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INTERNATIONAL STANDARD

colour inside

Optical fibre cables –
Part 3-11: Outdoor cables – Product specification for duct, directly buried, and lashed aerial single-mode optical fibre telecommunication cables

IEC 60794-3-11:2010(E)

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Part 3-11: Outdoor cables – Product specification for duct, directly buried, and lashed aerial single-mode optical fibre telecommunication cables

FOREWORD

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International Standard IEC 60794-3-11 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2007. It constitutes a technical revision.

The main changes with respect to the previous edition are as follows:

- the title of the specification has been updated to include lashed applications;
- the fibres specification clause (subclause 5.2.2) has been enlarged to include fibre types B6_a.

The text of this standard is based on the following documents:

FDIS	Report on voting
86A/1314/FDIS	86A/1326/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 60794 series, published under the general title *Optical fibre cables,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

OPTICAL FIBRE CABLES –

Part 3-11: Outdoor cables – Product specification for duct, directly buried, and lashed aerial single-mode optical fibre telecommunication cables

1 Scope

This part of IEC 60794 sets forth technical requirements and characteristics of single-mode optical fibre cables for duct and direct buried installation.

This specification includes functional mechanical, environmental and optical requirements, recommended features and test methods for assessing the product against the stated requirements.

The specified test methods, where applicable, are those referenced in IEC 60794-1-1 and described in detail in IEC 60794-1-2.

The requirements of this specification supplement those of IEC 60794-3 and IEC 60794-3-10

Multimode fibre requirements are not addressed in this standard; see IEC 60794-3-12.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60708, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath*

IEC 60793-1-22, *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*

IEC 60793-1-40, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-1-48, *Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60794-1-1, *Optical fibre cables – Part 1-1: Generic specification – General*

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

IEC 60794-3 (all parts), *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 60794-3-10, *Optical fibre cables – Part 3-10: Outdoor cables – Family specification for duct, directly buried and lashed aerial optical telecommunication cables*

IEC 60811-1-1, *Common test methods for insulating and sheathing materials of electric cables and optical cables – Part 1-1: Methods for general application – Measurement of thickness and overall dimensions – Tests for determining the mechanical properties*

IEC/TR 61931, *Fibre optic – Terminology*

IEC/TR 62000, *Single mode fibre compatibility guidelines*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61931 apply.

3.2 Symbols

The following symbols are used in this document:

λ_{cc} cable cut-off wavelength

d outer cable diameter

SZ technique in which the lay reverses direction periodically.

4 General information

4.1 Overview

Single-mode optical fibres are widely used for telecommunication purposes and are cabled to satisfy the functional requirements of the installation environment. Further, cables placed into ducts and sub-ducts may be installed using solely, or a combination of, pushing, pulling, and air-assisted installation techniques. For duct installation, the environment and infrastructure can be varied and may also involve the use of single and multiple sub-ducts. Directly buried cables may be installed by a variety of methods such as ploughing and trenching with different environments and infrastructure. This may require specific cable design solutions based on multiple layers of armours and sheaths. It is recognised that certain designs of cable for direct buried applications involving such solutions may also be suitable for duct installation. The functional requirements and test methods featured in this specification are based upon adherence to established and recognised installation techniques such as those included in Annex C of IEC 60794-1-1.

NOTE Annex C of IEC 60794-1 should become a technical report.

4.2 General cable description

4.2.1 Characteristics of optical fibre

Single-mode optical fibres are classified according to their operational wavelength and dispersion characteristics. The fibres covered by this specification are categorised as type B and are described in IEC 60793-2-50. The fibre types featured in this specification are listed below:

- dispersion unshifted (B1.1, B1.3);
- bending loss insensitive (B6);
- dispersion shifted (B2);

- cut-off shifted (B1.2), non-zero dispersion (B4) - While cut-off shifted B1.2 fibre can be used in terrestrial applications, it is mainly used in submarine applications;
- wide-band non-zero dispersion-shifted (B5).

(See Annex A for ITU-T cabled optical fibre references).

Optical fibre cable elements such as buffer tubes (loose or not), slotted core, fibre ribbons, fibre bundles and central/core tubes shall be suitably designed to provide adequate means of fibre location, identification, modularity, protection during cable manufacture, installation and termination. The structure of these elements, and the materials used in their manufacture, shall not have any long term detrimental effects on fibre performance during the service life of the cable, splice enclosure and/or cabinet. To satisfy these functional requirements, the different elements shall comply with the requirements of IEC 60794-3 series as well as those outlined in Clause 6 of this standard.

Optical fibre cables, for the intent of this standard, are completed cable products as shipped by the manufacturer typically on disposable reels. Such products do not require additional assembly, or the use of additional materials or protection to meet the requirements contained herein. Some assembly or added protection is usually required only where the cables are terminated to other cables or equipment, and typically involve the use of an optical fibre closure or other hardware to protect cable splice or connectorization points. The required levels of protection for the fibre can be achieved by laying up or assembling the cable elements in association with suitable strength and/or anti-buckling members. These can be either metallic or non-metallic and positioned at the centre of the cable core or as peripheral members in or underneath the outer cable sheath. The cable may also contain moisture barrier tapes, metallic or non-metallic tapes, and water blocking or swellable materials.

IEC Guide 104 should be taken into account as far as possible. The materials of the cables in contact with the environment shall not be hazardous to the environment and personnel.

It should be noted that the cables specified by this standard are rarely accessible once installed. Therefore, the risk of exposure to hazardous materials, if any, is mostly a concern in the handling of the cable during manufacturing and installation. Additionally, the type of outer sheath specified herein is generally considered to be non-toxic, therefore the risk to the environment or personnel is minimal once properly installed.

