles are 8 or 9 degrees for G.652-type fibres. Typical end surface radius is in the range of 5 to 12 mm.

7.5 Coupling mechanism

The most common systems for mating together two plugs (or the plug and the socket) are:
– push-pull mechanism;
– screw mechanism;
– bayonet mechanism.

8 Characterization parameter definitions

8.1 Optical parameters

The fibre optic connectors are characterized by several parameters; the most important are:

8.1.1 Attenuation

The attenuation, A, introduced by the fibre optic connector is defined as:

$$A = -10 \cdot \log \frac{P_i}{P_0} \qquad \text{[dB]}$$

where P_0 is the optical power just before the connection and P_i is the optical power just after the connection.

8.1.2 Return loss

The return loss introduced by the fibre optic connector is defined as:

$$RL = 10 \cdot \log \frac{P_r}{P_0} \qquad \text{[dB]}$$

where P_0 is the optical power measured at the connection interface and P_r is the optical power reflected by the connector.

8.1.3 Classes of wavelength

Connector assemblies should be suitable to operate in the wavelength range of at least 1260 to 1625 nm.

8.2 Mechanical parameters

8.2.1 Vibrations

This parameter assesses the resistance of the connector during the applications of sinusoidal oscillations along three orthogonal axis.

8.2.2 Strength of the coupling mechanism

It is the pulling force withstood by the coupling mechanism just before the disconnection of the connector.

8.2.3 Mechanical resistance of the attachment of the fibre/cable to the plug connector

It is the resistance of the attachment point of the fibre or cable to the plug when it is subjected to mechanical stress as pulling and torsion.

8.2.4 Mechanical endurance

This parameter assesses the number of connections that the connector shall guarantee without deteriorating its optical performances.

8.3 Environmental parameters

8.3.1 Operating temperature

It is the range of temperature in which the performances of the fibre optic connector are guaranteed.

8.3.2 Climatic effects

It is the range of variation of environmental conditions that is applied when evaluating changes in mechanical and optical performance. This includes changes in temperature and humidity, as well as the rate of change of these conditions.

9 Performance criteria and test methods

For the characterization or validation of a connector system, fibres with the same nominal[1] mode field diameter should be used, in order to avoid incorrect results due to mismatches between different fibres. For single mode fibre, more details on fibre dimensions and tolerances can be found in [IEC 61755-1].

9.1 Optical performances

9.1.1 Attenuation (IEC 61300-3-4)

Four grades of attenuation can be defined according to [IEC 61755-1]:

Table 9-1 – Insertion loss grades

Attenuation grade	Attenuation (IEC 61300-3-4)
Grade A	Not defined yet
Grade B	≤ 0.12 dB mean ≤ 0.25 dB max. for > 97% of samples
Grade C	≤ 0.25 dB mean ≤ 0.50 dB max. for > 97% of samples
Grade D	≤ 0.50 dB mean ≤ 1.0 dB max. for > 97% of samples

These values are referred to random mating between randomly selected plugs from production.

9.1.2 Return loss (IEC 61300-3-6)

Four grades of return loss can be defined according to [IEC 61755-1]:

Table 9-2 – Return loss gades

Return loss grade	Return loss random mated (IEC 61300-3-6)
Grade 1	≥ 60 dB (mated) and ≥ 55 dB (unmated)
Grade 2	≥ 45 dB
Grade 3	≥ 35 dB
Grade 4	≥ 26 dB

These values are referred to random mating between randomly selected plugs from production.

The grades 2, 3 and 4 are referred to the PC fibre end face finish while the grade 1 is referred to the APC fibre end face finish.

[1] This does not necessarily mean the exact same fibre, but fibre that complies to the same standard.

9.2 Mechanical and environmental performances

9.2.1 Vibration (IEC 61300-2-1)

The variation of the attenuation shall be ≤ 0.20 dB. The change in attenuation during the test shall be measured by means of transient monitoring according to IEC 61300-3-28. The RL value shall remain in the specified class during and after a vibration test with the following characteristics:

– frequency range: 10-55 Hz
– endurance duration per axis: 0.5 hour
– number of axis: three, orthogonal
– number of cycles (10-55-10): 15
– vibration amplitude: 1.5 mm (peak-to-peak)

9.2.2 Strength of the coupling mechanism (IEC 61300-2-6)

The test is performed applying a specified axial load between the plug and the adapter.

The value of the load and the duration of the test are specified according to the specific coupling mechanism and the manufacturer's rating for the specific connector design. The recommended minimum load value is 40 N during 120 seconds.

During and after the test the attenuation shall not increase more than 0.20 dB.

9.2.3 Mechanical resistance of the attachment of the fibre/cable to the plug connector

9.2.3.1 Fibre/cable retention (IEC 61300-2-4)

The test is performed applying an axial load between the cable and the plug.

The load should be:

– 2 N for primary coated fibre;
– 5 N for secondary coated fibre;
– 50 N for aramid reinforced cable ≤ 2 mm diameter;
– 70 N for aramid reinforced cable > 2 mm diameter.

During and after the test, the attenuation shall not increase more than 0.20 dB.

9.2.3.2 Torsion (IEC 61300-2-5)

The test is performed applying a torque on the cable at the distance of 10 cm from the connector; the cable is kept taut by a load. The load should be the maximum manufacturer's rating for the specific connector design.

During and after the test, the attenuation shall not increase more than 0.20 dB.

9.2.4 Mechanical endurance (IEC 61300-2-2)

The test is carried out by connecting 500 times a plug and an adapter (one side of the connector set only in the case of a plug-adapter-plug configuration).