This standard does not address the use of all types of cable materials that may be utilized in various cable designs to support meeting the requirements unique to a specific type of special application (e.g., very high temperatures or resistance to specific chemical attack). In such cases, it is incumbent on the customer and supplier to agree on the requirements applicable to such materials and cable designs, and to determine any special handling precautions or instructions needed as a result of their use.

All of the single-mode fibre types covered in this specification can readily achieve very low splice loss levels using a range of commercially available splicing techniques.

Typical bi-directional splice losses at 1 550 nm should be below 0,1 dB, with an average of 0,05 dB for fusion splices between fibres of the same category (B1-B1, or B2-B2, etc.) performed by skilled operators on active alignment splicers according to the current best practices. Additional fibre compatibility guidelines are provided in IEC/TR 62000.

NOTE 1 Higher maximum splice losses can be tolerated without affecting the link transmission capability.

NOTE 2 Splices of fibres of the same category, but different manufacturers and/or different production processes, do generally not exceed the above values.

NOTE 3 If fibres of different categories (B1-B2, B1-B4, etc.) are spliced, typically the splice loss is slightly higher than with splices between fibres of the same category.

4.4 Testing

4.4.1 General

For all test procedures, the atmospheric conditions shall be (23 °C ± 5 °C, and 20 % to 70 % relative humidity), unless otherwise specified. All measured and computed values are to be rounded to the number of decimal places given in the corresponding acceptance criteria for each requirement. The number of fibres to be tested shall be agreed upon between the customer and supplier.

4.4.2 No change in attenuation

4.4.2.1 General

For some of the parameters specified in this standard, the objective is no change in attenuation.

These parameters may be affected by measurement uncertainty arising from measurement errors or calibration errors due to a lack of suitable reference standards. Acceptance criteria shall be interpreted with respect to this consideration.

4.4.2.2 No change in attenuation - single-mode

The total uncertainty of measurement for this standard shall be ≤ ± 0,05 dB for attenuation or ± 0,05 dB/km for attenuation coefficient. Any measured value within this range shall be considered as "no change in attenuation".

The requirement for these parameters is indicated as "no change (≤ 0,05 dB)" or "no change (≤ 0,05 dB/km)". By agreement between the customer and the supplier, minor deviation from this limit may be accepted at some low frequency, e.g. less than 10 %. However, for mechanical tests no deviation in excess of 0,15 dB shall be accepted. For environmental tests, no deviation in excess of 0,10 dB/km shall be accepted.

4.4.3 No change in fibre strain

For some of the parameters specified in this standard, the objective is zero strain.

These parameters may be affected by measurement uncertainty arising from measurement errors or calibration errors due to a lack of suitable reference standards. Acceptance criteria shall be interpreted with respect to this consideration.

The total uncertainty of measurement for this standard shall be ± 0,05 % strain. Any measured value within this range shall be considered as "zero".

5 Requirements for cabled single-mode optical fibres

5.1 Fibre materials

Use optical fibre as specified in IEC 60793-2-50.

The coating surface shall be cleaned (e.g. from cable filling compounds) with only those cleaning agents recommended by the fibre manufacturer. In any case, chlorine-based cleaning agents shall not be used because of the health hazards involved.

5.2 Optical requirements

5.2.1 General

All optical fibre transmission attributes shall comply with 5.4 of IEC 60793-2-50. Attributes of the cabled fibre (attenuation, point discontinuity, polarization mode dispersion, cable cut-off wavelength and group index) are specified in the following subclauses. Other fibre attributes in IEC 60793-2-50 are summarized in the informative Annex B.

5.2.2 Attenuation coefficient

The cabled fibre attenuation coefficients for the fibre types covered by this specification shall meet the following requirements in Table 1, or as otherwise agreed upon between the customer and the supplier.

Table 1 – Requirements for the attenuation coefficient of cabled fibre

	Fibre type (maximum attenuation in dB/km)						
Wavelength	B1.1	B1.2	B1.3	B2	B4	B5	B6_a
1 310 nm	0,40	NA	0,40	0,50	[a]	NA	0,40
1 383 nm	NA	NA	0,40 [b]	NA	NA	NA	0,40 [b]
1 550 nm	0,35	0,30	0,30	0,35	0,35	0,35	0,30
1 625 nm	0,40 [c]	0,40 [c]	0,40 [c]	0,40 [c]	0,40 [c]	0,40 [c]	0,40 [c]

NA = Not applicable.

[a] 1 310 nm is not specified unless agreed otherwise between the customer and the supplier.

[b] 1383 nm attenuation is specified after hydrogen aging as per IEC 60793-2-50.

[c] 1625 nm attenuation values are optionally specified by the customer.

Fibre type definitions are provided in IEC 60793-2-50 for single-mode fibre. For informative purposes, they are described below:

- B1.1: Single-mode fibre with a zero dispersion between 1 300 nm to 1 324 nm, which is optimised for use in the 1 310 nm region and is compatible in the 1 550 nm region.
- B1.2: Dispersion unshifted single-mode fibre that is optimised for 1 550 nm transmission with a cable cut-off wavelength <1 530 nm.
- B1.3: Single-mode fibre similar to B1.1 but has a low loss at 1383 nm to provide additional compatibility between 1 360 nm to 1 460 nm.
- B2: Dispersion shifted single-mode fibre with a zero dispersion in the 1 525 nm to 1 575 nm region.
- B4: A non-zero dispersion shifted single-mode fibre (NZDSF) that is optimised for 1 550 nm transmission with the zero dispersion outside the 1 530 nm to 1 565 nm region.
- B5: A non-zero dispersion shifted single-mode fibre (NZDSF) that is optimised for 1 460 nm to 1625 nm transmission with the zero dispersion region below 1 460 nm.
- B6_a: A bending loss insensitive fibre compatible with B1.3 fibre that is suitable for use in the access networks, including inside buildings.

Test procedure:

Measurements shall be made in accordance with IEC 60793-1-40 at room temperature (23 °C ± 5 °C).

5.2.3 Attenuation discontinuities

Point discontinuities / local variations representing non-reflective events shall be: ≤ 0,10 dB.

a) Test procedure:

Measurements shall be made in accordance with IEC 60793-1-40, method C (backscattering technique).

b) Measurement variables:

Wavelength: 1 310 nm and/or 1 550 nm.

5.2.4 Cable cut-off wavelength

Cable cut-off wavelength λ_{cc} shall be:

λ_{cc} ≤ 1 260 nm for fibre types B1.1 and B1.3;

λ_{cc} ≤ 1 270 nm for fibre type B2;

λ_{cc} ≤ 1 450 nm for fibre type B4 and B5;

λ_{cc} ≤ 1 530 nm for fibre type B1.2;

λ_{cc} ≤ 1 260 nm for fibre types B6_a.

Test procedure:

Cut-off wavelength measurements shall be made in accordance with IEC 60793-1-44.

5.2.5 Polarization mode dispersion (PMD)

Polarization mode dispersion (PMD) is usually described in terms of a differential group delay (DGD), which is the propagation time difference between the principal states of polarization of an optical signal. PMD in cabled fibres and optical components causes an optical pulse to spread in the time domain, which may impair the performance of a long length and high bit rate (e.g. 10 Gbit/s transport over 400 km) optical fibre system. For these systems, only the following evaluation may be useful.

Concerning the statistical nature of PMD in installed cable links, reference is made to IEC 60794-3, Annex A.

The appropriate test method shall be selected from IEC 60793-1-48, which also describes the statistical nature of PMD (see Introduction of IEC 60793-1-48):

– For links > 400 km, the link design value (PMD_Q) shall be less than or equal to 0,20 ps/$km^{0,5}$. Note, from ITU-T Recommendation G.652 Table I.2/, this maximum link design value should allow the possibility of 3 000 km links at 10 Gbit/s and 80 km (to 200 km) at 40 Gbit/s.

– For links ≤ 400 km, the link design value (PMD_Q) shall be less than or equal to 0,50 ps/$km^{0,5}$. Note from ITU-T Recommendation G.652 Table I.2 /, this maximum link design value should allow the possibility of 400 km links at 10 Gbit/s.

5.2.6 Group index

This parameter is used to determine the fibre length within cables or cable lengths (taking construction into account) using IEC 60793-1-22, Method B. The group index shall be given at 1 310 nm for B1.1, B1.3, and B2 fibres and at 1 550 nm for all fibres. The group index shall be given at 1 625 nm for any cable specified for operation at 1 625 nm.

6 Requirements for cable elements

6.1 Element design

6.1.1 General

An optical fibre cable element is an assembly of optical fibres arranged in such a way to maintain its structure both inside the cable and once the sheath is removed.

The design intent of a fibre optic cable element is to organize fibres so as to facilitate fibre identification and to improve handling.

Current cable designs may include the following fibre optic cable elements:

- tube(s);
- slotted core(s);
- fibre bundle(s);
- fibre ribbon(s);
- central / core tube.

6.1.2 Modularity

The most common modularities are: 1, 2, 4, 6, 8, 10, 12, 24.

6.1.3 Fibre and element identification

6.1.3.1 Fibre identification

The coated fibre or buffer shall be distinguishable by means of colour coding or positioning. Fibre and cable units shall be distinguishable by means of numbering or colour coding. Cable units are defined as structures within the cable that combines the fibres into groups. For example, this can be accomplished by placing fibres inside a tube, wrapping them with a thread, placing them in a ribbon, placing them inside a slot, or any other method that combines a group of fibres into an identifiable unit. Standard colours listed below alphabetically in Table 2 shall be used, as near as possible (reasonable match) to IEC 60304.

The colour code system is to be agreed upon between the customer and the supplier.

Table 2 – Colour for individual fibres or units (listed alphabetically)

Colour
Black
Blue
Brown
Green
Grey
Orange
Pink

Colour
Red
Turquoise
Violet
White
Yellow

NOTE For units containing more than 12 fibres, fibres should be identified by combining the above sequence with an added identification (e.g. ring marking, dashed mark, tracer or coloured unit binders).

6.1.3.2 Element identification

The optical fibre cable elements shall be identified uniquely. One method is by the same colour code as for the fibre identification. The first twelve elements (1-12) are identical to the first twelve fibre colours. The next groups of twelve elements shall be identified by combining the twelve colour sequence with an added identification.

Further alternatives are

- printing the sequential number on the element,
- marker/reference system (e.g. first element blue, second element yellow, followed by other elements uncoloured),
- marking of the slots or the ribs in slotted core construction,
- block-bar numbering.

6.2 Element characteristics

6.2.1 Ribbon

Optical fibre ribbons shall comply with IEC 60794-3.

6.2.2 Tube kinking

The resistance of stranded loose tube elements to kinking shall be tested in accordance with IEC 60794-1-2, method G7.

Test conditions:

Number of cycles: 5

Length L = 100 mm for tube diameter: $d < 2{,}0$ mm
Length L = 70 mm for tube diameter: $2{,}0 \text{ mm} < d < 2{,}8$ mm
Length L = 50 mm for tube diameter: $d > 2{,}8$ mm

Length $L1$: 350 mm
Length $L2$: 100 mm

The sample may be smoothed using a hot air fan.