The connector may be cleaned at a specified interval (not less than 10 mating cycles) during the test, and it may be cleaned before measurement on completion of the test.

The variation of the attenuation shall be less than 0.20 dB and the return loss shall not fall below the minimum for the grade.

9.2.5 Operating temperature

The recommended temperature ranges in which the connector performances should be guaranteed are from –40°C to +70°C for outdoor applications ("uncontrolled environment") and –10°C to +60°C for indoor applications ("controlled environment").

9.2.6 Climatic endurance

Patchcords shall be tested by placing the complete test assembly in the climatic test chamber. A typical test assembly contains 2 connections plus the necessary cables: two (2) to five (5) metres of cable between connectors plus the leads to connect the patchcord to the equipment outside the climatic test chamber.

9.2.6.1 Cold (IEC 61300-2-17)

Temperature: –10°C (for indoor applications) or –40°C (for outdoor applications)

Duration: 16 hours

Preconditioning and recovery: 2 hours in room temperature condition.

Attenuation shall be measured before, at a maximum interval of 1 hour during and after the test. The maximum allowed change in attenuation during and after the test shall be ≤0.5 dB for the complete assembly.

Return loss shall be measured before, during and after the test and shall satisfy the requirements for the specified class.

9.2.6.2 Dry heat (IEC 61300-2-18)

Temperature: 60°C (for indoor applications) or 70°C (for outdoor applications)

Duration: 96 hours

Preconditioning and recovery: 2 hours in room temperature condition.

Attenuation shall be measured before, at a maximum interval of 1 hour during, and after the test. The maximum allowed change in attenuation during and after the test shall be ≤0.5 dB for the complete assembly.

Return loss shall be measured before, during and after the test and shall satisfy the requirements for the specified class.

Strength of coupling mechanism shall be measured on completion of test after recovery procedure.

9.2.6.3 Condensation test (IEC 61300-2-21)

Z/AD profile with exposure to cold

Temperature extremes: –10°C ± 2°C to +65°C ± 2°C

Relative humidity: 93 ± 3% at the maximum temperature

Dwell time: 3 hours at the temperature extremes

Duration: 10 cycles

Attenuation shall be measured before, at a maximum interval of 1 hour during and after the test. The maximum allowed change in attenuation during and after the test shall be ≤0.5 dB for the complete assembly.

Return loss shall be measured before, during and after the test and shall satisfy the requirements for the specified class.

9.2.6.4 Change of temperature (IEC 61300-2-22)

High temperature: 60°C (for indoor applications) or 70°C (for outdoor applications)

Low temperature: –10°C (for indoor applications) or –40°C (for outdoor applications)

Duration at extreme temperature: 1 hour.

Temperature rate of change: 1ºC/min.

Number of cycles: 12

Preconditioning and recovery: 2 hours in room temperature condition.

Attenuation shall be measured before, at a maximum interval of 10 minutes during and after the test. The maximum allowed change in attenuation during and after the test shall be ≤0.5 dB for the complete assembly.

Return loss shall be measured before, at a maximum interval of 10 minutes during and after the test and shall satisfy the requirements for the specified class.

10 Connector identification

It is important to be able to distinguish cable assemblies by their characteristics such as fibre and cable type, polishing type and attenuation and return loss grades.

While no complete international standard is approved at this time, the general trend is to colour code the plastic body connectors to distinguish the PC type from the APC type independently of the return loss performances.

The blue colour is used for the PC and the green one for the APC.

As an alternative means, labels may be applied for connector type/class/grade identification, as it is independent on regional differences in colour code conventions. Especially for metallic body connectors, this may be a good alternative.

In any case, an appropriate identification system is to be agreed between the customer and the supplier.

Appendix I shows different regional conventions and the IEC standard on this subject.

Appendix I

Overview of international and regional conventions for colour coding of single-mode fibre optic connectors

(This appendix does not form an integral part of this Recommendation)

In IEC (International) and Cenelec (Europe) standards, the colour coding of connectors is limited to the difference in fibre end face angle: PC (=Blue body) and APC (=Green body).

For other connector properties (e.g., return loss properties), no colour coding is defined in these standards.

Table I.1 shows the colour code of the various parts of plastic body as per Telcordia GR-326, which is generally adopted in the United States.

Table I.1 – Colour code for optical connectors (United States of America, Telcordia GR-326)

Plug type	Attenuation	Return loss class	Plug Body	Boot
PC	Not specified	≥ 30 dB ≥ 40 dB ≥ 55 dB	Blue	Red White Dark Blue
APC 8°	Not specified	≥ 60 dB	Green	Green
APC 9°	Not specified	≥ 60 dB	Green	Green

Table I.2 shows the colour code of the various parts of plastic body connector used in China.

Table I.2 – Colour code for optical connectors (China)

Plug type	Attenuation	Return loss class	Plug Body	Boot
PC	≤ 0.30 dB	≥ 45 dB ≥ 55 dB	Blue	White
APC 8°	≤ 0.30 dB	≥ 60 dB	Green	Green

It is noted that a colour code standardization for the single fibre cable may also be desirable in order to distinguish the G.652 and G.653 fibres; for example, Italy uses blue and orange respectively for G.652 and G.653 fibres. However, operating companies in some other countries do not use single fibre cables with G.653 fibres. In the United States and Spain, yellow has universally been the colour code for single fibre cables with G.652 fibres ever since G.652 fibres existed.

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[b-IEC 61300] IEC 61300-series (2004), *Fibre optic interconnecting devices and passive components – Basic Test and Measurement Procedures*.

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