7 Requirements for optical cables

7.1 Cable construction

7.1.1 General

The cable construction shall ensure protection of fibres from damage during shipping, storage, installation and use. It shall further ensure to maintain the optical characteristics of the fibres within the specified limits during the entire lifetime of the cable.

The features and characteristics given in the following paragraphs are for all general applications of the cables covered by this standard. Special applications may require deviations from these characteristics, to be agreed between the customer and the supplier.

The cable manufacturer shall give a description of the cable and particularly the arrangements of cable elements and the location and material of the strength members. The description may include a schematic cross-sectional drawing.

7.1.2 Cable core

Unless otherwise agreed, the cable core shall be longitudinally water-blocked, which may be achieved by gel, water swellable materials or other suitable materials.

7.1.3 Anti-buckling and strength element splicing

Splices are allowed in anti-buckling or strength elements if the mechanical requirements of the cable are fulfilled (e.g. tensile strength and bending requirements).

Every anti-buckling and strength element splice shall have a strength of at least 80 % the nominal strength of the relevant anti-buckling and strength elements. The diameter of a spliced anti-buckling element shall not be greater than the nominal anti-buckling element diameter.

7.1.4 Cable element stranding

Optical fibre cable elements as described in Clause 6 may be laid up according to the following configurations:

- single optical element(s) without a stranding lay;
- multiple homogeneous optical elements using helical or reverse oscillating (SZ) lay method;
- a number of hybrid configurations in loose tube(s), slotted core(s) or central core tube(s) such as fibre bundles, ribbons or loose tubes.

Fillers, insulated copper wires such as pairs or quads may be laid up with the optical elements, if required.

NOTE The intent of this requirement is that sufficient fibre length be available in the cable structure to accomplish fibre routing and splicing in mid-span access. SZ and single central elements are obvious solutions, but any construction meeting this intent is acceptable.

7.1.5 Spliced fibres

Spliced fibres in the factory length of a cable are not allowed, unless agreed between the customer and the supplier.

7.1.6 Spare fibres

Optical fibre cables shall not contain spare fibres unless agreed between the customer and the supplier.

NOTE A spare fibre is a fibre which is added to a cable element in extension of the nominal fibre content of this element.

7.1.7 Cable sheath removal

The supplier shall provide an appropriate method for sheath removal, such as the provision of one or two ripcords under the sheath.

7.1.8 Armouring

For direct burial, armouring (metallic or non-metallic) may be required, depending on mechanical and environmental conditions as agreed between the customer and the supplier including adapted mechanical cable requirements (see 7.5). Additional cable mechanical testing can be agreed upon by the customer and the supplier.

7.2 Marking

7.2.1 Sheath marking

The cable shall be marked by one of the following methods: sintering, embossing, hot foil, ink-jet, laser, indent or imprinting.

The abrasion resistance of the sheath markings shall comply with IEC 60794-1-2, method E2B.

Depending on the cable marking method used, one of the following test methods shall be used:

Method 1: Steel needle diameter d = 1,0 mm

Load: 4 N

Number of cycles: 100 to 300 cycles depending on customer requirement.

or

Method 2: Felt pad to consist of either 1) water soaked wool felt or 2) rayon felt with ≤ 30 % wool

Weight: ≥ 450 g

Number of cycles: 3

7.2.2 Identification marking

The markings on each length of cable shall be in accordance with the customer and the supplier requirements. Unless specified otherwise, the marking shall contain, at minimum, the following:

- designation (e.g. words or graphic identifying cable as an "optical cable");
- number of fibres;
- type of fibres (e.g. B1, ...);
- name of the supplier or product brand name;
- year of manufacture.

7.2.3 Cable length marking

Unless otherwise agreed, the difference between the length shown by the length marker and the actual length shall not be more than $^{-1}_{0}$ % of the actual length (that is the actual cable length shall always be equal to or longer than the marked length). Other tolerances can be allowed provided the cable length is assured by other means.

The cable shall have sequentially numbered length markings on the sheath at 1 m intervals. Alternate length marking is also acceptable. The length marking shall not be reset to zero for the entire length of cable. The length marking can start with a value different from zero.

If agreed between the customer and the supplier, cables may be re-marked in accordance with the following.

Defective marking may be removed and the cable re-marked with the same colour.

Alternatively, the defective marking may remain and the cable re-marked, using preferably a yellow marking on a different portion of the circumference. This marking shall meet all of the original requirements. Any cable that contains two sets of cable markings shall be labelled to indicate the colour of the marking to be considered.

7.3 Cable core materials

7.3.1 Tube filling compound material (if required)

The tube filling compound, if used, shall comply with IEC 60794-1-2, method E15. The following acceptance criteria apply:

- bleeding: ≤ 2 %;
- evaporation: ≤ 0,5 %, at 80 °C;
- duration: 24 h.

7.3.2 Water-blocking material

Dry water blocking materials and/or compounds may be used to ensure water-tightness of the cable core. Flooding compound may also be used as the water blocking material in the cable core.

Filling and water-blocking material flow:

A representative sample of cable shall be tested in accordance with IEC 60794-1-2, method E14. The filling and water-blocking materials shall not flow at or below 70 °C.

7.3.3 Cable material compatibility

The compatibility of fibre coating and tube filling material shall be tested in accordance with IEC 60794-1-2, method E5.

7.3.4 Tube material

The tube shall be such that the fibres maintain their performance under operating conditions. Handling requirements for buffer tubes shall be agreed upon by the customer and the supplier.

7.4 Cable sheath

7.4.1 Sheath material

The recommended sheath material is UV-resistant black polyethylene. Other suitable materials can be considered.

7.4.2 Sheath thickness

Unless otherwise agreed, the minimum outer sheath thickness at any spot shall meet the below criteria:

a) Outer sheath of multiple-jacket cables: 0,8 mm.
b) Outer sheath of single jacket unarmoured cables: 0,9 mm.
c) Outer sheath of single jacket armour cables: 1,0 mm.
d) Outer sheath over embedded strength members: 0,4 mm over embedded strength members.

For special applications, other sheath thickness may be chosen when agreed between the customer and the supplier.

The test method shall be as given in IEC 60811-1-1 (end sample measurement).

7.4.3 Outer cable diameter

The outer diameter of the cable shall be measured in accordance with IEC 60811-1-1 and shall not exceed the supplier's stated maximum.

7.4.4 Moisture barrier

If required, additional moisture protection shall be provided by a tape. If the tape is metallic it shall be coated on at least one side with a polymer film with a sufficient longitudinal overlap and bonded to the sheath. The adhesion of the metallic tape to the sheath shall be tested in accordance with IEC 60708.

The nominal thickness of the tape, excluding the polymer layer(s), shall be sufficient to prevent ingress of moisture.

7.4.5 Rodent resistant barrier

If required, additional protection layers shall be applied over the cable core. Protective barriers shall use materials of sufficient design and thickness to meet rodent resistance requirements as agreed upon by customer and supplier.

7.5 Mechanical requirements

7.5.1 General

For directly buried or armoured cables, the mechanical requirement could be adapted by agreement between the customer and the supplier.

7.5.2 Bend

The cable shall be tested in accordance with IEC 60794-1-2, method E11.

a) Detail requirements

There shall be "no change (≤ 0,05 dB)" in attenuation when measured in the 1 550 nm region at room temperature. For 1625 nm applications, performance criteria shall be mutually agreed upon between the customer and the supplier.

If required by the customer, after the cable has come to thermal equilibrium at –30 °C or at the lowest specified installation temperature for warmer climates, the change in attenuation relative to ambient temperature shall be ≤ 0,1 dB.

b) Test conditions

Diameter of mandrel: The greater of ≤ 20 d or the static bend diameter agreed between the customer and the supplier.

For cable incorporating a non-metallic rod and/or metallic armouring, bending shall be limited to a value from 20 d to 80 d.

Number of turns/helix: 4

Number of cycles: 3

7.5.3 Impact

The cable shall be tested in accordance with IEC 60794-1-2, method E4.

a) Detail requirements

Under visual examination without magnification there shall be no damage to the sheath or to the cable elements. The imprint of the striking surface on the sheath is not considered mechanical damage.

The residual increase in attenuation shall be ≤ 0,1 dB at 1 550 nm. For 1625 nm applications, performance criteria shall be mutually agreed upon between the customer and the supplier.

b) Test conditions

Striking surface radius: 10 mm or 300 mm ± 3 mm.

Impact energy:

Non-armoured cable: 3 J with striking surface radius of 10 mm or 10 J with striking surface radius of 300 mm.

Armoured cable: 10 J with striking surface radius of 10 mm, or 20 J with striking surface radius of 300 mm depending on particular customer conditions.

Other criteria may be agreed between the customer and the supplier.

Number of impacts: One in 3 different places spaced not less than 500 mm apart.

7.5.4 Crush

The cable shall be tested in accordance with IEC 60794-1-2, method E3.

a) Detail requirements

After release of the short term load, there shall be "no change (≤ 0,05 dB)" in attenuation when measured at 1 550 nm.

Prior to release of the long term load, there shall be "no change (≤ 0,05 dB)" in attenuation when measured at 1 550 nm.

For 1 625 nm applications, performance criteria shall be mutually agreed upon between the customer and the supplier.

Under visual examination, there shall be no damage to the sheath or to the cable elements. The imprint of the plate or mandrel on the sheath is not considered mechanical damage.

b) Test conditions

It is optional to perform the crush test with either a plate/plate or a mandrel/plate (mandrel diameter = 25 mm). Note that the short term test may be performed separately or prior to the long term test. The choice of plate/plate and mandrel/plate should be agreed upon between the customer and the supplier.

Short term test: Apply the following load for 1 min, after release of load measure the change in attenuation.

	Plate/Plate	Mandrel/Plate
Unarmoured cable:	1,5 kN	1,5 kN
Armoured cable:	2,2 kN	2,0 kN

Alternative loads may be applied as agreed upon between the customer and the supplier to meet particular customer conditions.

Long term test: Apply the load for 10 min.

	Plate/Plate	Mandrel/Plate
Unarmoured cable:	0,75 kN	0,75 kN
Armoured cable:	1,1 kN	1,0 kN

Alternative loads may be applied as agreed upon between the customer and the supplier to meet particular customer conditions.

7.5.5 Tensile performance

The cable shall be tested in accordance with IEC 60794-1-2, method E1A (attenuation change) and method E1B (fibre elongation strain).

a) Detail requirements

The maximum rated cable installation load T_M (Newton) shall be specified. It should be noted that this is a short term load. Depending on the application and cable construction and agreement between the customer and the supplier, a maximum tensile force less than the calculation (for example 2 700 N) may be allowed.

The main criteria are as follows:

T_M shall be ≥ "9,8 × a × m" .

m is the mass of 1 km of cable, in kg.

9,8 is the acceleration due to gravity on earth, in m/s^2.

a is the multiplier for to cover variations in application conditions. "a" = 1; however different values may be used with agreement between the customer and the supplier (i.e. some regions specify "a" = 1,5 for cable pulled into ducts).

At T_M , the fibre strain shall be less than 60 % of the proof test level of the fibre. Fibre strain shall be measured in accordance with IEC 60794-1-2, method E1B.

The long term operating load T_L shall be 30 % of the maximum rated installation load.

At T_L, the fibre strain shall be less than 20 % of the proof test level of the fibre.

At T_L, the attenuation increase shall be "no change (≤ 0,05 dB)" at 1 550 nm. For 1 625 nm applications, performance criteria shall be mutually agreed upon between the customer and the supplier.

Other criteria may be agreed between the customer and the supplier.

Under visual examination without magnification, there shall be no damage to the sheath or to the cable elements.

b) Test conditions

Cable length under tension: not less than 50 m. Taking into account the measurement accuracy and end effects, shorter lengths may be used by agreement between the customer and the supplier.

Load duration:	5 min.
Fibre length:	Finished cable length.
Tensile load on cable:	Rated maximum tensile load during installation (short term load) for the cable and maximum rated long term load. Other loads may be applied in accordance with particular customer conditions.
Diameter of test pulleys:	1 m but not less than the minimum loaded bending diameter specified for the cable. The dynamic bend diameter under load shall be agreed between customer and supplier.

7.5.6 Torsion

The cable shall be tested in accordance with IEC 60794-1-2, method E7.

a) Detail requirements

Under visual examination without magnification, there shall be no damage to the sheath or to the cable elements.

The variation on attenuation for each fibre shall be less than or equal to 0,10 dB at 1 550 nm. For 1 625 nm applications, performance criteria shall be mutually agreed upon between the customer and the supplier.

There shall be no permanent change in attenuation after the test.

b) Test conditions

Length under test:	Maximum 1 m.
Sample rotation (degrees torsion/m):	90 °/m turn in each direction (e.g. one half turn of 180 ° over the length of 2 m in each direction).
Number of cycles:	5.

7.5.7 Repeated bending

The cable shall be tested in accordance with IEC 60794-1-2, method E6.

a) Detail requirements

Under visual examination without magnification, there shall be no damage to the sheath and to the cable elements.

b) Test conditions

Bending radius: 20 d.

Load: Adequate to assure uniform contact with the mandrel.

Number of cycles: 25 or different number of cycles may be applied in accordance with particular customer conditions.

Duration of cycle: Approximately 2 s.

7.6 Environmental requirements

7.6.1 Temperature cycling

The cable shall be tested in accordance with IEC 60794-1-2, method F1. All but the last cycle may use the "one cycle procedure". The last cycle shall use the "combined test procedure".

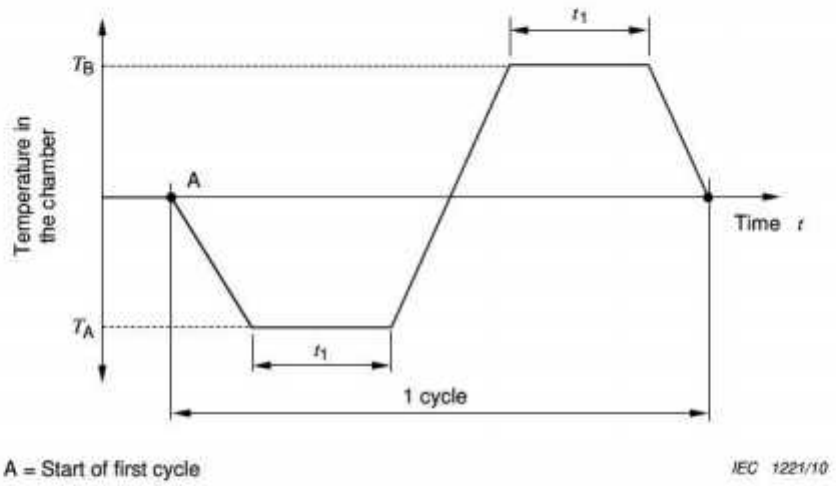

Figure 1 – For all cycles except last

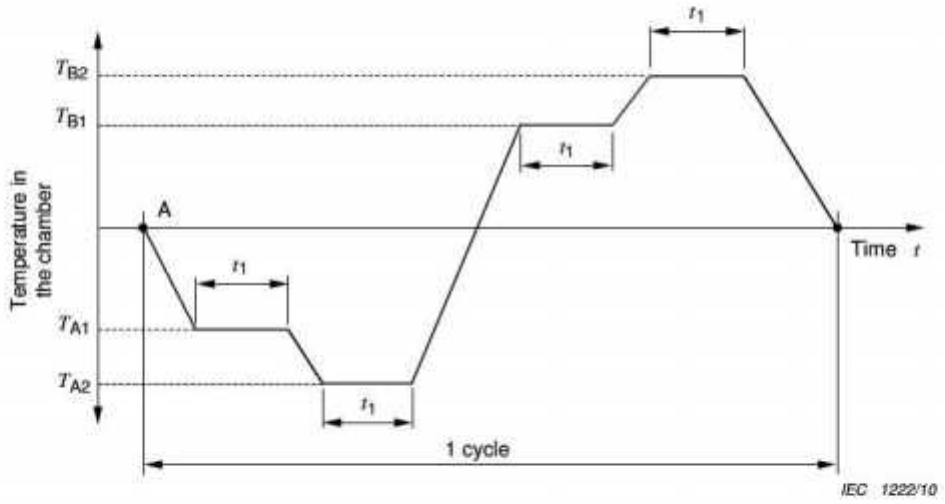

Figure 2 – Last cycle

a) Detail requirements

For T_{A2} and T_{B2}, the change in attenuation coefficient measured in the last cycle shall be ≤ 0,15 dB/km from the initial ambient temperature.

For T_{A1} and T_{B1}, there shall be "no change (≤ 0,05 dB/km)" in attenuation coefficient measured during the last cycle from the initial ambient temperature.

On completion of the test at the ambient temperature, the change of attenuation coefficient shall be less than 0,05 dB/km.

The measurements shall be made in the 1 550 nm region. For 1625 nm applications, performance criteria shall be mutually agreed upon between the customer and supplier.

b) Test conditions

Sample length: Finished cable length of at least 500 m.

Temperature

High temperature, T_{B2}: +60 °C or +70 °C, depending on customer requirements.

Low temperature, T_{A2}: –40 °C or –45 °C, depending on customer requirements.

High temperature, T_{B1}: +30 °C to +60 °C, depending on customer requirements.

Low temperature, T_{A1}: –10 °C to –20 °C, depending on customer requirements.

NOTE Alternative high and low temperatures may be agreed between the customer and the supplier for warmer or colder climates.

Rate of heating: Sufficiently slow that the effect of changing the cooling temperature does not cause temperature shock.

t_1: Temperature cycling test dwell time sufficient to reach thermal stability throughout the entire cable test length.

Definition of the temperature range in a cycle: T_{A2} to T_{B2}

Definition of the temperature range in the last cycle: T_{A2}, T_{A1}, T_{B1}, T_{B2}

Number of cycles: 2, but additional cycles may be required in accordance with particular customer requirements.

For some cable constructions, it can be important to specify which fibres are tested. For example, ribbon cables should include fibres in the corners and middle of the ribbon stack. These details should be agreed between the customer and the supplier.

7.6.2 Stripping force stability of cabled optical fibres

The fibres of the cable shall be tested in accordance with IEC 60794-1-2, method E5.

a) Detail requirements

After conditioning: At standard atmospheric conditions, the average strip force required to remove 50 mm of the fibre's coating shall not be greater than 5 N and not less than 1 N.

b) Test conditions:

Test condition should be agreed between the customer and the supplier. For example, 168 h at 70 °C is a test condition that may be used.

7.6.3 Water penetration

Water-blocked cables shall be tested in accordance with IEC 60794-1-2, method F5 (end test).

7.6.4 Environmental impact

Any material used in the cable shall be non-toxic and shall not provide a health hazard during normal operational conditions. If requested, the manufacturer shall be capable of providing details on the environmental impact of the cable.

7.7 Electrical protection

All metallic elements used in the cable (e.g., longitudinally applied metallic tape, steel strength members, insulated copper conductors) shall be electrically continuous.

8 Quality assurance

Compliance with specification requirements shall be verified by carrying out tests as indicated in the relevant part of IEC 60794. It is not intended that all tests shall be carried out on every length of cable. The frequency of testing shall be agreed between the customer and the supplier.

It is the responsibility of the supplier to establish quality assurance by quality control procedures, which ensure that the product meets the requirements of this standard. When the customer wishes to specify acceptance tests to other quality procedures, it is essential that an agreement is reached between the customer and the supplier at the time of ordering.

Annex A
(informative)

Guidance for ITU-T and IEC cabled fibre and fibre references

A.1 Guidance for ITU-T and IEC cabled fibre and fibre references

This specification is intended to provide cable that is compatible with:

- ITU-T Recommendation G.652, *Characteristics of a single-mode optical fibre and cable*
- ITU-T Recommendation G.653, *Characteristics of a dispersion-shifted optical fibre and cable*
- ITU-T Recommendation G.654, *Characteristics of a cut-off shifted optical fibre and cable*
- ITU-T Recommendation G.655, *Characteristics of a non-zero dispersion-shifted optical fibre and cable*
- ITU-T Recommendation G.656, *Characteristics of a fibre and cable with non-zero dispersion for wideband transport*
- ITU-T Recommendation G.657, *Characteristics of bending loss insensitive single mode optical fibre and cable for the access network".*

This specification references the following IEC optical fibre specifications to be used within the cable:

- IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*
- IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications - Sectional specification for class B fibres*

The fibre specifications are organized as a series of sectional specification standards beneath a general specification. Within each sectional specification there is a series of normative annexes that define the requirements for the different family specifications. Within the fibre sectional specification, IEC 60793-2-50, for example, are the family specifications for the B1.1, B1.2, B1.3, B2, B4, B5, and B6 fibre categories.

Table A.1 – ITU-T and IEC cross-reference

IEC Designation	B1.1	B1.2	B1.3	B2	B4	B5	B6_a
ITU Designation	G.652.A and G 652.B	G.654	G.652.C and G 652.D	G.653	G.655	G.656	G.657.A

B1.1: Single-mode fibre with a zero dispersion between 1 300 nm to 1 324 nm, which is optimised for use in the 1 310 nm region and is compatible in the 1 550 nm region.

B1.2: Dispersion unshifted single-mode fibre that is optimised for 1 550 nm transmission with a cable cut-off wavelength <1 530 nm.

B1.3: Single-mode fibre similar to B1.1 but has a low loss at 1 383 nm to provide additional compatibility between 1 360 nm to 1 460 nm.

B2: Dispersion shifted single-mode fibre with a zero dispersion in the 1 525 nm to 1 575 nm region.

B4: A non-zero dispersion shifted single-mode fibre (NZDSF) that is optimised for 1 550 nm transmission with the zero dispersion outside the 1 530 nm to 1 565 nm region.

B5: A non-zero dispersion shifted single-mode fibre (NZDSF) that is optimised for 1 460 nm to 1625 nm transmission with the zero dispersion region below 1 460 nm.

B6_a: A bending loss insensitive fibre compatible with B1.3 fibre that is suitable for use in the access networks, including inside buildings.

Annex B
(informative)

Fibres

B.1 Fibre materials

The materials used in the manufacture of single-mode optical fibres for incorporation into cables to this specification, shall be of a uniform quality. The core and cladding regions of the fibre shall be made from predominantly purified silica (SiO_2) with a defined and closely controlled refractive index difference. The refractive index of either the core and/or the cladding shall be controlled by the inclusion of small amounts of highly purified dopant materials.

The glass surface shall be protected with one or more layers of suitable inert coating material, such as UV cured acrylates. The coating shall be in intimate contact with the cladding surface to avoid delamination which may expose the glass surface to the environment and shall facilitate removal for connecting and splicing purposes without damage to the fibre.

Optical fibres are inherently robust and strong, but the strength can be reduced due to the combination of environmental conditions, unavoidable microscopic surface flaws introduced during fibre manufacture, and stresses imposed on the fibre during handling, cabling and installation. The strength degradation can be as a result of dynamic or static fatigue as well as through ageing with no stress component. Dynamic fatigue is more likely to occur during installation while static fatigue could occur over the lifetime of the fibre arising from residual strain in the cable or within coiled fibre housed in a splice enclosure or foot-way box. The attenuation of cabled fibre could also increase during its lifetime if the fibre is not suitably protected from mechanical stresses and environmental hazards or if inappropriate and incompatible materials are used in the cable construction. Reference should be made to the guidance given in IEC/TR 62048.

The recommended cable design features, test parameters and requirements outlined in this specification are designed to mitigate these risks and hazards for the optical fibres.

B.2 List of fibre attributes

Tables B.1 to Table B.5 provide a list of fibre attributes.

Table B.1 – Dimensional attributes and measurement methods

Attributes	*Measurement methods*
Cladding diameter	IEC 60793-1-20
Cladding non-circularity	IEC 60793-1-20
Core-cladding concentricity error	IEC 60793-1-20
Primary coating diameter	IEC 60793-1-21
Primary coating non-circularity	IEC 60793-1-21
Coating-cladding concentricity error	IEC 60793-1-21
Fibre length	IEC 60793-1-22

Table B.2 – Mechanical attributes and test methods

Attributes	*Test methods*
Proof test	IEC 60793-1-30
Tensile strength	IEC 60793-1-31
Primary coating strippability	IEC 60793-1-32
Stress corrosion susceptibility	IEC 60793-1-33
Fibre curl	IEC 60793-1-34

Table B.3 – Transmission attributes and measurement methods

Attributes	*Measurement methods*
Attenuation coefficient	IEC 60793-1-40
Chromatic dispersion	IEC 60793-1-42
Cable cut-off wavelength	IEC 60793-1-44
Mode field diameter	IEC 60793-1-45
Change of optical transmission	IEC 60793-1-46
Macrobending loss	IEC 60793-1-47
Polarisation mode dispersion	IEC 60793-1-48

Table B.4 – Environmental exposure tests

Attributes	*Test methods*
Damp heat tests	IEC 60793-1-50
Dry heat tests	IEC 60793-1-51
Change of temperature tests	IEC 60793-1-52
Water immersion tests	IEC 60793-1-53

Table B.5 – Attributes measured during or after environmental exposure

Attributes	*Test methods*
Change in optical transmission	IEC 60793-1-46
Attenuation	IEC 60793-1-40
Coating strip force	IEC 60793-1-32
Tensile strength	IEC 60793-1-31
Stress corrosion susceptibility	IEC 60793-1-33

Bibliography

IEC Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

IEC 60793-1 (all parts), *Optical fibres – Part 1: Measurement methods and test procedures*

IEC 60793-1-20, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

IEC 60793-1-21, *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry*

IEC 60793-1-30, *Optical fibres – Part 1-30: Measurement methods and test procedures – Fibre proof test*

IEC 60793-1-31, *Optical fibres – Part 1-31: Measurement methods and test procedures – Tensile strength*

IEC 60793-1-32, *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*

IEC 60793-1-33, *Optical fibres – Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility*

IEC 60793-1-34, *Optical fibres – Part 1-34: Measurement methods and test procedures – Fibre curl*

IEC 60793-1-42, *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*

IEC 60793-1-45, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*

IEC 60793-1-46, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

IEC 60793-1-47, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*

IEC 60793-1-50, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state)*

IEC 60793-1-51, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat*

IEC 60793-1-52, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature*

IEC 60793-1-53, *Optical fibres – Part 1-53: Measurement methods and test procedures – Water immersion*

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

IEC 60794-3-12, *Optical fibre cables – Part 3-12: Outdoor cables – Detailed specification for duct and directly buried optical telecommunication cables for use in premises cabling*

IEC/TR 62048, *The power law theory of optical fibre reliability*

ITU-T Recommendation G.652, *Characteristics of a optical fibre and cable*

ITU-T Recommendation G.653, *Characteristics of a dispersion-shifted optical fibre and cable*

ITU-T Recommendation G.654, *Characteristics of a cut-off shifted optical fibre and cable*

ITU-T Recommendation G.655, *Characteristics of a non-zero dispersion-shifted optical fibre and cable*

ITU-T Recommendation G.656, *Characteristics of a fibre and cable with non-zero dispersion for wideband transport*

ITU-T Recommendation G.657, *Characteristics of a Bending Loss Insensitive Single Mode Optical Fibre and Cable for the Access Network*

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